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Meeting Scotland's peak demand for electricity

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Summary

The closure of Longannet in 2016 raised debate about the ability of Scotland to meet its peak demand for electricity. Given Scotland's transmission links to the rest of Great Britain and the interconnection with Northern Ireland, how likely is it that the remaining generation fleet in Scotland can meet peak demand? The research we present in this report suggests that the answer in early 2017 is: extremely likely.

However, between now and 2030 major changes are expected to the Scottish electricity system: Hunterston and Torness nuclear stations are both expected to close by 2030, there is no certainty over the long term future of Peterhead gas power station, the capacity of wind generation is expected to grow, and the size of the peak demand is also likely to grow. The result is that flows of electricity across the transmission network will be considerably more variable, from large exports when it is windy to large imports when it is calm. Towards the end of the 2020s, at the latest, it is likely either new transmission links with the rest of Great Britain, or new generation capacity that is capable of being scheduled in advance will be required to ensure Scotland's peak demand security-of-supply.

Existing policy for planning the transmission network is based on a standard that was designed for a system where flows of electricity were more predictable and consistent than is the case today. This study analyses the level of transmission import capability and investigates the following question:

What transmission import capability is required into Scotland in order to provide confidence that peak-demand for electricity can be met?

The answer to this question can be thought of as defining the level of Scottish peak demand 'security-of-supply'. Security-of-supply does not mean guaranteeing that peak demand can be met under all circumstances, but that the level of confidence we have in being able to serve demand is acceptable. Before examining the results of our study it is important to place this question in the context of the wider GB system. In particular:

- The first condition of Scottish peak demand security-of-supply is that there is adequate generation across GB to meet the GB peak demand. Without system-wide security-of-supply, no part of GB, including Scotland, can be considered secure.

The results discussed below assume that GB generation adequacy is maintained according to the reliability standard laid down in UK law. To understand the need for transmission import we use a probabilistic[1] method, which allows us to understand the trade-off between secure import capability and the confidence of being able to serve peak demand in Scotland. We apply the method to a 2016 base-case, and then to a set of scenarios representing the expected future development of the Scottish electricity system representing 2020, 2025 and 2030.

[1] A probabilistic method is one where the probability (likelihood) of a particular outcome happening is considered as part of the process of reaching an answer.

Our key results are as follows:

- In the winter of 2016/17 with Peterhead, Hunterston and Torness power stations operational, the Scottish generation fleet combined with the transmission secure import capability of 2.65GW provides in excess of 99.9% confidence of being able to meet peak demand in Scotland (assuming sufficient generation is available in rGB).
- If there is to be the same degree of confidence in meeting peak demand in Scotland as today, the closure of Hunterston power station, expected in 2023, and Torness power station, expected in 2030, will increase the need for secure import capability. If Peterhead power station remains operational at current levels, modelling suggests that the 2030 secure import requirements is between 2.9GW and 3.7GW in order to provide 99% confidence of meeting a peak demand of up to 6.2 GW, around 15% higher than in 2016.
- The closure of Peterhead power station will increase the secure import requirement by between 350MW and 400MW.
- This increased requirement for secure import capability will be partially met by the commissioning in 2017 of the western HVDC link between Hunterston and Deeside in north Wales which will increase the secure import capability by around 1.2GW. However very large imports into Scotland, of the order of 3.5GW and larger, may require increased coordination in the operation of the transmission system across the whole of GB or further network reinforcements.
- There is likely to be a need for further secure import capability, or new schedulable generation in Scotland by 2030 (sooner if Scotland's existing power stations close earlier) in order to be certain that peak demand in Scotland can continue to be met.

We identified the following additional issues:

- Wind capacity should not be ignored when considering peak demand security-of-supply. The 2016 wind fleet of 5.5GW offsets the need for 700MW of secure import capability. In other words, if the wind generation capacity in Scotland were zero, the power import capability needed to provide the same degree of confidence of meeting peak demand would be 700MW larger.
- Interconnection with neighbouring electricity systems, notably on the island of Ireland and Norway, can reduce the import required from the transmission network in the rest of GB. However, they also introduce further uncertainty into future system operation. The reduction in costs to the Scottish and GB systems which interconnectors can potentially bring need to be carefully weighed against the additional risk that they can introduce.
- The ability to meet peak demand is not the only aspect of security-of-supply - other aspects deserve attention. In particular, the operation of the system at other times of year includes the need to take parts of the network out of service for maintenance and upgrading. Peak demand during these seasons, whilst lower than in winter, must be met from a reduced network and fleet of available generators. Against a background across GB of ageing assets in need of replacement and the requirement for reinforcements of the network, facilitating these network outages is a growing challenge for the system operator and transmission owners. Finally there is a need to ensure resources are available to allow Scotland to recover from a whole-system black out.

