An Examination of National Grid's *Future Energy Scenarios*

Do the scenarios deliver security of supply?

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Summary

National Grid, in its 2016 study Future Energy Scenarios, considered four alternative views of UK energy supply and demand up to 2040. While these may be useful as a framework within which to plan, they say nothing about one essential factor, security of supply. For each of the scenarios, we estimate the possibility of meeting an established risk baseline: a grid supply failure occurring in no more than four winters every hundred years (as used prior to privatization).

The maximum demand for energy, occurring early in the evening during winter, has to be met consistently if the risk criterion is to be fulfilled. Even with the use of all available means to reduce peak demand, including voltage and frequency reduction, the risk of power outage is significantly higher than 4% for all four scenarios.

The dependable (dispatchable) power from installed conventional, nuclear and hydro generators plus continental inter-connectors would be insufficient to meet peak demand, and this gap could not reliably be bridged using wind generation. Solar generation would make no contribution at all to meeting peak demand.

To meet peak demand in the period up to 2025, an additional 5 to 12 GW of firm, despatchable generating capacity would be required: six or more gas-fired power stations. As renewable energy capacity is increased, these power stations would lie idle for large periods, but would be essential to maintain security of supply in the winter.

After 2025, two of the scenarios – Gone Green and Consumer Power – appear to offer security of supply but only if European inter-connectors can be fully relied upon.

In these circumstances, we strongly recommend that the security of the UK's electricity supply is reviewed again from first principles and appropriate steps taken to ensure that consumers, industry and economic growth do not suffer.

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1 Introduction

1.1 In 2016 National Grid (NG) published a document entitled Future Energy Scenarios(1) which postulated four scenarios of future energy demands for GB up to 2040, and how those demands could be met. They considered both gas and electricity demands, but this document will focus only on the plans for electricity generation and supply. This paper will examine the Risk to Security of Supply implied by the Demands and Generation specified in the FES 16. It will also estimate the extra generation capacity that will be required to bring the Loss of Load Probability (LOLP) Risk down to 4% (the Standard that was used for planning pre-privatization).

1.2 The NG FES 2016 paper describes four scenarios:

1. Gone Green[1]

   Gone Green is a world where green ambition is not restrained by financial limitations. New technologies are introduced and embraced by society, enabling all carbon and renewable targets to be met on time.

2. Slow Progression

   Slow Progression is a world where slower economic growth restricts market conditions. Money that is available is spent focusing on low cost long-term solutions to achieve decarbonisation, albeit it later than the target dates.

3. No Progression

   No Progression is a world focused on achieving security of supply at the lowest possible cost. With low economic growth, traditional sources of gas and electricity dominate, with little innovation affecting how we use energy.

4. Consumer Power

   Consumer Power is a world of relative wealth, fast paced research and development and spending.

1.3 The NG FES 2016 document indicates likely outcomes for each scenario until 2040. The document is silent about detailed strategic fuel procurement, and generation engineering and management considerations that would be required. It is also silent on:-

(a) Security of Supply to the GB grid,

(b) the scale of modifications required to the transmission system,

(c) the practicality (in terms of cost, difficulty of construction, availability of generation outside of GB) of any of the required interconnections to Europe,

(d) estimates of the cost of the scenarios, and

(e) the attractiveness of the scenarios to the builders and operators of generating plant (particularly fossil-fuel developers).

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1 *Gone Green*, *Slow Progression*, *No Progression* and *Consumer Power* are names given to the scenarios by National Grid.

1.4 This present study will, for each of the four scenarios determine the LOLP Risk for each scenario. If the scenario cannot achieve a risk of loss of load below 4% (the planned Risk prior to privatization) then the amount of fossil-fuelled or nuclear generation that must be added to achieve an LOLP risk no higher than 4% will be determined.

2 Method: calculating the loss of load probability

2.1 Reliability for the UK grid supply system was historically taken as a risk of no more than four winters of grid supply failures every 100 years, implying a risk of failure of 4 %.

2.2 Figure 1 illustrates the method of calculating the risk of loss of supply for a given demand load forecast and generation capacity. The probability of not being able to meet the demand for each segment of the generation probability density function (pdf) is the product of generation probability (the orange shaded area) and the probability that the demand load will exceed the generation level (the green shaded area). Summing across all segments of the generation pdf then gives a total risk of loss of supply for the modelled generation capacity.

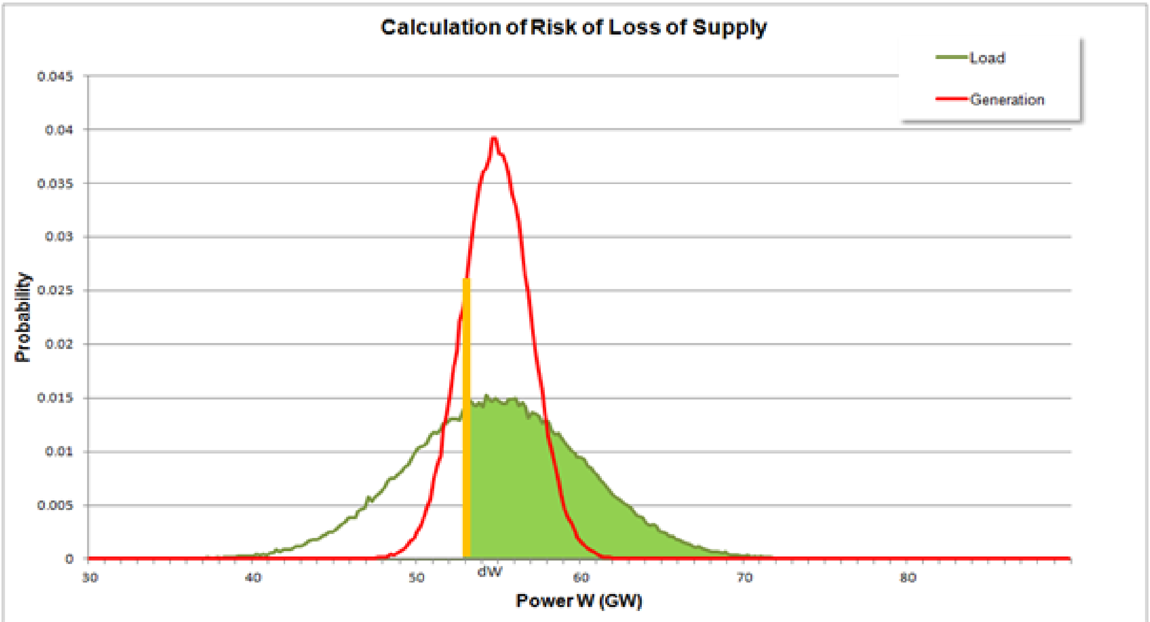

Figure 1 The LOLP risk calculation method[2]

2.3 System Maximum Demand data for the scenarios are taken from Chapter 3 of the FES document. Three series of studies are run for each scenario viz: using the Average Cold Spell (ACS)[2] Demand, the ACS Demand reduced by Demand Side Reduction (DSR)[2] and Time of Use Tariffs (TOUTS)[2], and a third series with the demand further reduced by two stages of voltage reduction and frequency adjustment.

2.4 In each of the studies, the System Maximum Demand (SMD) is taken to have a Gaussian probability density function (pdf) with a median value of the figure given in the FES and a Standard Deviation (SD) driven by a combination of economic and weather uncertainties. The values for of economic and weather uncertainty for the period 2015-22 are shown in Table 1 based on the Electricity Council Report on the Security Standard, 1985.

[2] ACS, DSR and TOUTS are all abbreviations used in National Grid's Future Energy Scenarios document.

