BRIEFING NOTE

Renewable generation, constraints and the cost of balancing the electricity system

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Over the last decade the annual cost of balancing the electricity grid has increased from £692 million in 2006 to £1,207 million in 2016 even though the average system demand has fallen from 40.1 GW to 32.6 GW. These costs are passed on to electricity consumers via National Grid's charges for the use of the grid, which form a part of the cost of transmission and distribution of electricity.

The increase in cost has been accompanied by a large increase in the share of renewable generation as a proportion of total electricity supply. One well-publicised element of these balancing costs are the constraint payments made to wind farms to switch off that arise when particular segments of the grid are unable to cope with the amount of generation. The idea behind such payments is that they compensate such generators for the loss of revenue that they would otherwise receive, in particular subsidies that are linked to the amount of electricity which they produce.

While constraint payments are controversial, the truth is that they represent only a small part (£82 million in 2016) of the total costs of balancing the grid associated with renewable generation. The other costs, such as maintaining the frequency and voltage of supplies or ensuring adequate reserve margins, are largely ignored but fall on consumers rather than the generators whose decisions give rise to the costs. Further, constraint payments are made to wind farms with grid connections, whereas output from solar and smaller wind generators connected to distribution networks may impose even larger costs on the electricity system.[1]

Understanding the relationship between renewable generation and balancing costs involves careful statistical analysis of a large dataset on costs, generation and demand, weather, etc for half-hour periods over 8 years from 2009 to 2016. This type of analysis has not been carried out in the past, apparently not even by National Grid, but the results are both strong in statistical terms and have important implications for energy policy.

The crucial findings concern the additional cost of balancing the electricity system for each extra MWh of either wind or solar output, after controlling for factors such as demand, weather conditions, time of day, etc. In the case of wind generation, this additional cost was £22 per MWh at the average level of wind generation in 2016 (3.1 GW). It increases to £37 per MWh at an output of 7.3 GW which was the 95th percentile of wind generation in 2016 (the amount exceeded in 5% of all half-hour periods in the year). If the amount of wind capacity increases up to 2020 or 2025 as envisaged by the Scottish and UK Governments, the additional cost of balancing the system will rise to about £80 per MWh for substantial periods of each year within 10 years.

[1] These are referred to as "embedded generators". The crucial point is that the System Operator has limited or no information about their operation and is unable to control them in the same way as grid-connected generators.

To put these figures in context, the average market value of wind output in 2016 was £38.5 per MWh. So, at the average level of output the additional cost of balancing the system imposed on consumers was 57% of the market value of the additional output. Allowing for these costs, in net terms an additional MWh of wind generation was worth a little more than £16 per MWh. For 13% of all half-hour periods in 2016 (roughly 1140 hours in the year) the additional balancing cost per MWh for wind output exceeded the market value of the electricity produced. This situation will only get worse as more wind capacity is added to the system. The total costs of balancing wind output are projected to increase by at least 100% and perhaps as much as 200% by 2020. By then the net value of additional wind output will be negative – i.e. the additional balancing cost will exceed the market value of the wind output – in 25-33% of all half-hour periods in the year.

While the costs of balancing the electricity system associated with wind generation are high, it is important to note that the costs associated with solar generation are substantially higher. The analysis is a little more complicated because of the way in which solar generation affects the grid, so that there is a large fixed cost as more solar capacity is added while the contribution of additional output is smaller. Still, the average balancing cost for solar output in 2016 was £34 per MWh at median output and £77 per MWh at the 95th percentile. Again, the overall level of balancing costs associated with solar generation will continue to rise so that by 2020 on current projections they will be 160% higher at the bottom end of the forecast or 260% higher at the top end.

These estimates refer only to the direct costs of balancing the electricity system associated with renewable generation. There are substantial additional costs which are recovered from other charges which fall on users. For example, National Grid and Scottish Power are building the Western Link, a high voltage undersea DC line from Deeside to Hunterston, which is required to export surplus wind power from Scotland to England & Wales. When complete the cost of building and operating the link will be recovered via the transmission charges paid by all consumers. Similar expenditures on upgrading or extending core parts of the grid – e.g. the Beauly-Denny and the Caithness-Moray lines – are recovered in the same way.

The total revenue from transmission (TNUoS) charges is expected to be £2.63 billion in 2017-18 and to increase to £3.10 billion in 2021-22 (at 2017-18 prices). Almost all of the increase to 2021-22 is attributable to additional costs associated with renewable generation. On the most conservative assumptions, the transmission charges due to wind and solar generation paid by electricity consumers will increase from about £7 per MWh of renewable output in 2016 to £12-13 per MWh in 2020.

