WHERE HAS ALL THE WIND-POWER GONE?

AN ANALYSIS OF OFFICIAL STATISTICS ON ELECTRICITY GENERATION 2002-2008

By T.A.W.E. (*Truth About Wind Energy*)

This examination of government statistics reveals evidence that the supply of electricity from UK wind-farms falls well below their recorded output and that their contribution towards the reduction in CO^2 emissions is minimal.

If these conclusions are true then the costs of wind-energy are being underestimated adding weight to the view that investing in wind-power provides poor value for money when compared with alternative means of reducing emissions and producing energy.

Some experts argue that the contribution wind-power can make to electricity supply and reductions in CO^2 emissions is being over-estimated, and that the energy cost of balancing the rapidly fluctuating input from wind-turbines and providing back-up generating plant for when the wind doesn't blow detracts significantly from their output.

Wind-energy is potentially very expensive both in monetary and environmental terms and if we are to bear this extra cost - possibly over £4 billion a year between now and 2020[1] - we should at least expect to begin to see some evidence of the effectiveness of UK wind-farms.

Whilst the current output of UK wind-farms is very small in relation to total UK electricity demand (around 2%), already a very large land-area has been affected by the development of over 2,500 industrial-scale turbines, including some sensitive and valuable landscapes, and considerable sums have been contributed by the consumer, so we do not consider it premature to begin to look for evidence of results.

We have posed the question: ***'is there any evidence that UK wind-farms are delivering the claimed reductions in CO^2 emissions and contribution to electricity supply?'*** To find an answer we have analysed official data on electricity generation in the UK.

The Dept. of Business, Enterprise and Regulatory Reform (BERR) publishes detailed statistics on electricity generation which are available on its website (*Digest of UK Energy Statistics – Tables 5.6 and 7.4*). These figures are summarised in the yearly tables in Appendix 1. In addition, the Government publishes statistics on CO^2 emissions on its website (*http://www.statistics.gov.uk/STATBASE/Expodata/Spreadsheets/D5695.xls*) - (See Table 1, Appendix 1 for summary.)

We decided that the best way to analyse these figures was to compare the amounts of CO^2 emissions, fuel used and electricity supplied year by year up to when the most recent statistics were available (2008) and starting in a particular base year (2002).

We chose 2002 as the base year for the following reasons:

1. It is the earliest date when government figures were released in a format that was directly comparable against the figures for the following years.

[1] Source: *Compliance Costs for Meeting The 20% Renewable Energy target in 2020 – March 2008.* Commissioned by the Government from Pöyry plc.

2. Most of the growth in UK wind-power installation took place since 2002, from 534 Megawatts (Mw) to 3,406 Mw of installed capacity (maximum potential output) in 2008 (see table 2, Appendix 1).

CO² Emissions

From 2002 to 2008 CO² emissions from electricity generation grew from 169,931,000 tonnes to 181,150,000 tonnes, an increase of 11,219,000 tonnes or 6.6% (See Table 1, Appendix 1).

The Government asserts that the reason for this increase is that there has been a change in the mix of fuels used in electricity generation, in particular a switch from nuclear to fossil fuels and increased use of coal due to the loss of nuclear generation and the increased price of gas.

By analysis of the statistics we can test this assertion.

There are four possible reasons for the increase:

1. A change in the mix of fuels used.
2. Increased demand for electricity (hence increased supply).
3. Changes in the efficiency of electricity generation –i.e. the conversion rate of fuel to electricity.
4. Changes in the conversion rates of fuel to CO².

The first of these factors, the mix of fuels, was primarily determined by the market and the fact that some nuclear power stations are coming to the end of their lives. These factors led to an increased use of coal over the period. There might also have been some influence from the introduction of wind-power because fossil-fuel power stations are used to balance wind-plant but this effect is impossible to distinguish from the available data.

The second factor is self-explanatory and the figures tell us that demand (and hence supply) in 2008 was 0.35% higher than in 2002, despite the recession. (See Table 3, Appendix 1). This possibly indicates that we are failing to provide adequate incentives to reduce energy consumption.

The remaining two factors, i.e. changes in the efficiency of electricity generation and the rates of conversion from fuel to CO2, could well be influenced by the integration of wind-power into the National Grid because of the need to run some power stations less efficiently to provide the back-up for a rapidly fluctuating input.

By analysis of BERR's figures it is possible to eliminate the effects of the changed fuel mix and increased supply (=increased demand) and thereby ascertain how much of the increase in CO² over the period was attributable to these last two factors alone.

