# Ofgem’s Electricity SCR Initial Consultation

# A response from Wärtsilä Corporation:
# Supporting modelling

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# 1 EXECUTIVE SUMMARY

## 1.1 Executive Summary

1.1.1 There is expected to be an increasing requirement for flexibility in the GB power market in future, and increasing value to flexibility. Our analysis suggests that without investment in flexible technologies, the costs of actions taken in the Balancing Mechanism to ensure reserve requirements are met could rise to nearly £700mn by 2020 in a Base Wind scenario, and over £800mn in a High Wind scenario.

1.1.2 The introduction of flexible supply side technologies could reduce the reserve costs in BSUoS[1] by £381mn (55%) in 2020 in a Base Wind scenario, and by £545mn (54%) under a High Wind scenario. Savings occur due to reduced balancing actions on coal and gas plant, which decrease running hours at inefficient part loads.

1.1.3 The effect of wind volatility within settlement periods is non-negligible. Our analysis of the value of flexibility at 10 minute resolution indicates that the savings could increase by (25-35%).

1.1.4 Market imperfections, caused by inefficient signals in cash out, may cause consumers to pay less in BSUoS but more in wholesale power prices. Our analysis demonstrates that there is a cost to 'free' headroom. A move to more market based pricing could be a net benefit to consumers if it reduces the incentive for generators to provide 'free' headroom.

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[1] Reserve costs in BSUoS are the costs of the actions taken by the SO in the Balancing Mechanism to ensure reserve and frequency response requirements are met.

# 2 MODELLING THE VALUE OF FLEXIBILITY

2.1.1 Wärtsilä commissioned Redpoint Energy and Imperial College London to assess the potential value of flexibility in the future GB electricity market, focussing on flexible supply side generation - referred to here as Smart Power Generation (SPG) - as one source of flexibility. This study supports Wärtsilä's response to the Electricity Balancing Significant Code Review, by providing a quantitative evidence base for discussion.

2.1.2 Redpoint Energy (a business of Baringa Partners) is a specialist economic and commercial energy consultancy, advising clients on investments, strategy, policy and regulation across Europe's power, gas and carbon markets. We recently completed a study[2] for DECC on the value of flexibility from Demand Side Response, supporting DECC's Electricity System Policy assessment. We have also worked closely with National Grid and Ofgem to build and deploy models of GB system balancing.

2.1.3 Imperial College London recently completed a study for DECC[3] on the merits of, and the interaction between, alternative flexible technologies: interconnection, flexible generation, storage and demand side response. For the Carbon Trust[4], Imperial College quantified the value of grid applications of storage technologies.

## 2.2 Overall modelling approach

2.2.1 The objective of the study was to analyse the value of flexibility under future scenarios for development of the GB generation mix. The value of flexibility is measured as the savings in GB generation costs and System Balancing Costs created by the addition of flexible technologies. Flexibility may be provided by supply side and demand side technologies, as well as by interconnection. For the purposes of this analysis we have focused on a single technology, flexible supply-side generation, or what we refer to as 'Smart Power Generation' (SPG)[5].

2.2.2 The analysis was performed in Redpoint's GB power market model, which models the dispatch of generation and the balancing of the system. The results were benchmarked

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[2] *Redpoint Energy & Element Energy:* Electricity System Analysis: future system benefits from selected DSR scenarios*:* http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/future-elec-network/5759-electricity-system-analysis--future-system-benefit.pdf

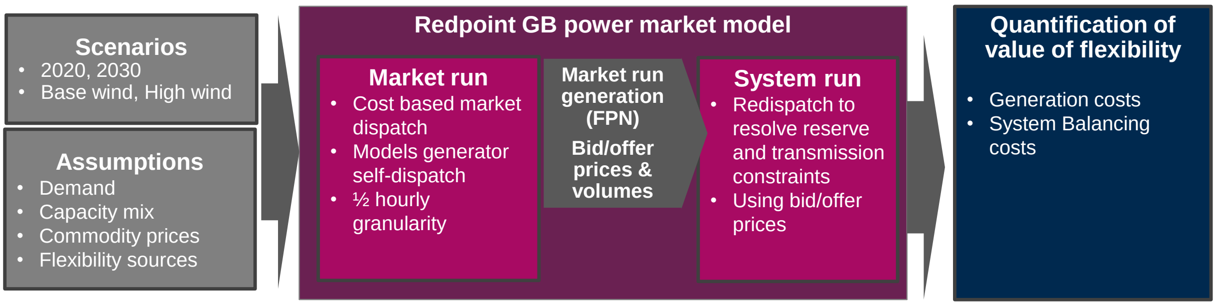
[3] http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/future-elec-network/5767-understanding-the-balancing-challenge.pdf

[4] http://www.carbontrust.com/media/129310/energy-storage-systems-role-value-strategic-assessment.pdf

[5] Such as the Wärtsilä plant described in Appendix A

against Imperial College’s stochastic scheduling model. In addition, Imperial’s model was used to analyse the additional value of flexibility on sub-half hourly timescales.

**Figure 1 – Modelling approach**



2.2.3 To simulate hourly dispatch we employ an industry leading third party product, PLEXOS for Power Systems, which enables us to configure bespoke models based on our in-depth understanding of the GB market. PLEXOS is highly regarded power market simulation software used globally by system operators, utilities and commodity traders and we have used it extensively over the last six years to model European power markets in detail.

2.2.4 PLEXOS is a simulation tool grounded in optimisation and determines the least-cost solution across the power system. At its heart lies a dispatch ‘engine’ that models power market outcomes based on physical characteristics of the system and customized market parameters derived from our input assumptions. In modelling an individual country such as GB, the software also takes account of neighbouring markets by incorporating a simplified representation of these markets into the optimisation.

2.2.5 Our calibration of PLEXOS is tailored to the GB market and captures the power system down to a unit-by-unit level. Key inputs include:

- Operating parameters of generating plant
- Operational constraints, e.g. minimum generation levels and minimum on/off times
- Wind profiles varying hourly across the year
- Demand load profiles varying half-hourly (derived from historic demand data)

2.2.6 The GB model is run in a two stage approach. In the first stage (Market run), generation capacity is dispatched at least cost to meet total demand. The key outputs of this stage are the Market generation schedule and power prices. The market generation schedule is used as an input to the second stage, the System run. In the System run, generation is re-dispatched to respect additional constraints on reserve provision.

2.2.7 This model structure reflects the current BETTA market arrangements, with the first stage reflecting the self-dispatch of generation capacity, and the second stage reflecting the actions taken by the System Operator (SO) in the Balancing Mechanism (BM) to ensure the system is balanced and secure[6].