	System Maximum Demand Standard Deviation							
	2015	2016	2017	2018	2019	2020	2021	2022-
Economic effects	1 %	1 %	2.5 %	4 %	5.5 %	7 %	8 %	9 %
Weather effects	3.87 %	3.87 %	3.87 %	3.87 %	3.87 %	3.87 %	3.87 %	3.87 %
Resultant SD	4 %	4%	4.6 %	5.6 %	6.7 %	8 %	8.9%	9.8 %

Table 1 Economic and weather uncertainties driving the demand standard deviation over the period 2015-22; later years repeat the 2022 values.

2.5 The authors have concerns, however, about DSR in the longer term unless bilateral contracts are agreed with participants specifying long-term commitments to taking no more than a fixed demand (capacity) at triad peaks. This would preserve NG's negotiating stance with regard to having the option of new generation.

2.6 Generation Data is derived for each scenario as follows: -

(a) Nuclear, fossil fuelled, hydro, onshore wind, offshore wind, and PV solar installed capacities are as per the FES. Firm, dispatchable capacity is taken as the sum of storage, biomass, CCS CHP, gas, coal, other thermal, and nuclear capacities. These summed capacities are multiplied by 0.85 to allow for planned and un-planned plant outages, and this value is then taken as the median of a Gaussian production distribution with a SD of 3.75%. (The authors are aware that both the Demand and the Generation pdfs may be 'fat-tailed' and not Gaussian which would increase the risk values.)

(b) For wind generation, the pdfs are derived from the papers of Dr. Capell Aris published by the Adam Smith Institute(3) scaled to match the installed capacities of each scenario. These are based on actual wind data over a period of nine years between 2005 and 2013. Wind generation can make a small contribution to meeting peak demand but is intermittent. The production probability curve is completely different to that of fossil fuelled plants, see Figure 2.

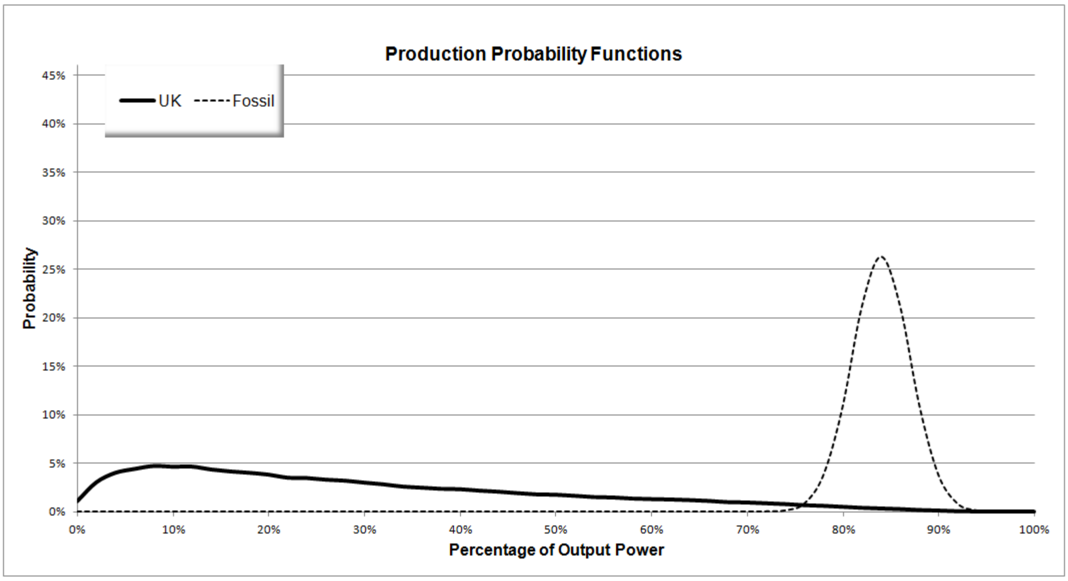

Figure 2 Probability Distribution for wind generation in the UK, compared with that for fossil/nuclear generation(3).

(c) It is noted that Solar generation can make no contribution to meeting ACS demand because no solar production occurs at the time of ACS (17:30 hours in winter months), as demonstrated in Figure 3 (2),

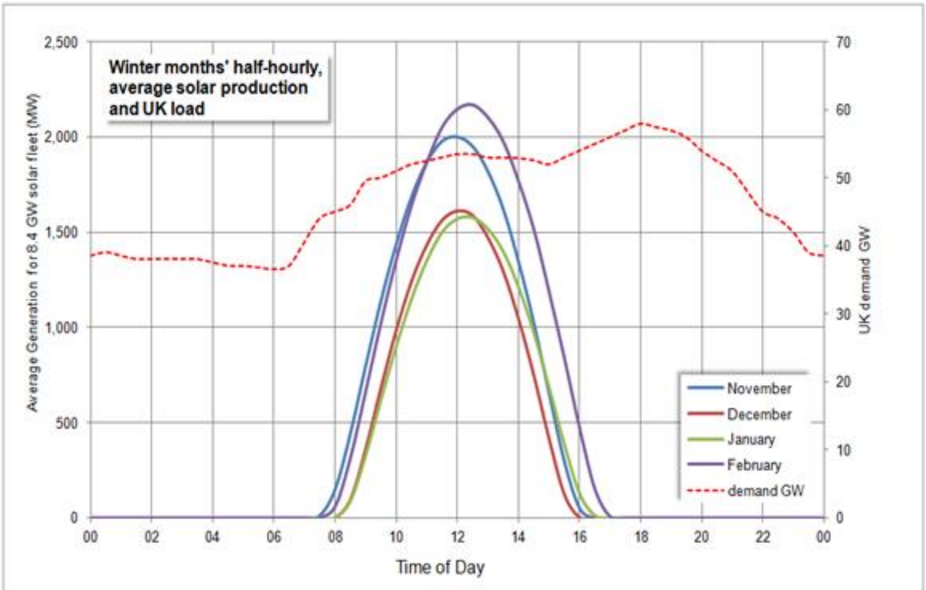

Figure 3 Average daily solar production from a modelled 8.4 GW UK fleet for the winter months, based on data similar to the UK wind generation study. Peak demand occurs at 17:30 when there is never any solar production(2).

(d) Marine and other renewables are not included in the risk of loss supply analysis.

(e) The various pdfs for each type of generation are conflated into one pdf in order that the LOLP Risk can be calculated.

(f) The stated interconnection capacities in each of the scenarios are included in the total, firm dispatchable capacity. However, the following points are noted and will be considered in later sections.

The interconnectors to France, and Netherlands (and thus northern Europe) will seek generation supply in competition with demand from within continental Europe. France and Germany dominate electricity production in this area. France has a surplus of dependable nuclear generation, but the nuclear fleet is old and undergoing a life-extension programme; by 2030-5 this fleet will require replacement. Germany is committed to its Energiewende project and a continued increase in renewable generation, see Figure 4, together with a government objective to close all its nuclear plants by 2025.

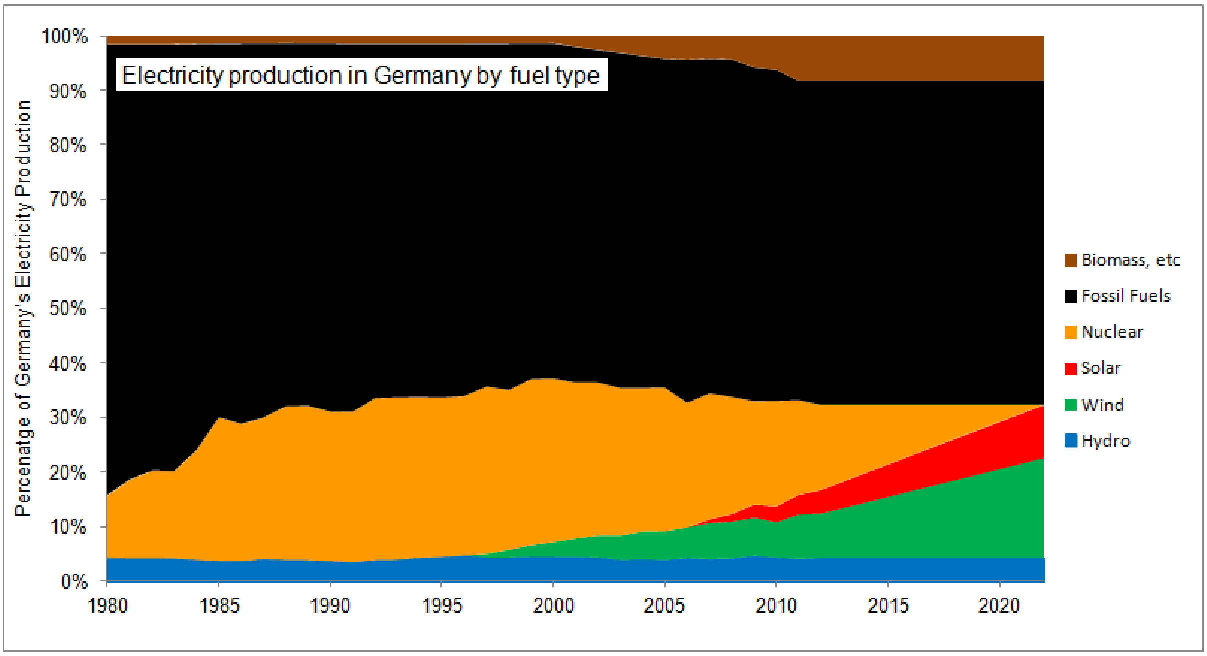

Figure 4 Germany's historic generation production, showing prediction to 2025. EIA data

North European (The sum of Ireland, UK, Belgium, Netherlands, Denmark, and northern Germany) renewables share similar intermittency patterns to those of the UK, see figure 5; the incidence of pan-European intermittency is summarised in Table 2 (2). Figure 5 shows the incidence of periods when renewable output fell below a varying percentage of this installed fleet size for 6 hours or more. The solid lines show the longest duration of such incidents that occurred during a nine year period (scale: left vertical axis). The dashed lines show the annual incidence of incidents longer than 6 hours (scale: right vertical axis).

If a statistical approach is not convincing, then a simple recollection of the occurrence of prolonged periods of pan European high pressure, often in winter, should provide ample warning that we can expect periods of low wind energy production annually.

This northern European renewable fleet size is (2014) 105 GW (excluding the Scandinavia hydro fleets), which is surprising since the wind fleet has a poorer capacity factor than the UK's (solar production is marginally higher than the UK). Since northern Europe is likely to suffer generation scarcity, and we share intermittency of renewables with the area, the north European interconnectors should not be considered a source of firm capacity. If 'firm' contracts were in place, then the capacity covered by the contracts could be considered.

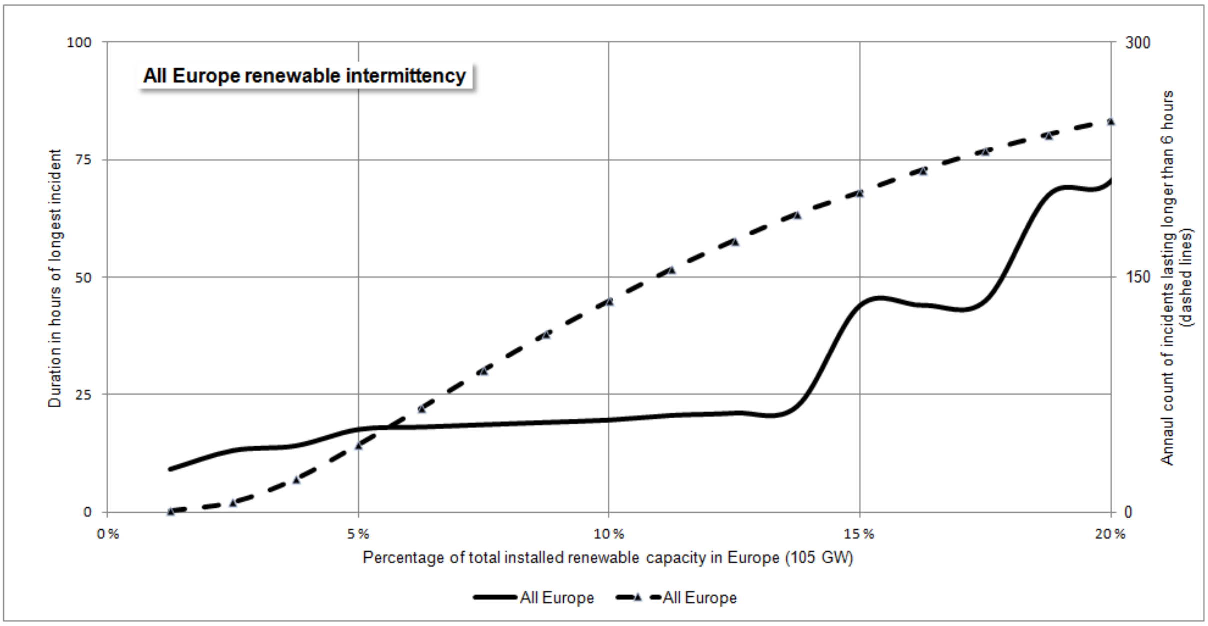

Figure 5 The scale of European renewable intermittency Inclusive of the UK fleets.

	Fleet power output as percentage of installed capacity			
	5 %	10 %	15 %	20 %
Annual incidence	43	135	204	250
Duration (hours)	6-18	6-20	6-44	6-71

Table 2 Modelled European solar and wind renewables fleet intermittency overview. (Total installed capacity 105 GW).

The Irish interconnector connects to a very small grid with a very large renewable generation component. Much the same comments as the foregoing apply to this interconnector.

Recent proposals for an interconnector to Iceland should caution that although Iceland certainly does have scope for expansion of its hydro and geothermal generation that (a) this will take time to design, approve and build, (b) will compete with the extent of Iceland's own 'Energy Change' programme to convert all transport to domestically produced hydrogen, and (c) requires an extremely long, ocean connection, crossing a deep Atlantic trough and the Hebridean sea, and then a 400 nm link to the UK load centres.

3 Risk of loss of supply for each scenario

The results of the Risk calculation for each scenario are shown in graphical form in Figures 6-9 below. This series of studies assumes the full interconnector capacity stated for each scenario and year is regarded as a generator with a median availability of 85% and an SD of 3.75%. The assumption of full interconnector *capability* as a firm *capacity* should be regarded as an optimistic assumption (see Section 2.6(f)).

These graphs show that for most of the study periods the power sent out by the dispatchable plants falls below ACS demand. If no other plant was available, then grid supply outages would be a certainty. The hope, then, is that the renewable plant will provide sufficient power to top-up the dispatchable plant and thus guarantee the demand is met. Between now and 2025 that is clearly not the case; in this period all of the scenarios will experience periods when the risk of a loss of supply has a probability higher than 4 %, the historic Central Electricity Generation Board (CEGB) criteria for a secure supply. This remains true even after the ACS is reduced by DSR and TOUTS demand reductions and two stages of voltage reduction followed by a grid frequency reduction. This jars the description

'Consumer Power is a world of relative wealth, fast paced research and development and spending'.