We did this by comparing the actual figures for CO² emissions for each year with what they would have been had there been no changes in the fuel mix since 2002 and then by expressing the CO² emissions as tonnes per Gwh of supply.

This was achieved by:

1. Re-calculating the figures for each year for fuel use and electricity supply as if the fuel mix was the same as it was in 2002.
   (See Yearly Tables, Appendix 1.)

2. Calculating the quantity of CO² emissions per Gwh of supply for 2002 and the relevant year and multiplying the difference by the supply for the relevant year. This gives the

amount of CO_2 saved or added due to changing efficiency/conversion rates. (See Table 3, Appendix 1).

It can be seen that the total amount of CO_2 emitted over the period 2003 to 2008 was slightly less (by 417.83 thousand tonnes) than would have been emitted had there been no changes in efficiency and conversion. In other words during the period 2002 – 2008 the amount of CO_2 emitted per unit of electricity supplied was virtually unchanged.

By contrast the total output from wind-farms during that period was 22,721 Gwh which should, according to the claimed benefit of wind-power, have *saved* 9,770 thousand tonnes of CO^2 (@ 430 tonnes per Gwh[2]). Thus there is evidence of only a very small saving in CO^2 emissions during that period compared to what we would have expected to find.

Contribution from wind to electricity supply

BERR's figures (Table 2, Appendix 1) show that during the seven years from 2002 to 2008 wind output averaged 23.64% of installed capacity (23.85% in 2008). That means that UK wind-farms produced less than a quarter of the electricity they would have done had they been running at full power all the time. In 2008 wind-farm output was 7,097 Gwh, that's 1.9% of total electricity supply in 2008 and 0.26% of total (primary) UK energy demand.

But the critical statistic is not output but *supply*, i.e. the amount of power actually supplied to the consumer. That there are losses between the turbines and the consumer is beyond doubt. A certain amount is lost in transmission lines, for example, particularly as the generating plant is often remote from the consumers. However, what is really at issue is how much is lost due to the inefficiencies created in balancing and backing up this variable resource.

The official figures enable the theoretical contribution from wind-power to electricity supply to be assessed by comparing how much of all the other fuels (i.e. all energy sources except wind) was used per unit of electricity supplied in 2002 and the following years to 2008. After adjusting for the change in fuel mix (by recalculating the figures for each year using the same fuel mix as 2002 – see annual tables, Appendix 1) we can see that in 2002 total fuel use excluding wind was 2.636 Gwh of fuel used per Gwh of electricity supplied. In 2008 it was 2.625 Gwh/unit. (See Table 4, Appendix 1). Multiply the difference by the total amount of electricity supplied and you get 4,942 Gwh of fuel saved against the wind output in that year of 7,097 Gwh. Over the six years 2002-2008 5,406 Gwh of *additional* fuel used was used against a theoretical contribution of 15,624 Gwh of wind output.

Now there may be many reasons for the increased fuel use in any particular year. The point is that BERR's figures as yet provide no actual evidence of a significant and cost-effective contribution to the UK electricity supply from wind-power and, as more wind-farms are built, we could in fact receive a falling return on our investment as the intermittency of wind impacts more and more on the efficiency of generation[3].

Reduced efficiency

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[2] This figure is now accepted by the British Wind Energy Association since a recent Advertising Standards Agency ruling (see: http://www.bwea.com/edu/calcs.html).

[3] *House of Lords Select Committee on Economic Affairs – Fourth Report, November 2008: ''total new installed electricity generating capacity required by 2020 would thus be roughly double the level needed if renewable generation were not expanded.''*

"Thirty gigawatts of wind maybe requires 25 GW of backup'': Rupert Steele, director at the Scottish arm of Spain's Iberdrola, one of the world's largest wind farm operators, reported by Reuters 22.04.09.

Engineers have pointed to the negative effect that the intermittency of wind-power has on the overall efficiency of electricity generation. There are two main potential reasons for reduced efficiency:

1. Energy can be wasted in balancing the power-swings that a highly variable wind-resource introduces into the distribution grid. Because the output from turbines varies with the cube of the wind-speed[4] the amount of electricity supplied is particularly prone to rapid fluctuations.

   Balancing is generally carried out by:
   a) 'ramping' up and down conventional base-load plant which consequently burns fuel less efficiently. Base-load plant is plant that is already producing electricity for the day-to-day needs of the consumer.
   b) using 'spinning reserve' i.e. conventional plant that has to be kept running on stand-by, burning fuel but not producing electricity and ready to deliver power as soon as the wind drops. As more wind is introduced into the grid more spinning reserve, dedicated to balancing wind fluctuations, will be required.
   c) Using stored energy such as hydro where energy is lost in the process of conversion to the storage medium and back to electricity again.
   d) Importing electricity at short notice from the Continent via undersea cables.