2.2.8 In the System run, the cost of redispatch is defined by the generator bid and offer prices submitted to the Balancing Mechanism. For coal and gas plant, bid and offer prices are calculated using multipliers on Short Run Marginal Cost (SRMC). The assumptions we have used are shown in Table 1.

**Table 1 – SRMC multipliers for coal & gas plant[7]**

| Type | Ratio |
|---|---|
| Desync bid (price to shut down) | 0.2 |
| Energy bid | 0.8 |
| Energy offer | 1.4 |
| Sync offer (price to start) | 1.6 |

2.2.1 For other generation types, the static assumptions we have used are shown in Table 2.

**Table 2 – Bid and offer prices for other technology types**

| Categories | Bid (£/MWh) | Offer (£/MWh) |
|---|---|---|
| Hydro | -1 | 290 |
| Pumped Storage | 5 | 150 |
| Onshore Wind | -40 | N/A |
| Offshore Wind | -80 | N/A |
| Biomass | -20 | 250 |
| Marine | -120 | N/A |
| Nuclear | -999 | 999 |
| Gasoil | 0 | 300 |
| Fuel oil | 0 | 300 |

2.2.2 Minimum reserve and response requirements are included in the model, and are met using the representation of the Balancing Model described above. These minimum reserve and response requirements are calculated every half hour, as demand and wind generation

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[6] For the purposes of this study we are modelling the requirement for the SO to ensure that sufficient reserve and response is available. We do not model other balancing actions such as resolving transmission constraints.

[7] For flexible generation types (including SPG) the Desync bid and Sync offer prices are not used.

fluctuates. The minimum response requirement is a function of: the largest single loss of generation on the system, and demand. The minimum reserve requirement is a function of: the largest single loss of generation on the system, demand, demand forecast error, wind generation, and wind forecast error. Forecast errors that cover all but 1/365 case are assumed to be 42% for wind and 4.5% for demand[8]. It is assumed that 1GW of reserve requirement is met outside of the Balancing Mechanism, through STOR type contracts. The minimum negative reserve requirement is assumed to be a constant 2.2GW, the middle of the range projected by National Grid in 2020[9].

2.2.3 Plant providing reserve must be available within approximately 30mins when called. To ramp to the desired level on these time frames plants must either be very flexible, or spinning (i.e. providing synchronised generation). Plant providing response must be available within approximately 30secs when called. To ramp to the desired level on these time frames only spinning plant are suitable; even the most flexible thermal plant cannot start-up at such short notice.

## 2.3 Modelling assumptions and scenarios

2.3.1 We include three types of gas generation plant in our modelling: Combined Cycle Gas Turbines (CCGTs), Open Cycle Gas Turbines (OCGTs), and Smart Power Generation (SPGs).

2.3.2 CCGTs are characterised by high efficiency (particularly new CCGTs), but are relatively inflexible due to slow ramp rates and high start-up costs. CCGTs are not flexible enough to provide standing reserve, but can provide spinning reserve when running at part load. OCGTs are characterised by low efficiency, but high flexibility, and as a result can provide standing reserve. SPGs sit between CCGTs and OCGTs for both efficiency and flexibility. Their efficiency is lower than a new CCGT running at full load, but higher than a part loaded CCGT or an OCGT. While SPGs do not have ramp rates as high as OCGTs, they are flexible enough to provide standing reserve. Table 3 below gives a summary of heat rates for typical gas plant in the model, and shows SPG sitting in between the efficiency of CCGT on full load and part load, while retaining a comparable flexibility to inefficient OCGT.

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[8] Wind forecasting error is assumed to have a standard deviation of 12%, which is then scaled by 3.5x to cover 1/365 cases. Demand forecasting error is assumed to have a standard deviation of 1.5%, which is assumed to be normally distributed and so scaled by 3x to cover 1/365 cases. Further explanation here: M. Black and G. Strbac, “Value of Bulk Energy Storage for Managing Wind Power Fluctuations”, *IEEE Transactions on Energy Conversion*, Vol. 22, No. 1, March 2007.

[9] *Future Balancing Services Requirements: Reserve,* Craig Dyke, National Grid http://www.nationalgrid.com/uk/Electricity/Balancing/services/FutureRequirements/

**Table 3 - Heat rates of typical gas plant**

| Plant type | Typical efficiency ( HHV ) |
|---|---|
| New CCGT (Full Load) | 55% |
| Wartsila SPG | 50% |
| New CCGT (Part Load) | 48% |
| OCGT | 28% |

2.3.1 We have modelled two scenarios for the years 2020 and 2030: 'Base wind' and 'High wind'. Base wind uses a capacity mix that is consistent with the Central scenario of DECC's UEP projections[10]. High wind has a higher capacity of onshore and offshore wind, in line with National Grid's latest Gone Green scenario (as published in the UK Future Energy Scenarios in October 2012[11].

2.3.2 In total 8 scenarios are modelled, as detailed in Table 4 below.

**Table 4 - Scenarios modelled**

| Scenario | Year | No SPG | With 4.8 GW SPG |
|---|---|---|---|
| **Base wind** | **2020** | ✓ | ✓ |
| | **2030** | ✓ | ✓ |
| **High wind** | **2020** | ✓ | ✓ |
| | **2030** | ✓ | ✓ |

2.3.3 Figure 2 below shows the capacity mix for the two scenarios, in 2020 and 2030, without SPG (i.e. using the same capacity mix as in the two core scenarios).

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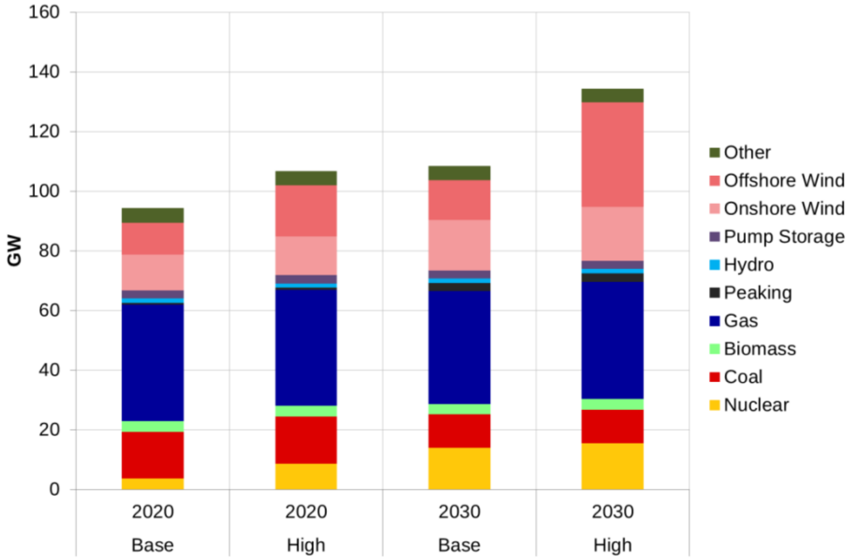
[10] *Updated Energy and Emissions Projections 2011, URN 11D/871,* Oct 2011 *http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx#2011-projections*