The report identifies the following important conclusions for policy makers:

- Development of either new transmission links or new schedulable generation capacity in Scotland is likely be required by the late 2020s. Given the time scales normally required for transmission and generation projects, it is important that system planners, regulators and policy makers ensure that further examination of the requirements and potential options begins soon.
- Scottish peak-demand security is only one of a number of aspects of security-of-supply. Ensuring that future system developments support all aspects of security will be vital to keeping the system operational and resilient. Regulators and policy makers need to be aware of the technical and multi-dimensional nature of electricity security-of-supply, and ensure that generation and network resources are designed to ensure that all aspects of security are maintained to acceptable levels.
- The current deterministic calculations used to estimate the required capability of the transmission system in respect of reliability of supply need to be revisited in light of two factors: (i) the increased penetration of

weather dependent renewable resources such as wind; and (ii) the emergence of a situation where large regions of the GB system, such as Scotland, have a small number of large conventional generation units.

The importance of GB generation adequacy

The current standard for GB generation adequacy is formulated from a probabilistic analysis. The reliability standard, enshrined in UK law[2], requires that the Loss of Load Expectation (LoLE) is at most three hours a year. That means that over the long term available generation should exceeds demand for all but three hours in a year. In the winter of 2016/17, National Grid estimates that GB has 73.7 GW of transmission contracted generation installed and nominally operational across the winter peak. Peak demand is expected to be 52.6GW[3]. The resultant LoLE will be around 0.5 hours per year – well within the standard. However, this includes 3.5GW Supplementary Balancing Reserve held outside the market without which the system would not meet the standard.

In future years, the Capacity Market is designed to ensure that the three hours LoLE standard is maintained. Auctions at four years and one year ahead of each winter will aim to procure sufficient capacity to meet the expected network conditions whilst considering a range of sensitivities for the future development of the system[4].

The LoLE standard is a calculated trade-off between the cost of generation capacity and the value we derive from being supplied with electricity. However, the expected outturn value of LoLE depends on a number of estimated variables where the uncertainty in their value is large enough to have significant impact on the LoLE value calculated for a given system. In 2014, analysis by National Grid showed that a change in de-rated capacity of 2.43 GW led to a change in LoLE from 1.1 hour per year to 8.9 hours per year. More recently, National Grid estimates of weather correct peak-demand were 1.3GW different from outturn in 2015/16 whilst assumptions about available interconnection import have risen from 1.1GW in 2015 and 2.0GW in 2016[5]. Greater understanding is needed about the uncertainty in input values for generation adequacy calculations, and the sensitivity of the required generation capacity to these uncertainties.

Interconnection reserve and the role of the transmission network

Secure transmission import capability allows Scotland to access generation resources elsewhere in GB and this sharing of resources reduces the costs of securing the whole system and Scotland in particular. The transmission system's ability to import power to a region is defined by the secure import capability. This describes not just the ability of the complete power system to transfer power on a particular day, but its capability under all likely configurations of generation, and its capability 'post-fault' - after any one of a range of credible contingencies. For an initially intact system the contingency list includes the loss of any one transmission circuit, and the complete loss of one of the two double circuits between Scotland and England[6].

The existing standard used for developing the transmission system is defined in the Security and Quality of Supply Standard (SQSS), and compliance is a condition of the license for the transmission owners and the system operator. The SQSS includes a deterministic calculation which defines the secure transfer capability into or out of a region in order to support security-of-supply. Inputs to the calculation include the capacity and type of generation within a region and across the whole system, and the peak demand within the region. This standard was designed for a system with low penetrations of weather dependent renewable generation such as wind, and where the underlying assumptions include an expectation that each region of the power system contains a large number of independent dispatchable units. These assumptions are becoming increasingly inappropriate for a number of regions of GB including Scotland.

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[2] The Electricity Capacity Regulations 2014, http://www.legislation.gov.uk/uksi/2014/2043/pdfs/uksi_20142043_en.pdf
[3] This is Average Cold Spell (ACS) peak demand, referring to the level of demand that has a 50% probability of being exceeded due to weather conditions, and can therefore be thought of as a measure of the underlying demand, independent of weather. WOR 2016
[4] See for example the 2016 EMR Electricity Capacity Report by National Grid: https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/47/Electricity%20Capacity%20Report%202016_Final_080716.pdf
[5] Within two months of publication, issues with the French Nuclear fleet and damage to half of the 2GW interconnector between Britain and France impacted the likely level of imports GB could expect over a sizable part of the winter) show that the size of uncertainties in this calculation are of sufficient size to significantly impact the results
[6] The SQSS requires that a certain minimum capacity of the transmission grid is planned for the secured event of the outage of a single transmission circuit, a double overhead line on the supergrid (275kV and 400kV) http://www2.nationalgrid.com/uk/industry-information/electricity-codes/sqss/the-sqss/. A double circuit consists of two electrically independent circuits carried on a single set of transmission towers, the four 400kV circuits between England and Scotland are grouped into two double circuits.

The method we use to investigate secure import requirements involves a set of Monte-Carlo[7] studies which estimate the *distribution* of imports needed to meet peak demand for a particular generation fleet and underlying demand. The studies take account of forced outages at conventional generators, the potential limitation of hydro-resources, historical variations in wind including its correlation across Scotland; and variations in the peak demand outturn.

In contrast to the reliability standard for generation adequacy, defining a universal requirement for regional security-of-supply is problematic due to the different characteristics of each region of the power system. The investment needed per unit of secure import capability is difficult to estimate, will vary significantly between regions, and will vary even for different capacity increases for the same region depending on which type of constraint is binding. For this reason, rather than attempting to set a single reliability level, we calculate estimates of the secure import capability required to give a range of confidence levels for meeting peak demand. Comparisons between scenarios are made using the 99% confidence level.

Figure 1 shows the distribution of import requirements for the 2016/17 base case and the secure import capability required at four confidence levels. The cumulative distribution, shown in Figure 1 (b) shows the probability that import requirements of less than a particular value are needed. The import required to provide four levels of confidence (90% - 99.9%) of the system being capable of meeting Scottish peak demand are illustrated.

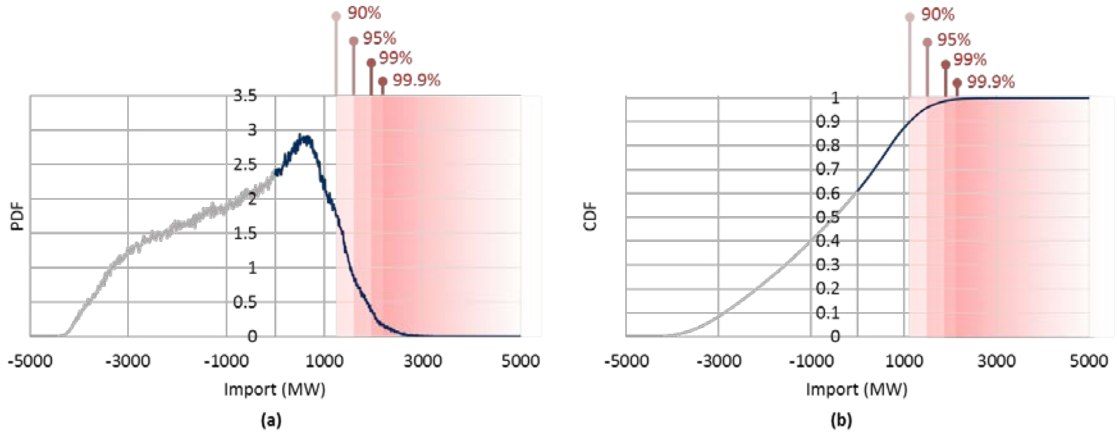


Figure 1: Distribution of import required at time of peak for the 2016 - base scenario; (a) shows the density function which shows the probability that import of a particular level is required; and (b) shows the cumulative function which presents the probability that import of less than a particular level is required.