2. Because wind-power needs back up for when the wind doesn't blow it doesn't replace conventional plant one-for-one. In fact only a small amount[5] of conventional plant can be retired because of wind-farms. Therefore two parallel sets of generating plant must be installed, operated, maintained, and replaced. Also additional equipment is required to integrate wind-power into the grid such as new transmission lines, transformers etc.

The argument is about how much energy is lost as a result of these complications. Proponents of wind-power say very little as there are already many variables in consumption and supply that have to be balanced and the additional fluctuations from wind are small in comparison. Our analysis of BERR's figures so far points to a different answer.

The effects of intermittency.

To produce an average of 10% of UK electricity supply would require wind-turbines with the capacity to produce 40% of average supply at full blast (based on a theoretical electricity supply from wind at 25% of capacity nationwide). That means potential swings between 0% and 40% of average total supply within a few hours. And, of course, if wind is actually only supplying, for example, 15% of capacity that means 10% of average supply will require wind capacity of 60%.

Furthermore, the greater the amount of wind-capacity connected to the grid, the greater the effect of power-swings, and this will further reduce the efficiency of the system. And before wind-farms can produce 20% of our average electricity supply they will begin generating surplus energy at times of good winds and low demand. This surplus will have to be stored (with consequent losses of energy), thrown away or exported overseas at a discounted price.

It should be noted that domestic-scale turbines are effectively connected to the grid and will also contribute to the energy-consuming fluctuations in demand on the stand-by conventional generating plant.

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[4] *If wind speed doubles you get eight times as much power and vice-versa.*

[5] *A study conducted by E. On Netz, one of Germany's two largest operators of wind-farms, concluded that German wind farms contributed 8% of their installed capacity. Additionally, E.On Netz predicts that the relative guaranteed amount of capacity supplied by wind in 2020 will fall to 4%. These results are based on E.On Netz's projection of 48,000 megawatts of installed wind power capacity in 2020, which would replace 2,000 megawatts of traditional energy production sources (E.On Netz 2005).*

Solutions to intermittency

Storage - The UK has very little capacity for the storage of electricity[6]. The only large-scale storage is done in elevated reservoirs, such as Festiniog and Dinorwig in North Wales, where water is pumped from a lower to a higher reservoir and released back to the lower one through turbines to recover some of the power when it is needed. However, some of the power, (our research suggests as much as 20%) is wasted due water evaporation, electric turbine/pump efficiency, and friction.

UK pumped storage systems can currently deliver less than 3,000 Megawatts which are used to help balance existing fluctuations in demand. Increasing the capacity of hydro-storage would require the identification of specialist locations where two nearby lakes or reservoirs are situated or can be created at the appropriate distance and height from each other. It would also require massive investment.

Other suggestions for the storage of electricity include batteries, compressed air, hydrogen and kinetic storage using immense fly-wheels.

All forms of storage involve converting electrical energy to a different form and then back again entailing the loss of large amounts of energy in the process. Hydrogen is particularly inefficient. On a sufficiently large scale they would also require additional massive financial investment. These costs may not be compensated for by the reduction in the costs of back-up and balancing.

Export - Exporting/importing some of the electricity produced by wind could help to 'smooth out' the troughs and crests in generation. However, if receptor countries were also utilising large quantities of wind there is a high probability that they would experience similar fluctuations simultaneously. Again, very substantial costs in creating a 'super-grid' would be involved.

Smart-grids - In short a Smart-grid is a means by which consumers can use increase electricity consumption when the wind blows and reduce consumption when it does not. Fridges and freezers can switch off when the wind-energy supply drops and electric vehicles can be charged when it rises. This is effectively a dispersed storage system. This idea is promoted by the Conservatives in their current energy policy but so far we have not seen any cost-analysis. We strongly suspect that, whilst it may reduce the need for back-up from power generators and hydro-storage, it will still be an equally expensive item on the already high-priced wind-energy shopping list. It remains to be seen.

The cost of wind

The Government predicts that the UK's total CO^2 emissions could be reduced by around 10% if the share of electricity generation from renewables were to be increased to 34%. The House of Lords Select Committee on Economic Affairs recently estimated that the cost of increasing renewables to 34% (from the current 6%, most of which is hydro) would be an extra £6.8 billion <u>per annum</u> up to 2020, a potential extra £200 -£300 a year on the bills every household

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[6] ***House of Lords Select Committee on Economic Affairs – Fourth Report, November 2008:***
'A breakthrough in cost-effective electricity storage technology would help solve the problem of intermittency and remove a major stumbling block to wider use of renewable energy in the longer term. However, ***no evidence we received persuaded us that advances in storage technology would become available in time materially to affect the UK's generating requirements up to 2020****. We recommend that the Government should as a matter of urgency encourage more research, development and demonstration in energy storage technologies'.*

in the UK (see table at end of report). On current policy by far the majority of this cost would be attributable to wind-power.