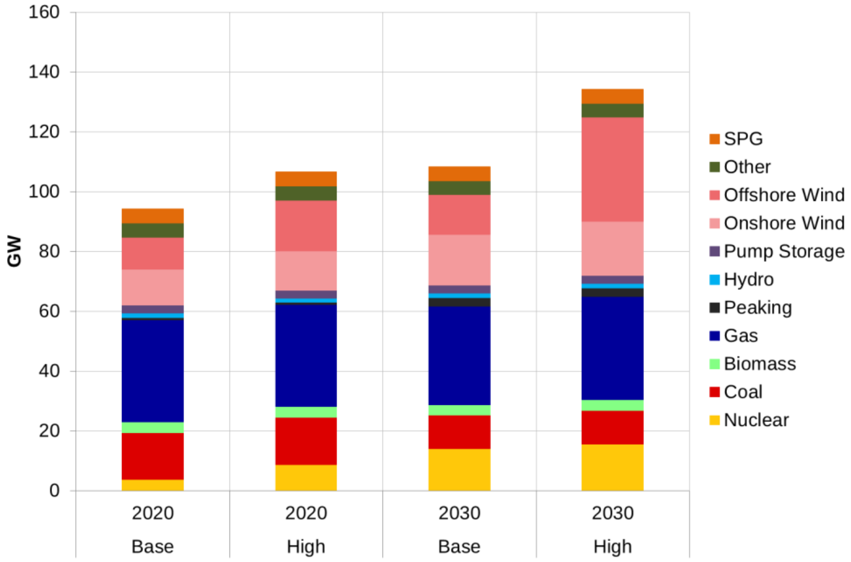
[11] *UK Future Energy Scenarios - UK gas and electricity transmission,* Sept 2012 http://www.nationalgrid.com/uk/Gas/OperationalInfo/TBE/Future+Energy+Scenarios/

**Figure 2 - Capacity mix, without SPG**



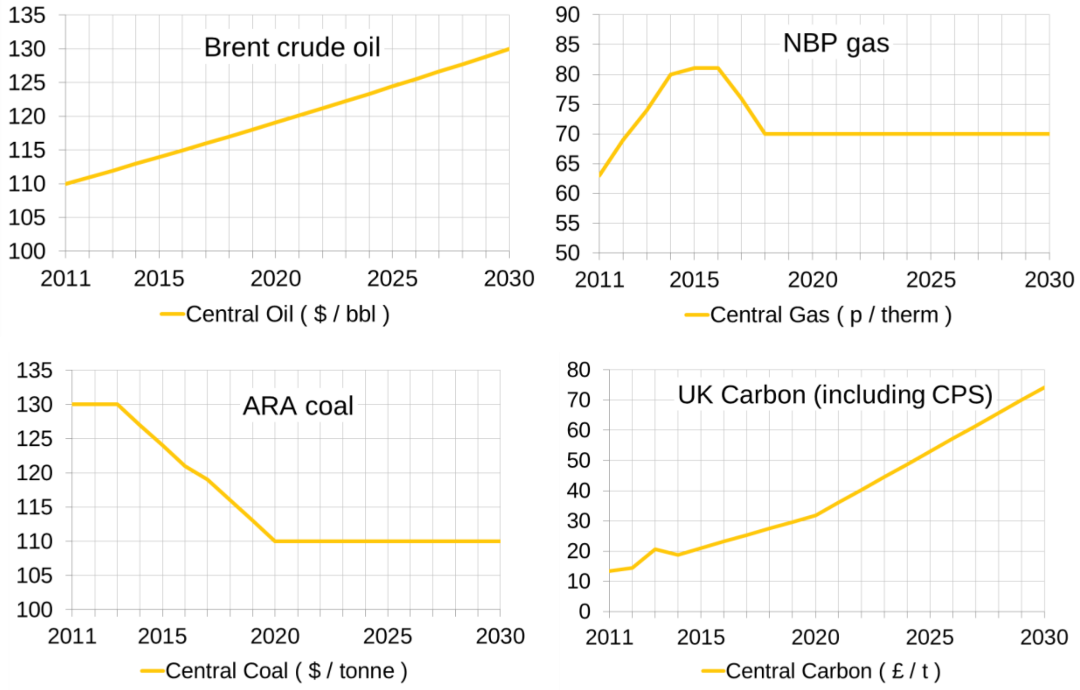
2.3.4 The effect of increased system flexibility is modelled by including 4.8 GW of SPG. This displaces 4.8 GW of new build gas CCGTs, such that the total system capacity is unchanged by the inclusion of SPG. Figure 3 shows the capacity mix when 4.8 GW of SPG plant are included.

**Figure 3 - Capacity mix, with SPG**



2.3.5 Fuel prices are consistent with DECC Central projections[12], and are shown in the charts of Figure 4.

**Figure 4 - Commodity price projections (real 2011 terms)**



2.3.6 In the Base scenario, demand is consistent with DECC UEP projections[13]. The High scenario demand is consistent with National Grid Gone Green scenario[14]. Annual and peak demand for both scenarios is shown in Figure 5.

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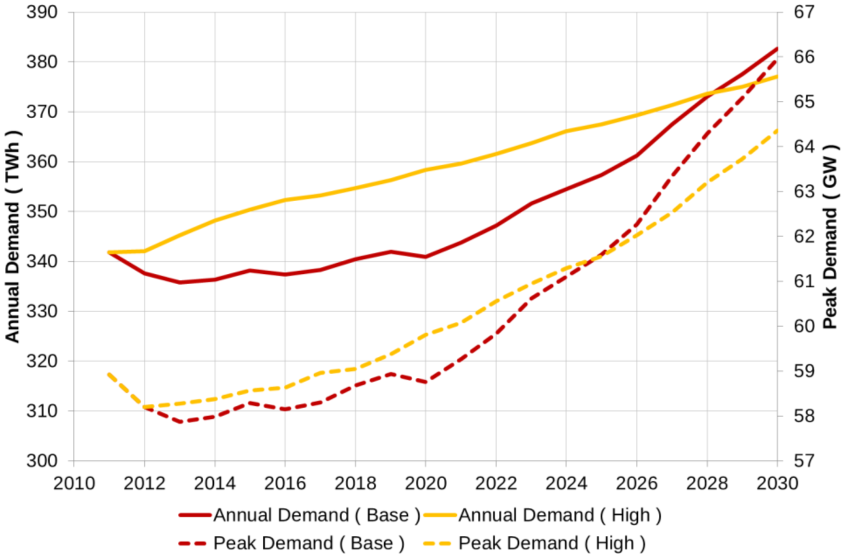
[12] *DECC fossil fuel price projections: summary*, Oct 2011
http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/ff_prices/ff_prices.aspx