Scottish secure transmission import requirements

We apply the method to scenarios representing Scotland in 2016, 2020, 2025 and 2030 with high and low assumptions for wind penetration and peak demand in each future year. The major changes to the generation fleet expected over this period are the closure of the two remaining nuclear plants at Hunterston and Torness, and the continued growth of wind. The main scenarios assume no interconnection with other power systems, and continued operation of Peterhead at its existing market-operating capacity of 400MW. Figure 2 shows the secure import required to provide 99% confidence of meeting peak demand and show that:

- Scenarios with higher demand require greater import capability.
- Scenarios with higher wind penetration require lower import capability. Whilst wind availability across Scotland can be low at times of peak demand, the addition of wind generation does reduce the probability of requiring high imports. The current wind fleet of 5.5GW can offset approximately 700MW of secure import capability whilst leaving Scotland with 99% confidence of meeting peak demand. This is a regional capacity credit of 12%.
- The expected closure of Hunterston in 2023 and Torness in 2030 lead to increasing requirements for import to meet peak demand, assuming that no new dispatchable generation is built in Scotland.

[7] The Monte-Carlo studies involve repeatedly simulating the conditions that may occur at peak demand in each year. Each variable (availability of each conventional generator, wind conditions and the size of peak demand) are randomly sampled from their underlying availabilities and an import requirement calculated for that trial. After 1 million trials, the import requirements are combined to produce the distribution of import.

- Scenarios in 2030 (with Hunterston and Torness closed) and using the low assumption of wind capacity have secure import requirements in excess of 3.5GW.

Figure 2 also shows the current secure import capability of 2.65GW, and an estimate of the value after commission of the HVDC Western Link project, expected during 2017, of 3.9GW[8]. The secure import capability is affected by more than just the network itself and published value with the Western Link commissioned is calculated under system conditions expected for the second half of the current decade, notably with continued operation of Torness and nuclear and coal generation in the north and midlands of England.

Discussion with industry suggests that the likely evolution of the generation background during the 2020s will further impact on several of the relevant power system constraints. Closure of some stations in Scotland and England may relieve certain constraints, for example freeing up thermal capacity on critical transmission circuits, but may tighten other constraints such the potential for voltage dips during a fault. Whilst power flows above 3.5GW can be achieved with the Western Link, they place greater constraints on other aspects of system operation which may, for example, require precise settings on transmission equipment elsewhere in Britain. Under some future scenarios the binding constraint on getting power into Scotland may be a limit on a circuit as far south as central England, for the reason that high levels of import into Scotland depend on being able to move power from southern England into central England and then onto northern England.

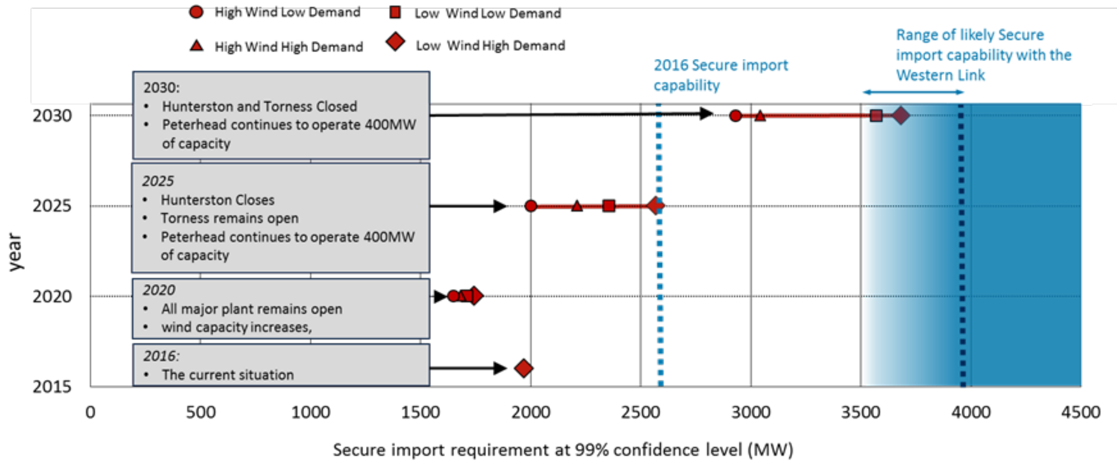


Figure 2: Secure import requirements at the 99% confidence level for the main scenarios assuming the remaining major generation capacity in Scotland operates as stated in 2016.