For practical purposes, the net economic value of additional wind and solar generation in the UK – i.e. the market value of the power less the additional costs incurred to transmit the power and balance the electricity system – was less than £10 per MWh in 2016 and will be negative in 2020. These are average figures over periods of high and low generation. The net economic value of generation during windy or sunny periods is much lower than during periods of low generation – partly because the market price is lower during periods of high generation and partly because the costs of balancing the electricity system increase steeply with the level of renewable output. In 2016 the net economic value of additional wind output was zero or negative for most periods when wind output exceeded 5 GW.

This analysis refers to the whole of the GB electricity system because balancing costs cannot be broken down to national or regional level. Still it is reasonably certain that the situation in Scotland is considerably worse than the GB figures imply. A separate analysis of the economic geography of transmission constraints and the associated balancing costs shows that they are heavily concentrated at the boundary in the North of England that separates the "Scottish" electricity network from the network serving most of England & Wales.[2] In addition, growth in wind generation south of this border is primarily from offshore wind which is less variable than onshore wind and bears the costs of offshore transmission under separate arrangements. On the basis of the distribution of net economic value for Great Britain, it is likely that (a) at least 50% of Scottish wind generation in 2016 had a zero or negative net economic value, and (b) this proportion will increase significantly up to 2020.

The conclusion that much of the output from wind and solar generation has a zero or negative net economic value implies that money spent on building wind farms, installing solar panels, etc is almost entirely wasted. The operators may earn a satisfactory return upon their capital expenditures but this simply reflects a transfer from electricity customers that gives rise to little or no economic benefit to the country as a whole. Electricity prices for residential, commercial and industrial consumers are higher to pay for the costs of generation.

The primary argument for promoting a switch to renewable generation is that it reduces emissions of CO2. The scale of the reduction is not easy to estimate because balancing intermittent output from renewable generators requires that thermal (fossil fuel) power plants spend longer periods starting up or operating on standby, emitting CO2 but producing little or no power for the grid. On the most favourable assumptions the balancing costs for renewable generation incurred to reduce CO2 emissions are equivalent to about £50 per tonne of CO2 (tCO2) for the increase in wind generation up to 2020 and about £200 per tCO2 for the increase in solar generation over the same period. Note that these figures cover the costs of balancing the electricity system alone. Once other costs – transmission plus the construction and operation of wind turbines or solar panels – are taken into account, the full cost of reducing emissions of CO2 by investment in renewable generation exceed £100 per tCO2 for wind power and £300 per tCO2 for solar power.

As a reference point, the UK Government's carbon floor price implies that reductions in CO2 emissions are valued at £18 per tCO2 up to 2020. Hence, the additional costs of balancing the electricity system alone are nearly 3 times the value of the saving in CO2 emissions as a result of additional wind generation. For additional solar generation the increase in balancing costs is at least 10 times the value of the saving in CO2 emissions.

[2] Technically, this is NETS boundary B7 which runs from Whitehaven in the west to Whitby in the east. Most wind farms in Cumbria, Northumberland and Durham lie north of this boundary.

Conclusion

Critics of the UK's energy policies over the last decade point to the need to manage electricity supply in order to ensure that the unavoidable intermittency of renewable electricity generation is offset by sources of backup generation when and where required. There are frequent references to the need to ensure that sufficient gas-fired capacity is built to replace coal-fired plants that have closed and to ensure an adequate margin of dispatchable generation. To fill the gap National Grid has entered into short and medium term capacity contracts with diesel and other generators to provide sources of emergency power when it is needed.

The analysis highlights the distortions resulting from current policies caused by the fact that intermittent generators do not have to take account of the costs that they impose on consumers and other generators. While renewable generation may be advertised as being clean and green, their economic and financial viability relies upon hidden subsidies whose costs are borne by consumers via higher network charges as well as levies built into electricity prices. In 2020 and beyond the net economic value of new renewable generation will be close to zero and may be negative. As a consequence, reliance upon renewable generation is an extraordinarily expensive way of reducing CO_2 emissions with a cost that is far higher than the upper threshold established for the energy sector as a whole.

Note: The results reported in this summary are based on an extended and updated version of G. Hughes, J. Constable & L. Moroney – When is adding generation capacity to a congested network justified? (Paper presented to CCRP Conference, Barcelona, July 2014)

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