[13] *Updated Energy and Emissions Projections 2011, URN 11D/871,* Oct 2011
*http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx#2011-projections*

[14] *UK Future Energy Scenarios - UK gas and electricity transmission,* Sept 2012
http://www.nationalgrid.com/uk/Gas/OperationalInfo/TBE/Future+Energy+Scenarios/

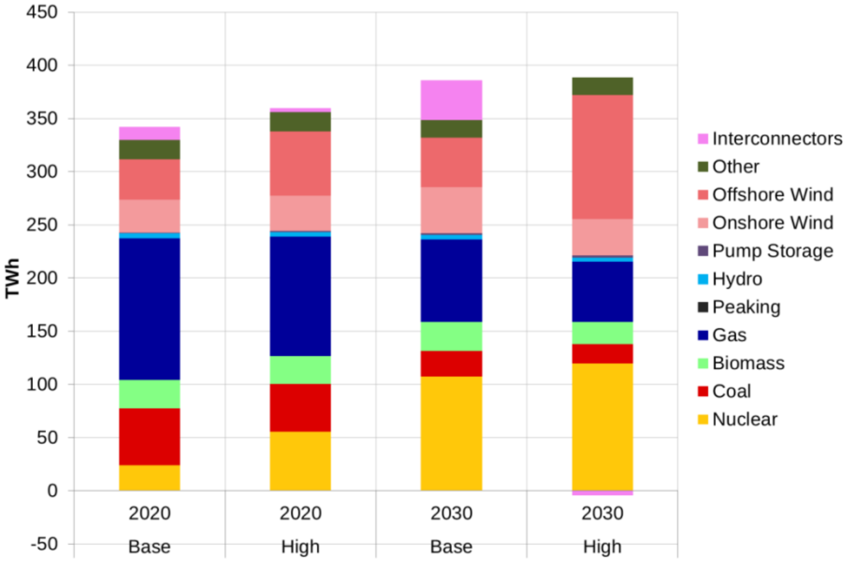
**Figure 5 – Demand scenarios**



## 2.4 Modelling results

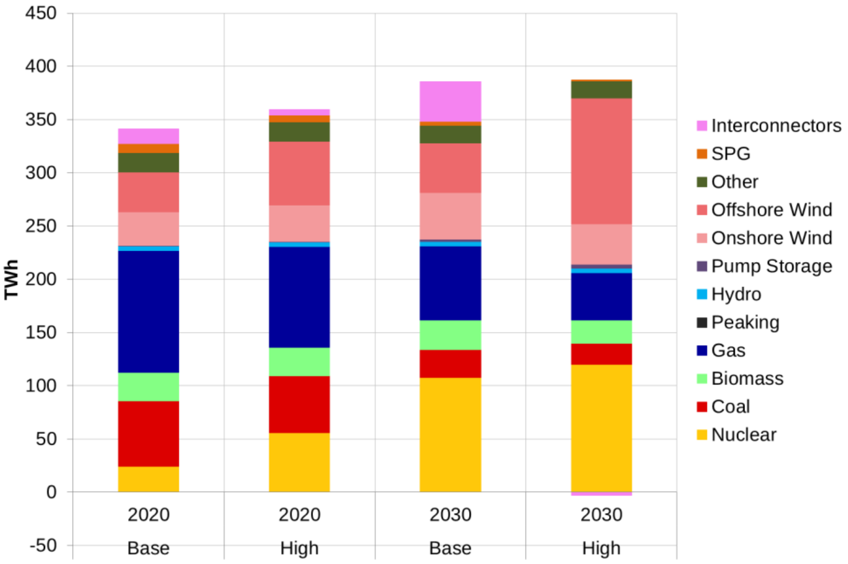
2.4.1 The key output from the model is the generation mix, from which other costs and metrics can be derived. Figure 6 shows the generation in all scenarios without SPG. It can be seen that from 2020 to 2030 a large increase in nuclear and wind capacity results in lower generation from gas and coal. Interconnectors provide a net import to GB in all scenarios other than 2030 High, where the extremely high penetration of wind results in GB low prices and net exports.

**Figure 6 - Generation (no SPG)**



2.4.2 Figure 7 shows the generation mix when 4.8 GW of SPG is included. The inclusion of SPG does not significantly change the generation mix. However, because SPG have a relatively high efficiency, they displace some older CCGTs and do generate, unlike the less efficient peaking OCGTs.

**Figure 7 - Generation (with SPG)**



2.4.3 To understand the effect SPGs have on generation and reserve provision, it is instructive to look at generation over a single day. In the following sub sections we present profiles for a single day (a Business Day in March), in the 2020 Base scenario.

2.4.4 Figure 8 shows the market schedule for generation (without SPG), before any balancing actions by the System Operator. The difference between generation and demand is met by interconnectors. Figure 9 shows the actual system generation, after System Operator balancing actions. It can be seen that on this characteristic day, coal generation is reduced and gas generation increased, from the market schedule to final system generation. Figure 10 shows the balancing actions explicitly, and it is clear that the reduction in coal generation is exactly met by the increase in gas generation[15].

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[15] It should be noted that, in modelling presented here, balancing actions are carried out to ensure adequate reserve and response provision only, and not to resolve transmission constraints.