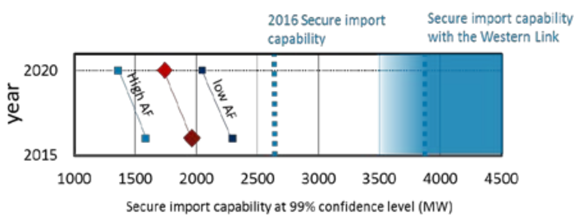
The results in Figure 2 show that the existing system, bolstered by the western interconnector is likely to provide sufficient secure import capability to give 99% certainty of meeting peak demand after the closure of Hunterston and possibly after the closure of Torness. However scenarios with secure import requirements in excess of 3.5GW show a need for careful consideration of how the system would be operated in such conditions, and whether further reinforcement of the system are needed.

Sensitivities

To understand the potential impact of other changes to the Scottish system on the secure import requirement sensitivity studies have been run in which, for each future year, the low wind and high demand scenarios form the baseline.

The impact of availability factor assumptions

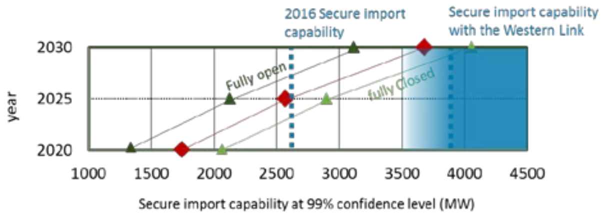
Availability factors are used to estimate the probability of a conventional generation unit being available to generate at the time of peak demand. They are estimated based on analysis of historic data. The base values used in this work are typical of those used in GB generation adequacy studies. However, it is likely that changes to the generation fleet such as aging will affect future availability factors. Two sensitivities (High AF and Low AF) are included to show the



[8] Security of Electricity Supply in Scotland, www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=40185

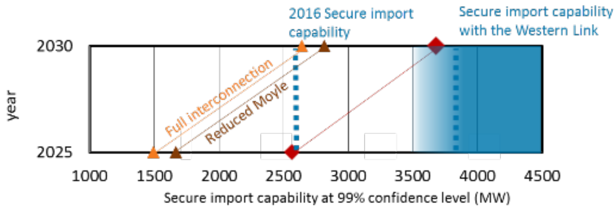
impact of varying the availability factors in 2016 and 2020. In the Low AF case, the availability factor for nuclear drops from 81% to 71% and the availability of CCGT drops from 87% to 83%. The result is an increase in the secure import requirements of approximately 300MW at the 99% confidence level compared to the base case.

Peterhead



In 2016 Peterhead operated at partial capacity with 400MW of its 1.18GW in the market and a further 750MW used by National Grid as contingency reserve. The base assumption in this report is that 400MW remains available in all years. Sensitivity for the years 2020, 2025 and 2030 show the impact of (a) closing Peterhead and (b) reopening its full capacity. Closing Peterhead increases the secure import requirement at the 99% confidence level by between 320MW and 372MW. Re-opening the full capacity decreases the secure import capability by between 421MW and 568MW. Results for the sensitivity with Peterhead, Hunterston and Torness closed in 2030 is the only sensitivity modelled where the secure import requirement exceeds 4GW.

Interconnection with other markets



The Moyle link with Northern Ireland is the only existing interconnector connected in Scotland. The Moyle cables have a capacity of 500MW, however import into Scotland is limited to 290MW and this is expected to drop to 80MW from 2017[9] due to limitations of the transmission network in South West Scotland, however this may increase again in future years. New interconnectors are proposed for connection, for example the 'North Connect' project between Peterhead and Norway.

Two interconnector sensitivities are modelled for both 2025 and 2030 which include Moyle and a 1.4GW interconnector with Norway. In the first sensitivity Moyle is modelled at full capacity and in the second with a reduced import capacity of 80MW. The ability of an interconnector to support Scottish security-of-supply depends not just on its technical availability, but on spare generation capacity in the market at the far end of the interconnector, and on an effective mechanism to direct power. We have taken optimistic assumptions in line with other studies for these factors[10].