The 4 % risk standard was devised when most generation plant was dispatchable and fossil-fuelled powered. If grid supply could not be met it was considered that this would be caused by failure of generation plant or a transmission fault and that these faults could be cleared in a few hours and power restored to the grid. Generation and transmission faults could still occur nowadays, but now we have to contend with the additional possibility of failure of our wind and solar fleets across the whole of Europe for periods which might last for several days. Winter periods will be an especial concern because solar generation becomes insignificant (Consumer Power assumes we will have 30 GW of solar by 2040)! This would mean loss of grid supply for days, not hours. Perhaps it is time to consider our security of supply standards? Is the security of supply standard applied here sufficiently stringent given that it dates from times when (a) we were far less dependent on the availability of supply for such things as communications, medical services, computer operation, and business and personal security and (b) restoration of supply was unimpeded by considerations of restoring renewable generation and a much lower inertia grid?

Slow Progression and no Progression only approach security of supply with a LOLP of 4 % after 2025 when all demand reduction measures are applied.

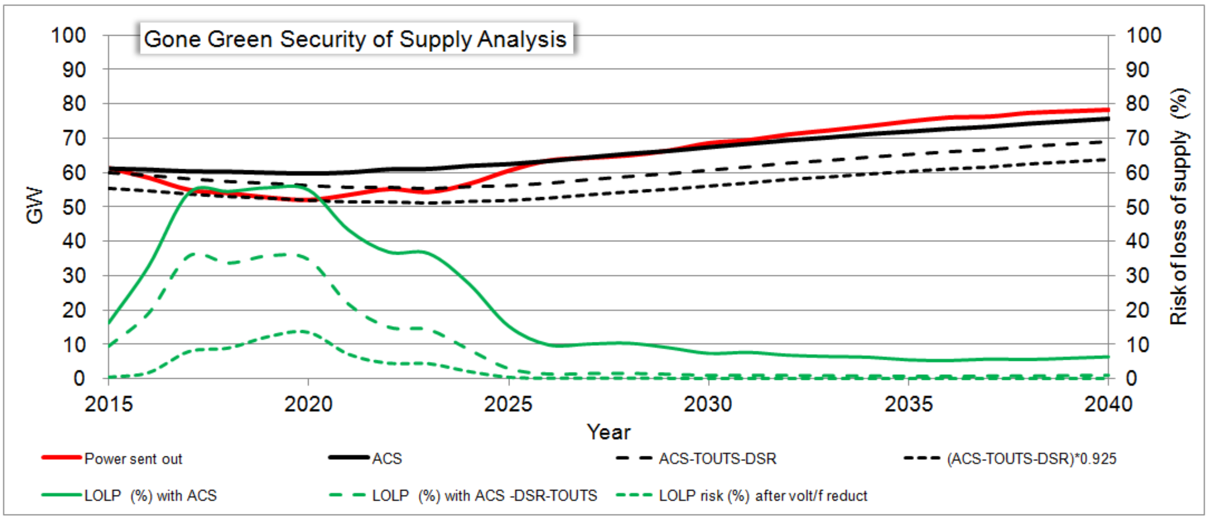

Figure 6 Gone Green scenario LOLP calculations

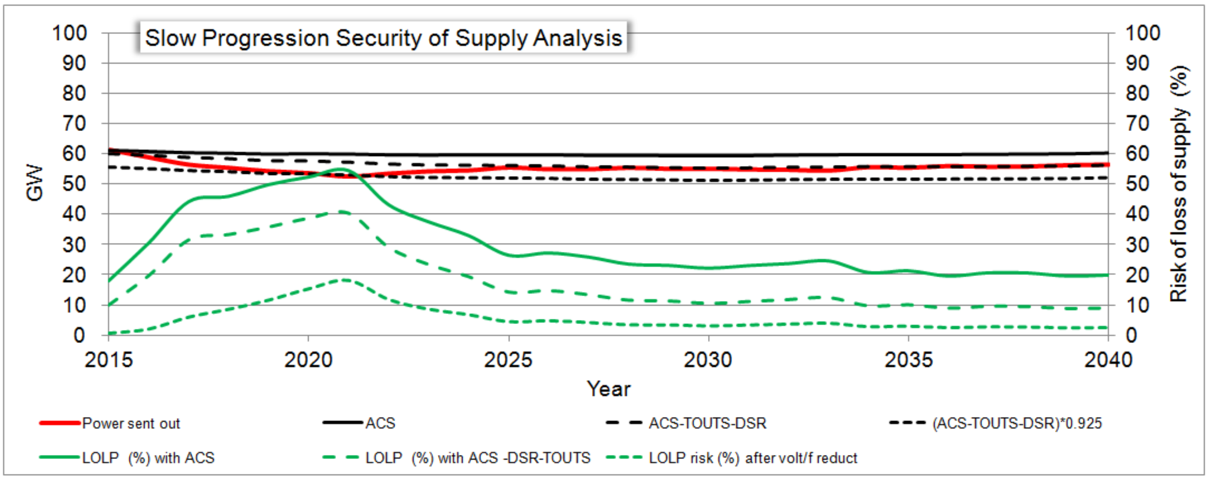

Figure 7 Slow Progression scenario LOLP calculations

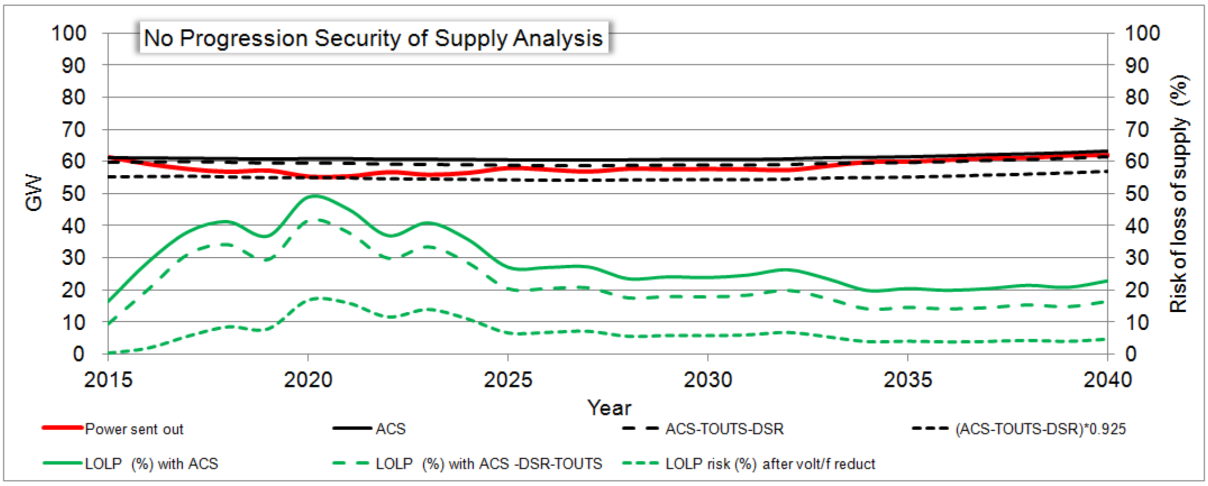

Figure 8 No Progression scenario LOLP calculations

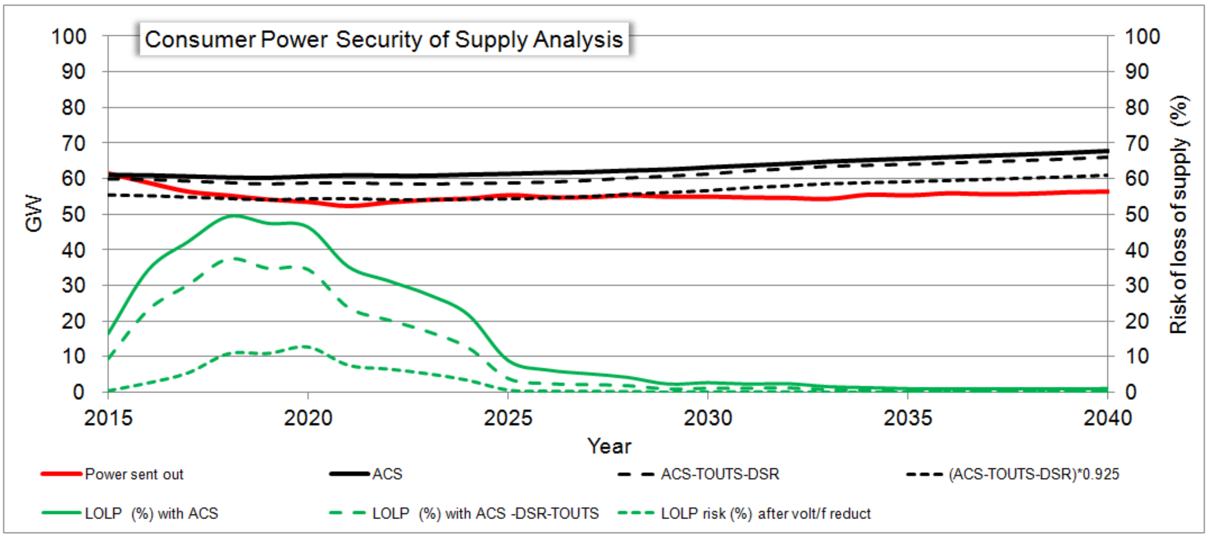

Figure 9 Consumer Power scenario LOLP calculations

4 Calculation of additional firm capacity to provide a risk of loss of supply of 4%.

If the scenario LOLP is calculated to be above 4% then more generation plant is required to make the scenario safe. We can calculate how much additional supply will be necessary by repeating the LOLP analysis adding increments of additional fossil fuelled plant until the risk falls below 4%. Note: the additional capacities determined here represent delivered or sent-out power, not installed capacity; if we continue to assume that sent out power is 85 % of installed capacity then these figures must be divided by 0.85 to calculate installed capacity.

The results of these calculations are shown below in Figures 10-13.

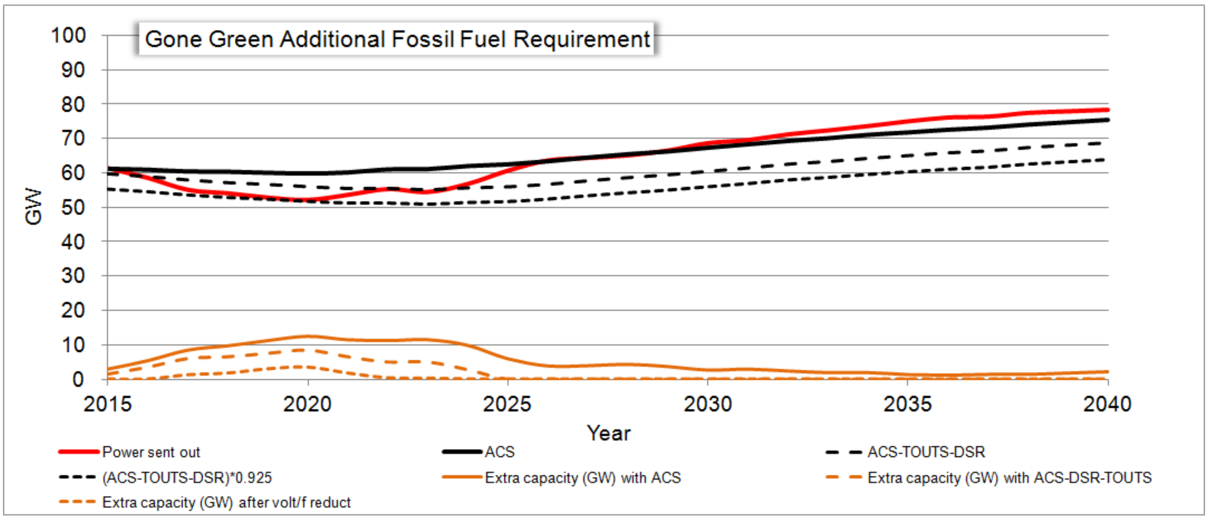

Figure 10 Gone Green scenario additional power requirement

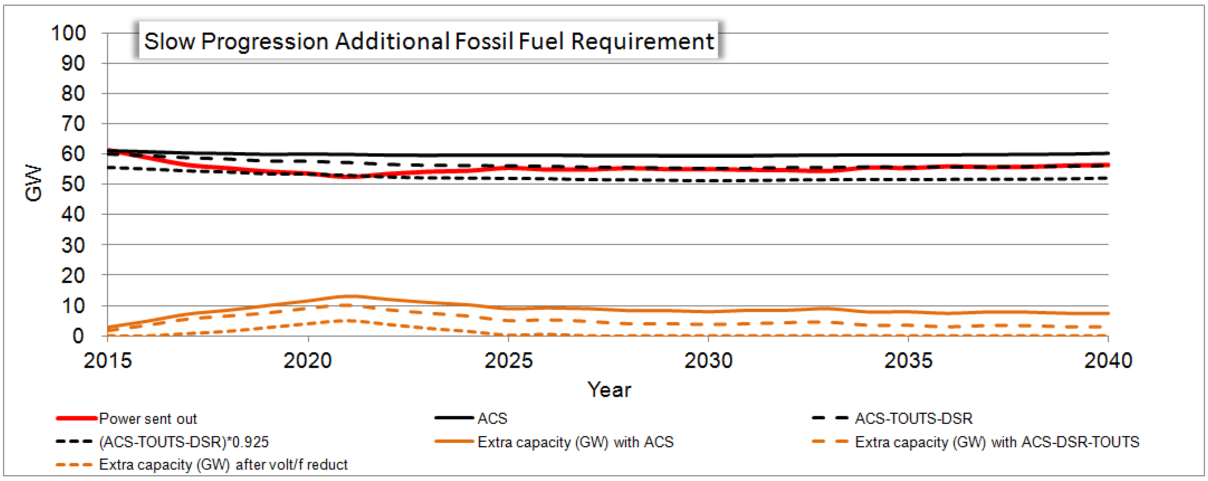

Figure 11 Slow Progression scenario additional power requirement

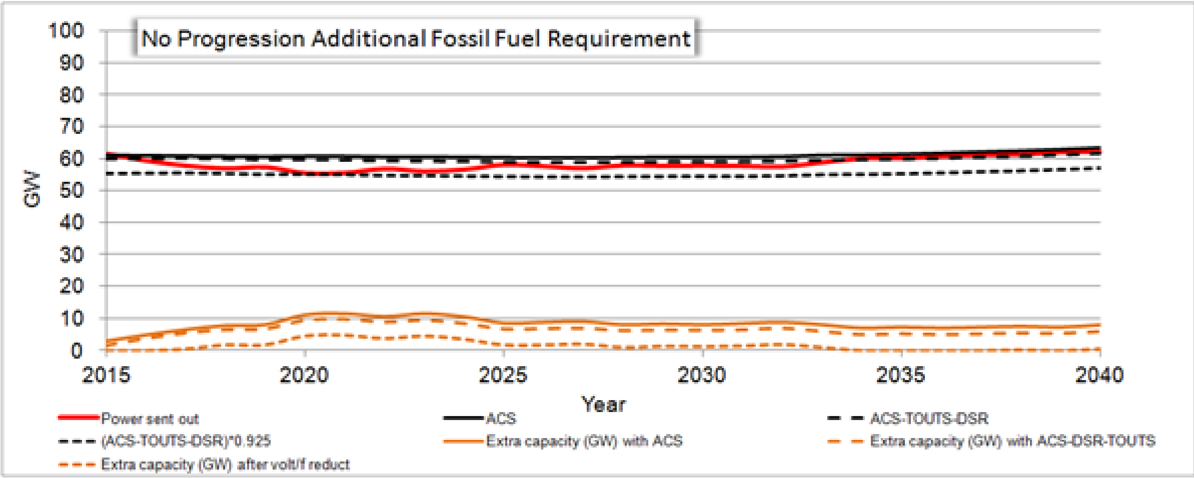

Figure 52 No Progression scenario additional power requirement

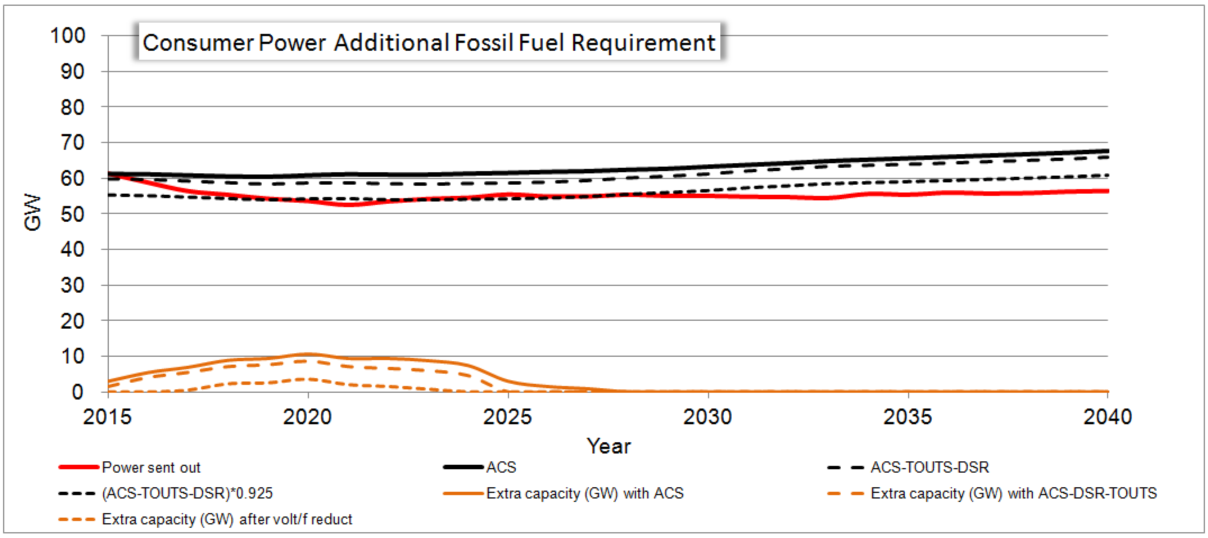

Figure 13 Consumer Power scenario additional power requirement

These figures suggest that up to 2025 all of the scenarios have a shortage of between 5 and 12 GW of sent out, dispatchable firm capacity. This requirement of extra capacity continues throughout the study period in the Slow and No Progession scenarios.

5 Loss of delivery from the interconnected European grid

The preceding observations have assumed, optimistically, that the interconnectors have delivered their full capability as a firm capacity at all times of peak load. The observations of Section 2.6(f) indicate that this is unlikely. If all, or part, of the interconnector capacity is deemed not to be firm then further additions of firm capacity will have to be added to the scenarios. NG state in the FES document, page 101, '*The system operability of having significant interconnector capacity will be considered in the System Operability Framework document which will be available online in November 2016*'.

If, as an exercise, we pessimistically delete all the interconnector contributions (and the CCS contributions in Gone Green on the basis that the results of the Boundary Dam CCS project have been dismal) then a very different picture emerges, see Figures 14-17.

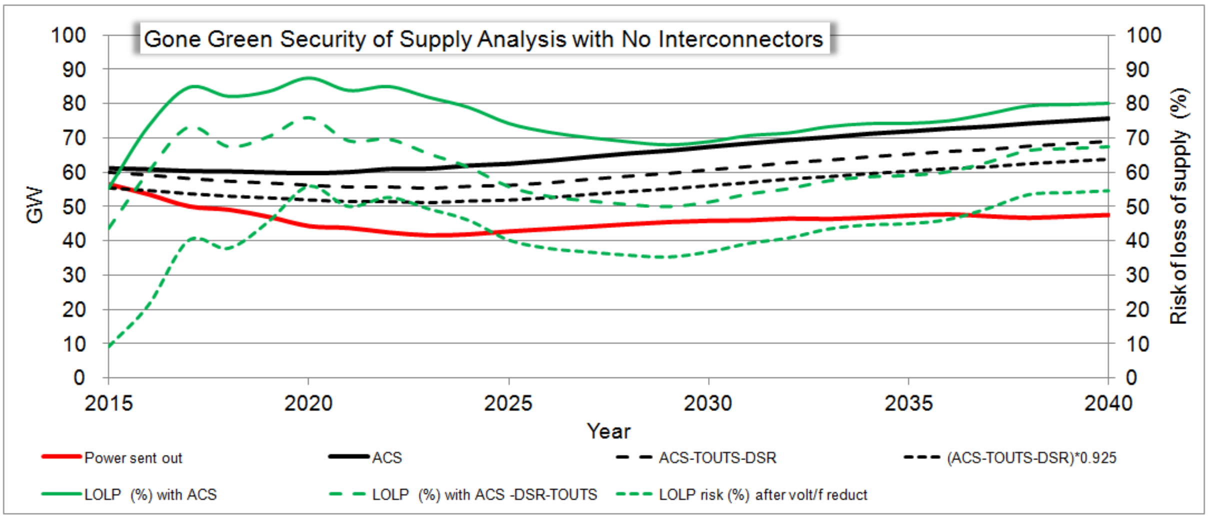

Figure 6 Gone Green Scenario with no interconnector and CCS contribution to firm capacity

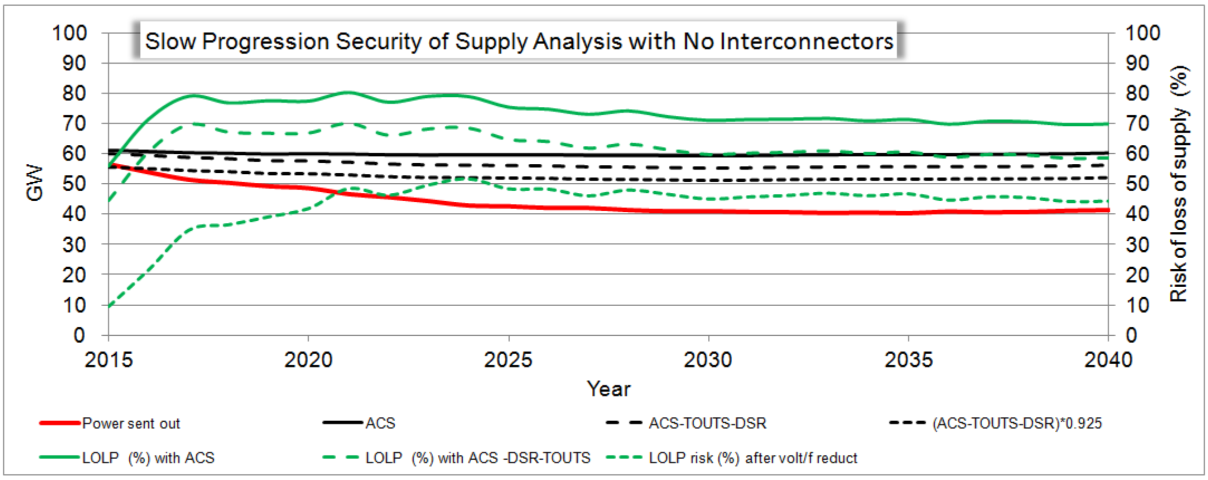

Figure 15 Slow Progression scenario with no interconnector contribution to firm capacity

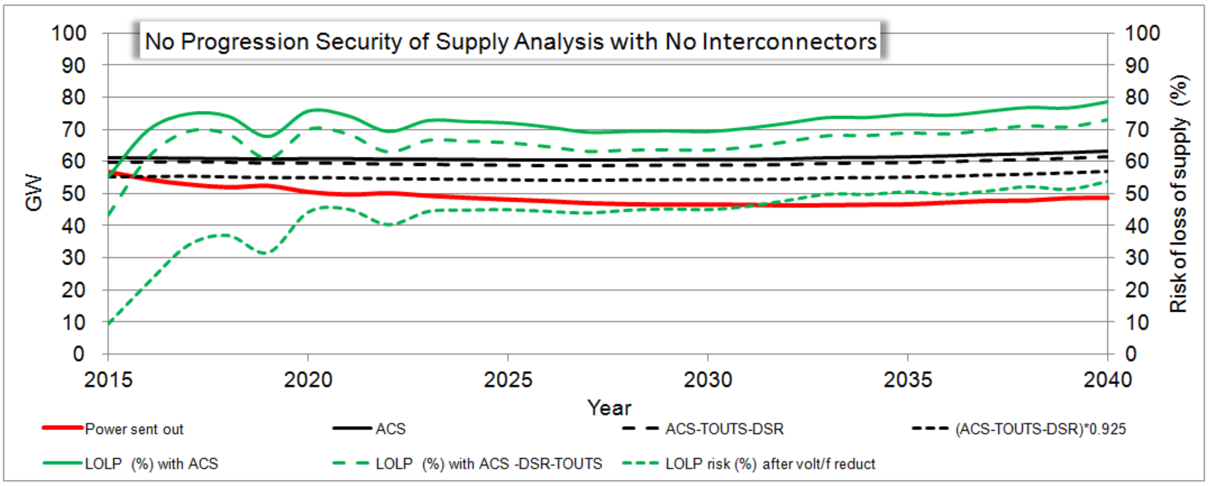

Figure 76 No Progression with no interconnector contribution to firm capacity

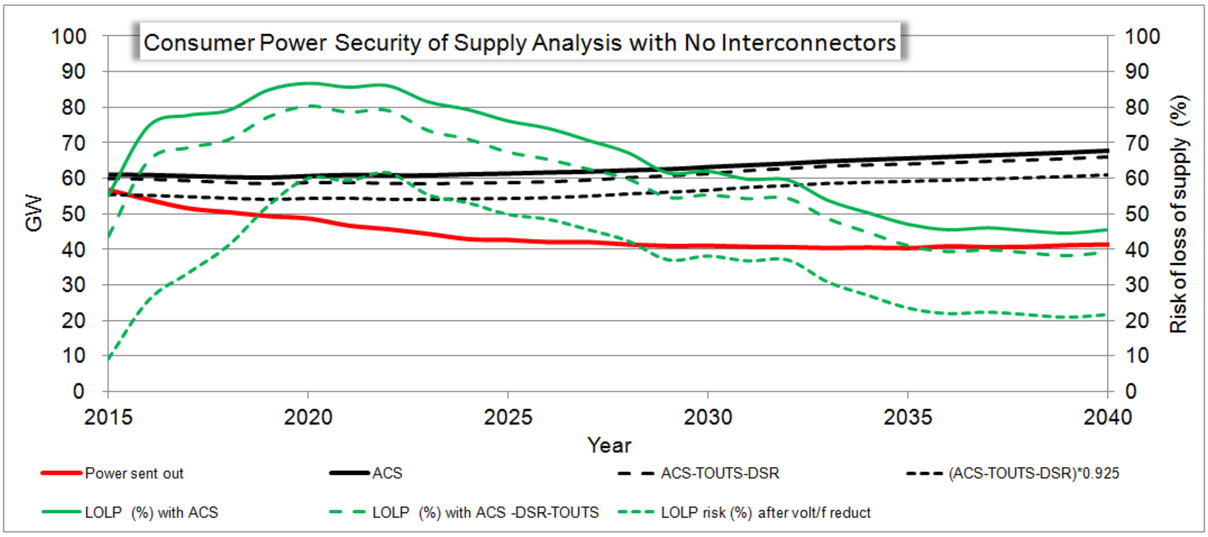

Figure 17 Consumer Power with no interconnector contribution to firm capacity

None of these results show a grid that is anything like secure.

The corollary of this observation is that the UK is becoming increasingly dependent for its secure grid supply upon the provision of interconnectors which provide no firm control or assurance of generation capacity.

Depending on the results of National Grid's study of the reliability of interconnected capacity, the risk of loss of supply will lie somewhere between the results graphed in Sections 3 and 5. Any shortfall in interconnector availability can be matched by adding further dispatchable plant to the scenario. These results are not shown for brevity but could require over 16 GW in the case of Consumer Power in 2040.

6 Add more renewable generation to fix the LOLP problem?

If a solution to the lack of security of supply discussed above is sought using renewables rather than fossil or nuclear fuelled plant then the capacities of wind power required will be far higher, see Figures 18-21.

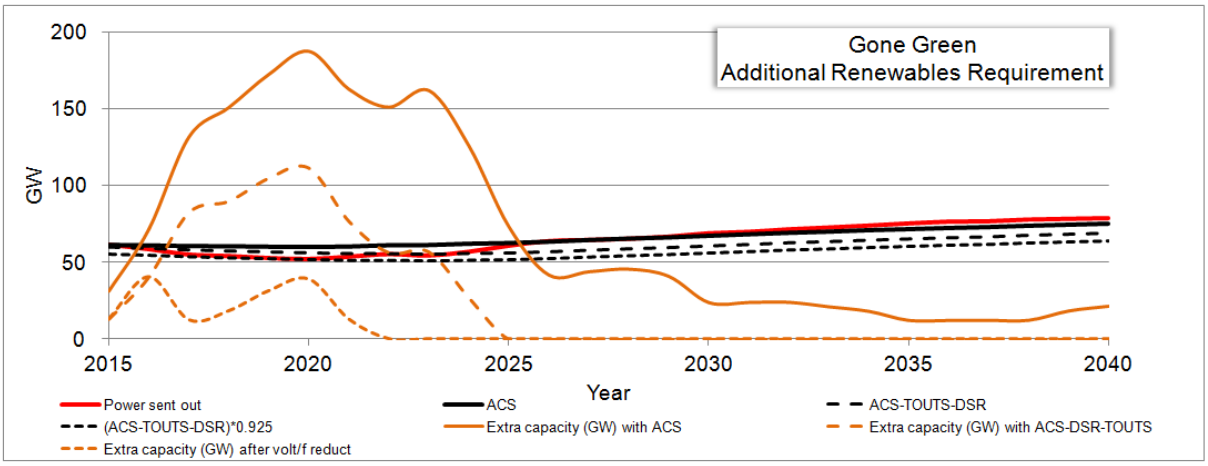

Figure 18 Gone Green additional renewable power requirement

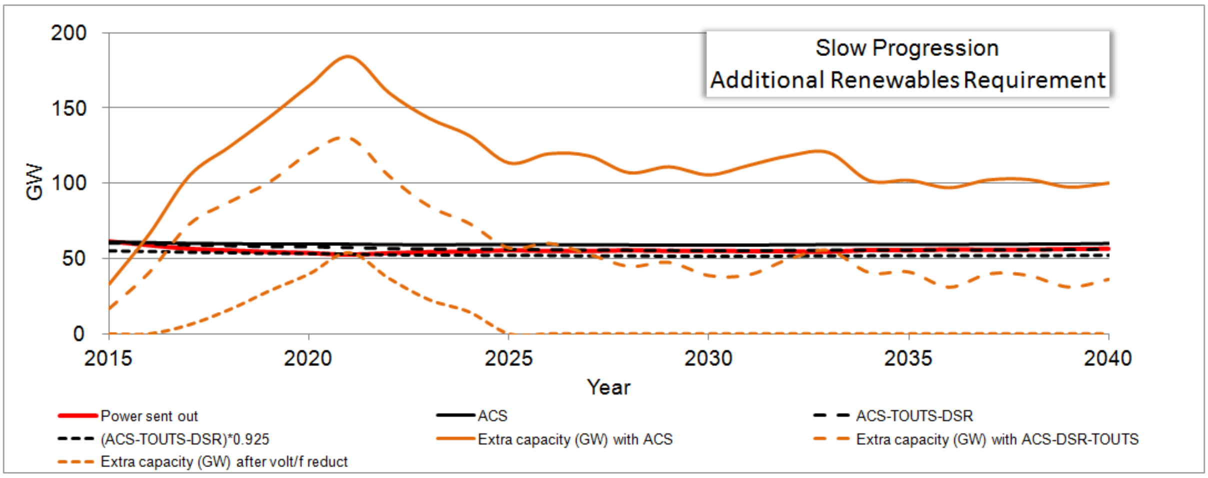

Figure 8 Slow Progression additional renewable power requirement

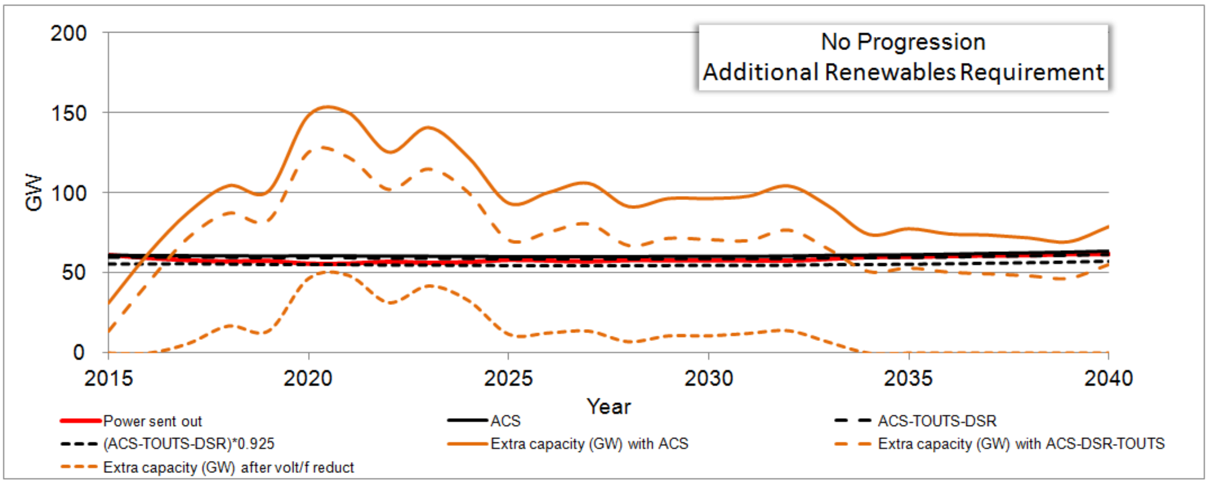

Figure 20 No Progression additional renewable power requirement

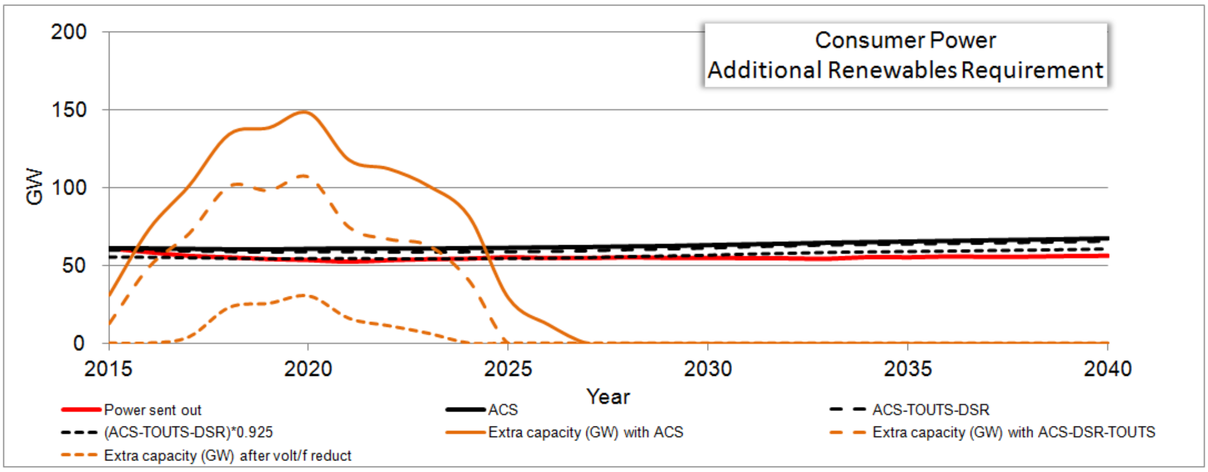

Figure 9 Consumer Power additional renewable power requirement

These results are not surprising. Various authors have investigated the contribution that wind power can contribute to the firm capacity of grid systems, know as the capacity credit. They show that the capacity credit (expressed as a percentage of the total wind capability) falls as more and more wind generation is added to a grid(3)(4).

7 Conclusions

This paper has studied the security of electricity supply of the four scenarios proposed by National Grid in their Future Energy Scenarios 2016 document. The main findings are:

1. Assuming full use of the UK's interconnection capacity to Europe, none of the scenarios guarantee security of supply in the period to 2025 unless the average cold spell demand is assumed to be subject to demand side reductions, time of use tariffs, voltage and frequency reductions.
2. An estimate of the additional capacity needed in this period to reach security of supply is between 5 and 12 GW.
3. Beyond 2025, only Gone Green and Consumer Power provide security of supply.
4. If we assume that on certain occasions the European interconnectors can provide no supplies to the UK due to a lack of renewable generation or excessive demand within Europe, then the security of the UK's grid becomes very weak.
5. Given the poor ability of renewable generation to provide firm supply to the UK grid, and the lack of guarantee of our European connections, perhaps it is time to re-examine our methods for assessing security.

Just as this report was being completed the European Network of Transmission System Operators for Electricity published its Mid term Adequacy Forecast which assesses the security of supply [of the various European grids]. From this:

> "The simulations show average Loss Of Load Expectation and Energy Non-Served values of between 7– and 8 hours and approximately 15 GWh, respectively. Great Britain has a reliability standard of 3 hours/year LOLE, which the Mid-term Adequacy Forecast 2016 results exceed." (p. 16)

We hope to continue this assessment of National Grid's FES 2016 document in the near future, exploring the costs of the scenarios.

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