**Figure 8 - Market schedule (no SPG)**

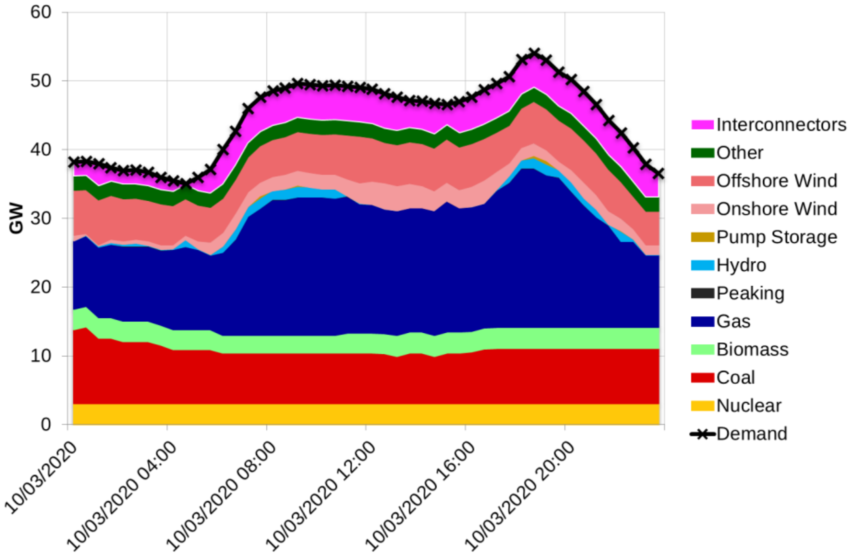


**Figure 9 - System generation (no SPG)**

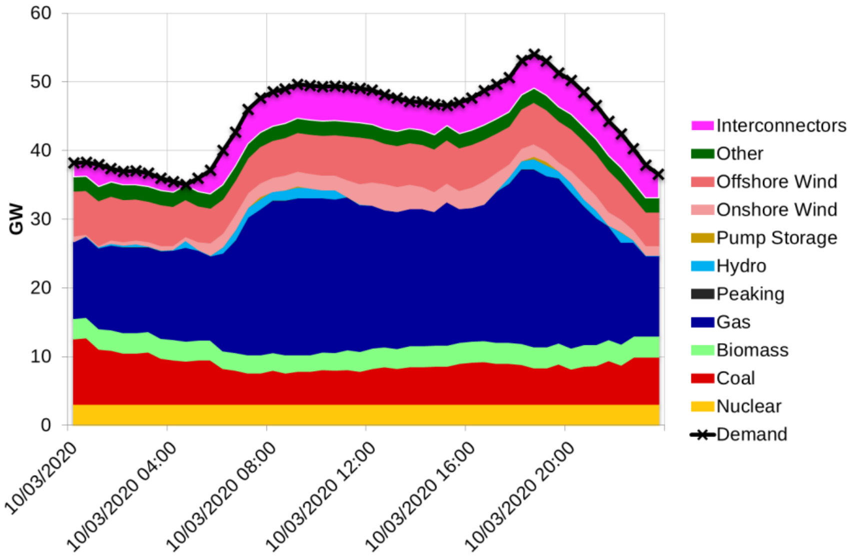
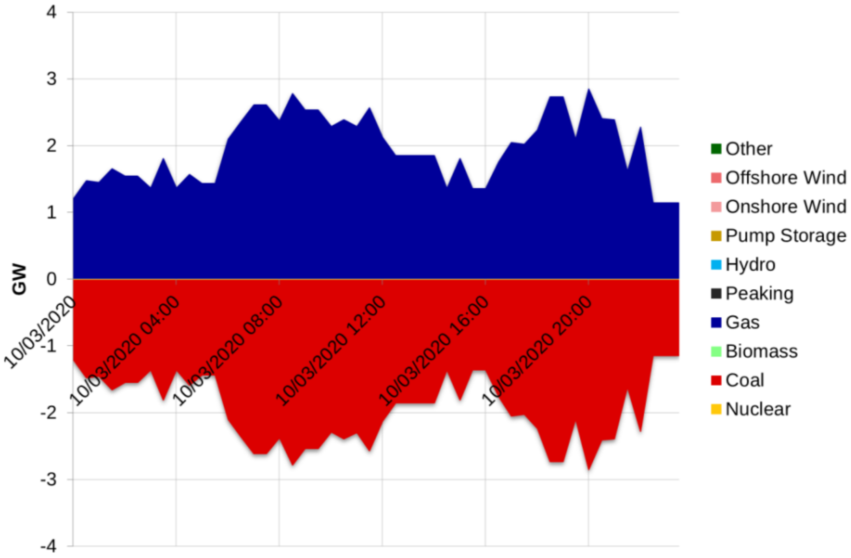


**Figure 10 - Balancing actions (no SPG)**



2.4.5 Figure 11 shows the provision by generation type, for the same day in March. It can be seen that pump storage provides a large amount of (standing) reserve, with another significant portion coming from spinning coal and gas[16]. In Figure 11 it can be seen that both coal and gas have a large increase in their reserve provision at approximately 06:00. This coincides with an increase in balancing actions, as shown in Figure 10. In this case the System Operator is turning down some coal plant from full load to part load, whilst balancing generation by turning on gas plant from standing to part load. Both actions create headroom from spinning plant running at part load. It should be noted that plant running at part load are less efficient than plant running at full load, as shown previously for CCGTs in Table 3.

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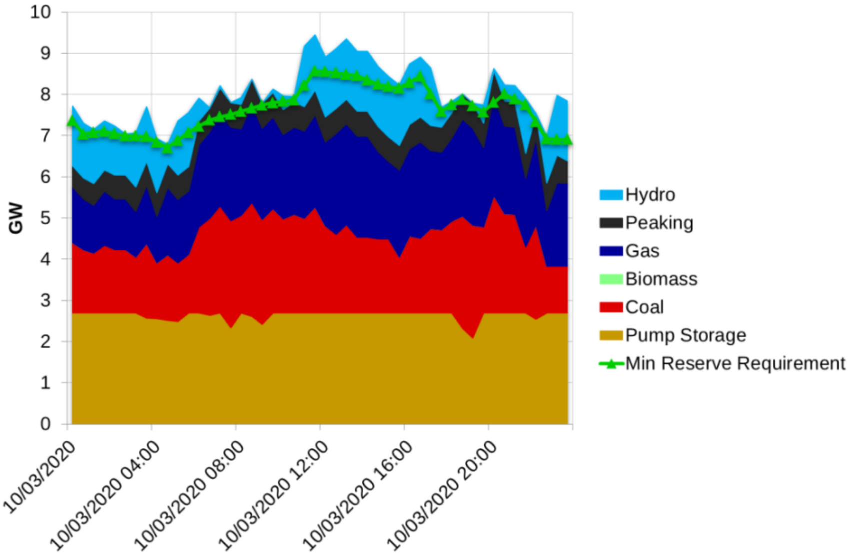
[16] Total reserve provision is often higher than the Minimum Reserve Requirement, as it is more expensive to meet this requirement *exactly* rather than simply ensure that it is met or exceeded.

**Figure 11 - Reserve provision (no SPG)**



2.4.6 The inclusion of 4.8 GW of SPG does not significantly affect the market schedule, as shown in Figure 12. However, it can be seen that SPG are efficient enough to displace older CCGTs, and on this day schedule to generate over peak periods. Figure 13 shows the actual generation after balancing actions; again coal generation is reduced and gas increased, though by a smaller amount than when no SPG is included in the capacity mix. The balancing actions are shown in Figure 14, and are clearly lower than with no SPG (Figure 10). During offpeak periods very little balancing is required by the System Operator.

**Figure 12 - Market schedule (with SPG)**

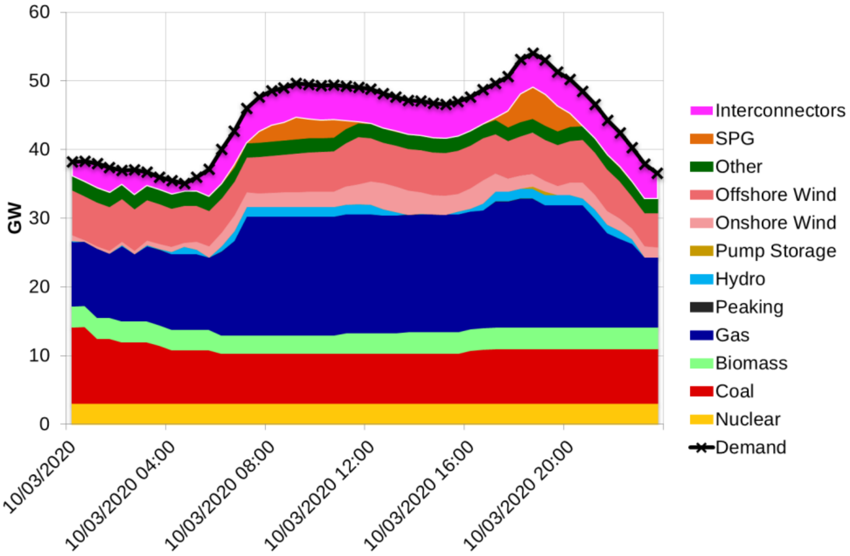


**Figure 13 - System generation (with SPG)**

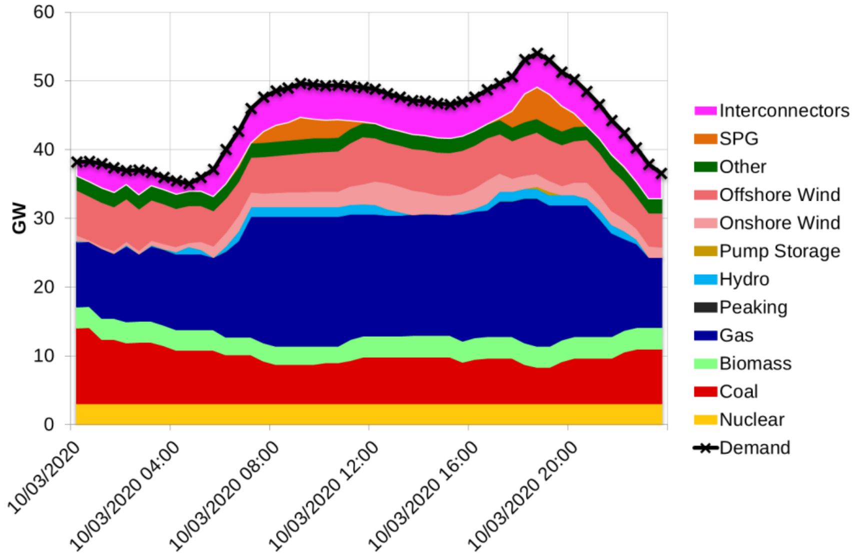
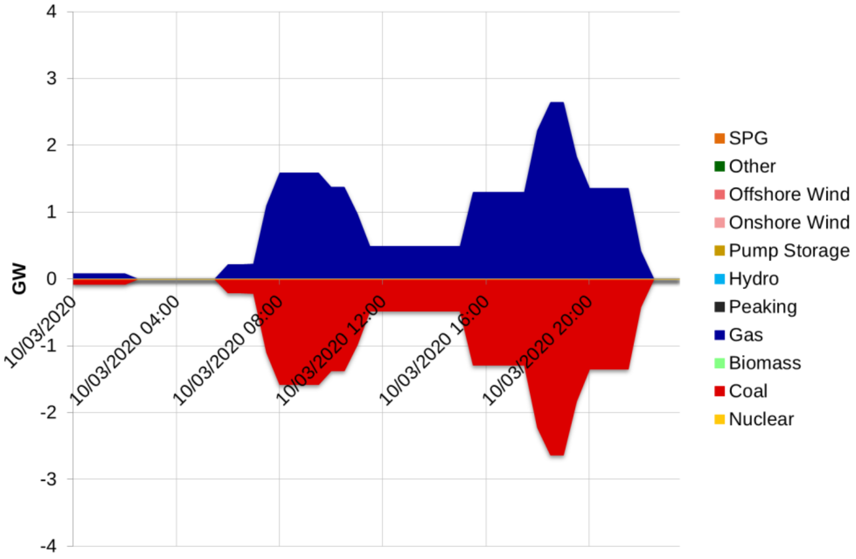
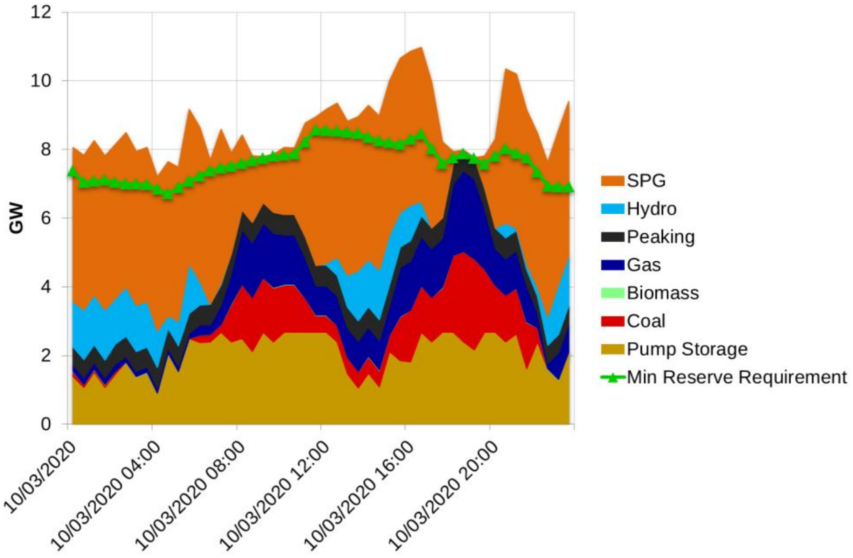


**Figure 14 - Balancing actions (with SPG)**



2.4.7 The inclusion of SPG has reduced the need for balancing actions when ensuring minimum reserve provision is met. Figure 15 shows the reserve provision over the day, and it can be seen that SPG provides a large amount of standing reserve. When combined with standing reserve provided by pump storage, SPG and pump storage nearly provide enough reserve to meet the minimum requirement. Only during peak periods are gas and coal balanced to create headroom, providing spinning reserve at part load. The inclusion of SGP has allowed more plant to run at full load more of the time, increasing efficiency and reducing running costs.

**Figure 15 - Reserve Provision (with SPG)**



2.4.8 At an annual level the standing reserve provided by SPG reduces the necessary reserve provision of other generators. Figure 16 shows the annual reserve provision without SPG across all scenarios; Figure 17 shows annual reserve provision with SPG. It can be seen that the reserve provision of gas and coal is reduced considerably, reducing the need for balancing actions to be applied to these generation types.

**Figure 16 - Annual reserve provision (no SPG)**

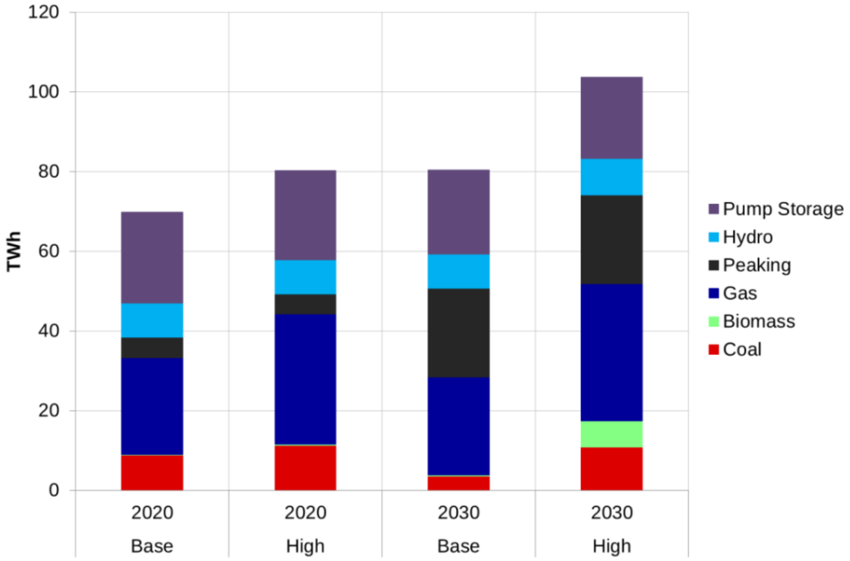
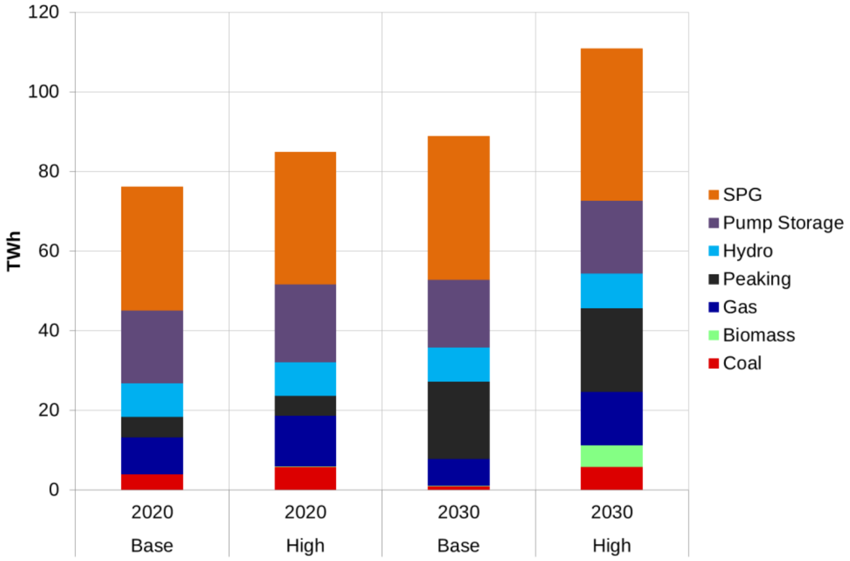


**Figure 17 - Annual reserve provision (with SPG)**



2.4.9 To understand the potential benefits of including SGP, a simple cost benefit analysis is performed. We focus on generation cost savings and BSUoS cost savings. Generation costs are the underlying costs of generation and include: fuel, carbon, start and shutdown costs, VO&M, and net imports. Table 5 shows the potential costs savings in generation costs due to the inclusion of 4.8 GW of SPG, across all scenarios.

**Table 5 - Cost benefit analysis for underlying generation costs**

| Generation Cost Savings ( £ mn per annun ) | 2020 | | 2030 | |
|---|---|---|---|---|
| | Base Wind | High Wind | Base Wind | High Wind |
| **Cost Saving due to SPG** | **22** | **103** | **197** | **742** |

2.4.10 Generation cost savings are seen in all scenarios, increasing from 2020 to 2030 and from Base to High Wind scenarios. These savings result from flexible SPG providing standing reserve, and reducing the need for coal and gas plant to provide spinning reserve when running at their less efficient part load. Cost savings increase in the High wind scenarios and in 2030. This is due to the increased proportion of intermittent wind and inflexible nuclear generation. As a result, reserve requirements are increased and system flexibility reduces, and which increases the benefits of flexible SPG.

2.4.11 An alternative metric is the savings in the cost of balancing actions taken by the System Operator, which are passed on to consumer through BSUoS. These costs are larger than changes in generation costs. This is a result of the spread in bids and offers submitted by generators, who seek to recover the operational costs incurred as a result of balancing. It can be seen that there are significant potential cost savings to the System Operator in all scenarios as a result of SPG. Again the costs savings increase in the High wind scenario, and in 2030. Due to higher levels of intermittent wind and inflexible nuclear generation in these scenarios, reserve requirements increase and system flexibility reduces. In these scenarios more balancing actions must be taken, but can be met with fewer flexible plant – increasing the benefit of flexible SPG.

**Table 6 - Cost benefit analysis for BSUoS reserve provision costs**

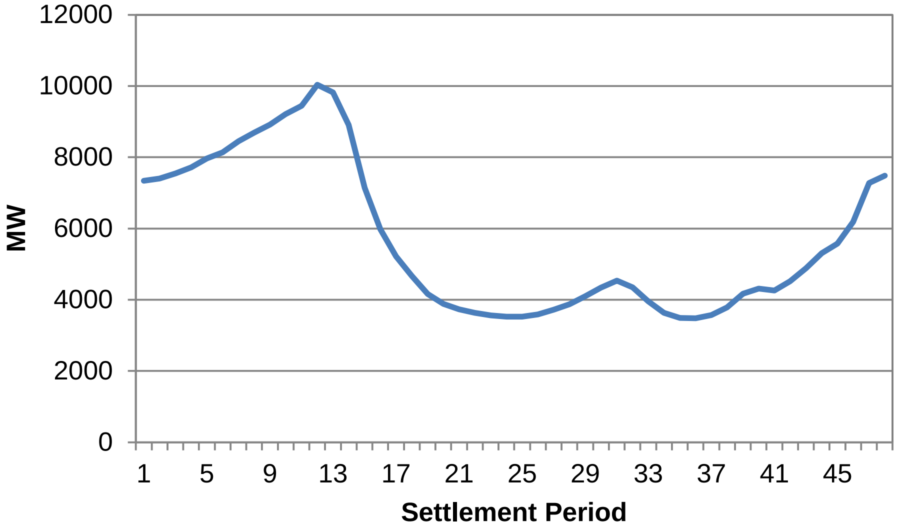
| BSUoS Costs - reserve provision ( £ mn per annun ) | 2020 | | 2030 | |
|---|---|---|---|---|
| | Base Wind | High Wind | Base Wind | High Wind |
| Costs - No SPG | 692 | 1008 | 834 | 2781 |
| Costs - With 4.8 GW SPG | 311 | 464 | 256 | 1244 |
| **Cost Saving due to SPG** | **381** | **545** | **578** | **1537** |

## 2.5 Modelling of the impact of market imperfections

2.5.1 The System Operator has a responsibility to ensure that sufficient reserve is available in each period. One source of this reserve is the headroom on generators that are operating at less than full output. This headroom can be created by the SO through clearing bids and offers in Balancing Mechanism. It may also be provided for 'free' (i.e. no cost to the SO) by the market if, at gate closure, generators submit Final Physical Notifications which are lower than their stated availability.

2.5.2 The historic levels of 'free' headroom are shown in Figure 18, calculated as an average of each settlement period over the three years 2009 – 2011. Minimum estimated 'free' headroom occurs at midday and at evening peak. Headroom is high overnight when demand is lowest and less flexible generators or those with high start costs may reduce output to a minimum, rather than turning off.

**Figure 18 – Estimated ‘free’ headroom available to System Operator (2009 -2011)** [17]



2.5.3 Under current cash out arrangements, portfolio generation owners have an incentive to schedule generation below the maximum capacity, to self-providing reserve and avoid potentially high System Buy Prices for being short. Alternatively, output may be held back by generators to create the option to provide energy at a premium in the BM (e.g. if the market is short, or to resolve constraints), or for operational reasons.

2.5.4 We have analysed the impact of a market imperfection under which generators as a whole provide a minimum of 1 GW of ‘free’ headroom. This value has been chosen as a conservative estimate of the actual ‘free’ headroom observed (given that our historic analysis may overestimate headroom). This is imposed as an additional constraint on the Market run, that coal and gas generators which are generating in any half hour must have a total of at least 1 GW of undispatched capacity.

2.5.5 We find that this so-called ‘free’ headroom reduces the volume of actions that has to be taken in the System run, as shown in Figure 19. The reduction in balancing actions due to this market imperfection leads to a corresponding reduction in the reserve costs in BSUoS of £105mn in 2020 (Table 7).

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[17] Source: Balancing Mechanism data, Redpoint analysis. Calculated from FPN and MEL aggregated at a station level. This approach counts headroom on the entire station if one unit is operating, and may significantly overstate the level of headroom relative to a calculation done for each Balancing Mechanism Unit.

**Figure 19 - System Operator balancing actions, 2020**

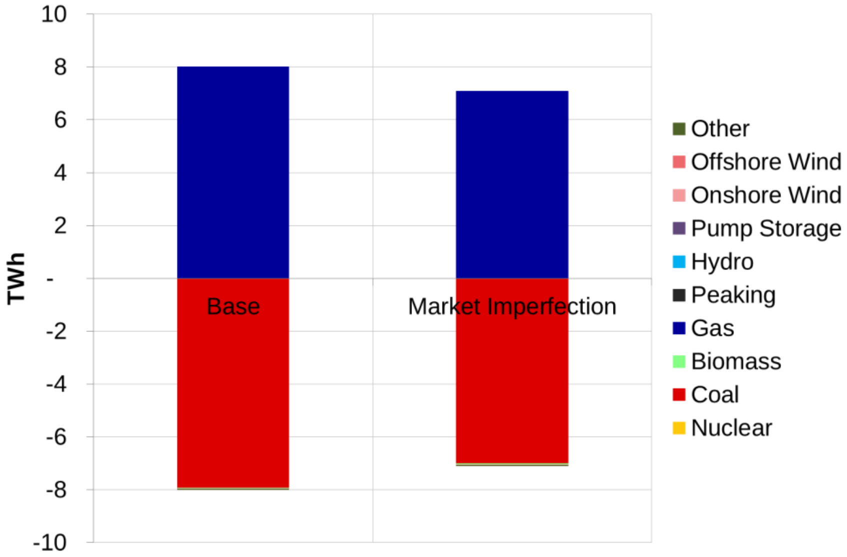

**Table 7 – Reserve in BSUoS cost savings due to market imperfections**

| Potential Cost Savings ( £ mn per annun ) | Base Wind 2020 |
|---|---|
| Generation Cost Saving | 6 |
| BSUoS Cost Saving - reserve provision | 105 |

2.5.6 However with generators providing headroom, their generation is reduced and additional, higher cost, generation capacity has to be scheduled. Our modelling indicates that this could increase wholesale power prices by 0.5 £/MWh (Table 8).

**Table 8 – wholesale power price changes**

| Time weighted wholesale price ( £ / MWh ) | Base Wind 2020 |
|---|---|
| Base | 66.1 |
| Market Imperfection | 66.6 |

2.5.7 This is equivalent to a £148mn increase in costs for consumers, which is greater than the £105mn saving in reserve costs in BSUoS. Our analysis therefore demonstrates that there is a cost to ‘free’ headroom, and that incentives for generators to provide headroom may impose a net cost on consumers through increases in the wholesale price of power.

## 2.6 Impact of sub-half hourly flexibility requirements

2.6.1 The results presented above are based on modelling at half hourly resolution. To consider the impact of sub half-hour flexibility requirements, