NATIONAL GRID

I am responding to your letter dated 28th November where you requested a response to the recommendation in paragraph 121 of the report by the Scottish Parliament's Economy, Energy and Tourism Committee into the achievability of the Scottish Government's renewable energy targets.

I attach, as an Appendix, a report which aims to provide further clarity on the impact of reduced thermal generation plant efficiency due to increasing intermittent wind generation on the overall carbon intensity of the electricity system. The report concludes that this effect causes only a small effect on the carbon intensity of thermal plant generation which is less than 1% of the benefit of carbon reductions from wind farms.

APPENDIX

The Committee further seeks clarity from National Grid and the UK Government on whether "reducing the carbon intensity" of the grid takes account of electricity which is generated from thermal plant but, due to despatch decisions, does not make it as far as the grid, whether this is expected to be a continuing issue and, if so, for how long?"

This response is provided on behalf of National Grid which owns and operates the high voltage electricity transmission system in England and Wales and, as National Electricity Transmission System Operator (NETSO), operates the Scottish high voltage and offshore transmission system. National Grid also owns and operates the gas transmission system throughout Great Britain and through our low pressure gas distribution business we distribute gas in the heart of England to approximately eleven million offices, schools and homes.

In Great Britain, our primary duties under the Electricity and Gas Acts are to develop and maintain efficient coordinated and economical systems and also facilitate competition in the generation and supply of electricity and the supply of gas. Our activities include the residual balancing in close to real time of the electricity and gas markets.

Summary

The intermittency of wind farms have a small effect on the carbon intensity of the remaining electricity system (e.g. thermal plant). Over the period studied it is estimated that the benefit in carbon dioxide reductions from wind farms was offset by 0.081% due to this effect. The scale of this reduction in benefit is dependant on whether coal or gas is the marginal fuel for electricity generation.

Introduction

Electricity Suppliers purchase electricity that they forecast their customers will use from Generators. Generators notify their consequent expected output profile to the NETSO and self-dispatch their plant to meet this profile. If necessary, the NETSO accepts bids and offers[1] from Generators to alter their output to ensure that actual electricity demand is met in real time. In addition the NETSO ensures that there is an appropriate amount of generating capacity (reserve) above and below forecast demand. This capacity ensures that the system remains secure, within a defined set of criteria, if the demand turns out to be higher or lower than forecast, if there are generation losses, if there are demand losses

e.g.: pumping demand) or if the output from the wind farm[2] fleet turns out to be higher or lower than forecast.

A proportion of reserve is either committed or stood down ahead of real time (Contingency Reserve); a proportion of reserve is held on unsynchronised plant

[1] Bids and offers are tendered by Generators to the NETSO specifying the price they would be paid for the energy if the NETSO wished to decrease or increase the output of the Generator

[2] Wind farms are the only form of intermittent generation to have achieved the scale to warrant holding reserve

(Short Term Operating Reserve); a proportion of reserve is held on synchronised plant (Regulating Reserve); a proportion of reserve is set aside to ensure frequency response requirements are met in real time.

To quantify wind generation impacts the carbon intensity of the remaining generation fleet, the following analysis has been carried out:

1. Direct carbon emissions reduction estimated through the total volume of energy generated by wind farms.
2. Volume of gas used by Generators compared with the amount of electricity generated over time to determine whether the intermittent nature of wind generators' output has affected the carbon intensity of the generation fleet.
3. Calculation of indirect carbon emissions arising from energy generated by Short Term Operating Reserve that is estimated to be due to real time wind output being less than forecast.

National Grid's system operator activities are principally concerned with energy transmission and balancing; although our response is primarily conveyed in these terms, estimations of carbon intensity have been included for illustration purposes. Note that in accordance with the Transmission Licence, National Grid does not own any Generation Stations.

1. Volume of energy generated by wind farms

The volume of energy generated by wind farms in Great Britain is shown in **Table 1**. This has been broken down into the three most recent six monthly periods. If the wind farms that generated this energy had not been constructed this energy would have been generated by what would have been the next most economic generator. From October 2011 to September 2012 this would likely have been a Combined Cycle Gas Turbine (CCGT)[3]. From April 2011 to September 2011 the marginal generator could equally have been a CCGT or a coal fired generator[4]. An average carbon intensity for gas and coal has been used for this period. It is assumed that CCGT's emit 392 tonnes CO_2/GWh[5] and coal fired generators emit 912 tonnes CO_2/GWh[5] of electricity generated.

[3] Fig F2, National Grid Winter Consultation Report 2012/13, http://www.nationalgrid.com/uk/Electricity/SYS/WinterOutlook/

[4] Fig F2, National Grid Winter Outlook Report 2012/13, http://www.nationalgrid.com/uk/Electricity/SYS/WinterOutlook/

[5] Provisional carbon dioxide emission figures for 2011, from Table 5A, 2012 Digest of UK Energy Statistics, http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Table 1 – Volume of energy generated by wind farms in GB and estimated consequent reduction in CO_2 emissions

Period	Estimated energy generated by small wind farms[6] (GWh)	Energy generated by large wind farms (GWh)	Total estimated energy generated by wind farms (GWh)	Estimated carbon intensity of displaced generation (tonnes CO_2/GWh)	Estimated reduction in CO_2 emissions (tonnes)
Apr 11 – Sep 11	2,174	3,841	6,015	652	3,920,000
Oct 11 – Mar 12	2,999	7,047	10,046	392	3,940,000
Apr 12 – Sep 12	2,193	5,453	7,646	392	3,000,000
18 month total	7,336	16,341	23,707		10,900,000