The Royal Academy of Engineering has estimated that the cost of wind power will be two to three times that of nuclear power per unit of electricity generated[7]. If the conclusions that our analysis point to are correct, i.e. that wind-power actually delivers less than is claimed, the relative cost per tonne of CO^2 saved or per Gwh of electricity supplied by wind-farms will be even higher.

Conclusions

Already large areas of our finest landscapes have been blighted by a couple of thousand industrial wind-turbines and large sums have been paid out by electricity consumers. Tens of thousands more turbines are proposed, yet the Government's own data so far reveals little evidence of CO^2 savings or any significant contribution to electricity supply from wind.

This is evidence that the cost of wind-power is being under-estimated. Even without this miscalculation, wind-power is extremely expensive compared to nuclear which it has now become apparent we are going to invest in heavily anyway.

Most of the back-up for wind will have to come from conventional generating plant. If that plant is powered by fossil fuels then a significant proportion of the benefit of wind-power is lost. If the back-up comes from CO^2–free nuclear plant then what's the point of doubling up with wind-farms? Either way two sets of generating plant (or storage facilities) are required to produce not much more energy that one could produce. This makes wind-energy excessively expensive.

There is evidence[8] that cheaper means of generating clean electricity exist and that there are more cost-effective means of reducing atmospheric CO^2. There is also growing evidence of the inefficacy of wind-energy in other parts of the world. If this is indeed the case then funds, political effort and public attention are being diverted into wind-power and away from better solutions to climate change and the focus on wind-power is actually hindering rather than assisting the government in its efforts to meet CO^2 reduction targets. In particular, it can be argued that far more resources should be provided for energy conservation technologies which are currently being starved of cash by the push for wind. The argument that we should be doing both doesn't hold water. Money spent on wind is money not being spent elsewhere.

Wind-power is highly visible and, partly because of misinformation, it has also been a political winner. It also generates large amounts of cash, taken from the pockets of hard-pressed electricity consumers, and this cash creates a huge pot of money into which landowners, industrialists and politicians can dip their hands. No wonder it's a favourite with policy-makers. But if we are to make serious in-roads into CO2 emissions we suggest a review of policy needs to be carried out.

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[7] '*The Cost of Generating Electricity'* - A Report for the Royal Academy of Engineers Feb 2004.
[8] *The subject of a study currently being undertaken by TAWE*

House of Lords Select Committee on Economic Affairs – Fourth Report, November 2008:

Predicted total costs in 2020 of electricity generation and transmission with 34% of generation from renewables, including allowance for back-up and grid integration

	Pence per kWh of **total** output	£ billion per year
Predicted base generation cost with 6% renewables	*4.31 p/kWh*	*£ 16.2 bn*
Cost of balancing and existing transmission system	*0.41 p/kWh*	*£ 1.5 bn*
Predicted total cost with 6% renewables	*4.82 p/kWh*	*£ 17.7 bn*
Extra costs of moving from 6% to 34% renewables		
Generation base cost	*1.14 p/kWh*	*£ 4.3 bn*
Predicted additional costs of system integration		
Intermittency (See para 102 and 113)	*0.33 p/kWh*	*£ 1.3 bn*
Transmission (See para 121-3)	*0.32 p/kWh*	*£ 1.2 bn*
Predicted total integration costs	*0.65 p/kWh*	*£ 2.5 bn*
All extra predicted costs for moving from 6% to 34% renewables	*1.79 p/kWh*	*£ 6.8 bn*
Predicted overall cost of generation and transmission with 34% renewables	*6.61 p/kWh*	*£ 24.5 bn*

A summary of the figures:

According to UK Government Statistics from 2002 to 2008:

- UK wind-power capacity increased from 534 to 3406 megawatts.
- Average UK wind-farm output was 23.6% of installed capacity.
- In 2008 UK Wind output was 1.9% of electricity supply and 0.26% of total (primary) UK energy demand.
- CO^2 emissions from UK electricity generation increased by 6.6%.
- Evidenced saving of 418 thousand tonnes of CO^2 emissions as against an expected saving of 9,770 thousand tonnes.
- 5,406 Gwh of additional fuel used was used against a theoretical contribution of 15,624 Gwh of wind output.