The impact of interconnection is to reduce the secure import requirement from the transmission system, however the reduction is significantly less that the total installed interconnector capacity. At the 99% confidence level, with Moyle operating at full import capability, the 1.85GW of interconnector capacity only reduces the secure import requirement by approximately 1.0GW. This reflects the uncertainties over the state of availability of generation in the market at the far end of the interconnector including a small probability that the Norwegian system would require import from GB due to a lack of hydro availability in Norway.

The impact of wind

Generation availability from wind farms is governed by the level of wind resource. At any one time across Scotland the availability of wind is neither fully correlated nor fully independent. Wind modelling in this study is based on sampling from a long term historic time series of winter-wind conditions across Scotland converted into power availabilities through the use of regional power curves. This ensures that the correct correlation between wind availabilities in different regions, and the correct rate of very high and very low wind availabilities across the whole of Scotland, are included.

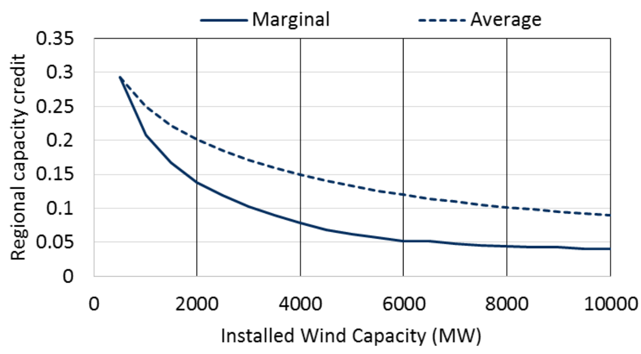


Figure 3: The regional capacity credit of a Scottish Wind generation with the total size of the wind fleet.

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[9] Transmission Entry Capacity register: http://www2.nationalgrid.com/UK/Services/Electricity-connections/Industry-products/TEC-Register/

[10] The scenario is the 'GB importing scenario' produced by Baringa Redpoint presented in 'New electricity interconnection to GB – operation and revenues' pg 18. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/266307/DECC_Impacts_of_further_electricity_interconnection_for_GB_Redpoint_Report_Final.pdf

Figure 3 shows the results of studies for the 2016/17 base case where the total wind capacity in Scotland was varied between 500MW and 10GW. It shows the ratio of displaced import requirement to installed wind capacity. This 'regional capacity credit' is in excess of 30% when the level of wind penetration is low, close to the seasonal capacity factor of wind, but this drops to less than 10% with a 10GW fleet. The reduction is due to the internal correlation between availability at different locations and directly reflects the fact that calm conditions are likely to affect a large proportion of the wind fleet at the same time.

Despite this, the results show that the 2016 Scottish wind fleet of 5.5GW can reduce the need for secure import capability by 700MW whilst leaving Scotland with the same confidence of meeting peak demand.

The main results in this study assume zero correlation between the level of peak demand and the availability of wind. We conducted further sensitivity analysis which show that the main conclusions remain valid when negative correlation between the level of peak demand and the availability of wind is assumed. The levels of this negative correlation are the same as those currently assumed in GB generation adequacy studies[11].

Other aspects of Scottish security-of-supply

Away from the winter peak, other factors drive day-to-day security-of-supply and these include a number of issues with much stronger location specific requirements, ones that cannot be met from outside Scotland. Controlling voltage requires resources at strategic locations across the network; the availability of large synchronous generators provides stability to the system and supports the ability to respond effectively to faults such as short circuits. Finally the ability to restart the system in the (albeit unlikely) event of a full system black out is significantly hampered if a large area of the power system is without a 'black start' generator – one that can restart without reliance on other sources of power. Research and development is underway into how these issues can be solved using new techniques such as the use of small scale distributed generators and the provision of some system services from wind farms, storage or interconnectors. However, whilst the results presented in this report suggest Scottish peak demand is secure to a high confidence level whilst at least one of the two nuclear stations remains operational, in the short to medium term it is important to consider these other aspects of security and resilience. Of particular importance will be the development of a better understanding of the locational value that Scottish generation provides across the whole gamut of ancillary services and ensuring that generators are able to realise the value that they provide because of their location, as well as the value their energy and capacity provide to the whole system.

[11] EMR Electricity Capacity Report by National Grid: https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/47/Electricity%20Capacity%20Report%202016_Final_080716.pdf