2. Analysis of the effects on carbon intensity on the remaining generation fleet due to the intermittent nature of wind

Half-hourly or Daily Data on the efficiency of thermal generation stations is not readily available. Therefore, for this analysis an approximation of the efficiency of gas fired plant has been made by analysing the amount of electricity generated by gas fired power stations and comparing it to the volume of gas consumed by the same stations.. There are two key findings:

- At a total gas fired power station fleet level, there was no correlation between the overall efficiency of the gas fired power station fleet and the amount of electricity generated by wind
- The analysis showed that there continues to be variations in the efficiency of gas fired power stations, but this could not be linked directly to wind intermittency

Variations in power station efficiency may be due to a range of reasons, including, but not limited to, the age of the plant, temperature, maintenance schedules and operating strategy and whether the plant is generating at or near its Maximum Export Limit or its Stable Export Limit. The method used for calculating gas fired power station efficiency, namely using gas delivered from National Grid's National Transmission System as a proxy for gas consumed by the power station can only provide an approximate indicator of power station efficiency, as it ignores the effect of gas linepack variations in the power station operator's system.

[6] In general small generators connect to Distribution Network Operators' (DNO) systems and are not visible to the NETSO. The output from small embedded wind farms has been estimated in this analysis

3. Analysis of the indirect effects on system carbon intensity due to over forecasting wind output

Should actual output from the wind farm fleet be less in real time than that forecast it may be that Short Term Operating Reserve has to be committed to cover this shortfall. In many cases Short Term Operating Reserve need not be committed to cover a shortfall in wind output, for example:

- Demand may turn out to be lower than forecast, with the wind and demand forecast errors cancelling each other out
- A proportion of GB's installed wind capacity has been built behind the derogated B1 and B6 boundaries. As such, it has often been the case that a significant proportion of the additional reserve requirement for wind can be held within the B6 boundary[7]
- The shortfall can be met by synchronised generating capacity (regulating reserve). This circumstance does not warrant further analysis beyond that in section 2 as the energy to meet the shortfall would be provided by the next most economic generator, which would also have been the case had the wind farms not been built

The volume of energy provided by Short Term Operating Reserve estimated to be due to wind output being lower than forecast is shown in **Table 2**. These figures were calculated by comparing forecast wind output with wind output outturn, reserve levels and energy requested from Short Term Operating Reserve throughout each period. Short Term Operating Reserve is provided by open cycle gas turbines, diesel generators, pump storage and demand reduction, it is assumed that its' average carbon intensity is similar to coal - 912 tonnes CO_2/GWh. If there were no wind farms this energy would have been generated by the next most economic generator(s) which would likely have been a CCGT from October 2011 to September 2012. If so, the carbon intensity would increase by 520 tonnes CO_2/GWh. From April 2011 to September 2011 the next most economic generator could equally have been a coal fired generator or a CCGT. Assuming an average carbon intensity for gas and coal for this period gives an increase in carbon intensity of 260 tonnes CO_2/GWh for this energy.

[7] E.g.: 1000MW of coal fired generation capacity might be constrained by the B6 boundary. The forecast wind output might be 1100MW. In real time the actual wind output might turn out to be 700MW. The 400MW loss can be covered by being able to generate 400MW more on the coal fired generators that are located within B6 (with 600MW of coal fired capacity remaining constrained)

Table 2 – Energy provided by Short Term Operating Reserve in GB which is estimated to be due to wind output being lower than forecast and consequent estimated additional CO_2 emissions

Period	Energy provided by Short Term Operating Reserve (GWh)	Energy provided by Short Term Operating Reserve which is estimated to be due to wind output being lower than forecast (GWh)	Estimated increase in carbon intensity for this energy (tonnes CO_2/GWh)	Estimated additional CO_2 emissions (tonnes)
Apr 11 – Sep 11	74	10	260	2,600
Oct 11 – Mar 12	129	11	520	5,700
Apr 12 – Sep 12	43	1	520	520
18 month total	246	22		8,800

Conclusion

Table 3 summarises the estimated benefit and indirect effects on carbon intensity attributable to the wind farm fleet.

Table 3 – Estimated benefit and indirect effects on carbon intensity

Period	Estimated reduction in CO_2 emissions (million tonnes)	Estimated additional CO_2 emissions due to intermittency impact (million tonnes)	Reduction of benefit (%)
Apr 11 – Sep 11	3,920,000	2,600	0.066%
Oct 11 – Mar 12	3,940,000	5,700	0.14%
Apr 12 – Sep 12	3,000,000	520	0.017%
18 month total	10,900,000	8,800	0.081%

Over the 18 month period the electricity generated by wind farms reduced the requirement for electricity from other sources by 23,707 GWh, resulting in an estimated 10.9 million tonnes less CO_2 being emitted. Because there were wind

farms on the system it is estimated that 22 GWh of electricity was provided at a higher carbon cost than would otherwise have been the case, resulting in an increase of 8,800 tonnes of CO_2 being emitted. This offset the benefit in the reduction in carbon intensity by 0.081% over this 18 month period.

National Grid's view on future energy scenarios and system operation challenges can be found at: http://www.nationalgrid.com/uk/Electricity/Operating+in+2020/.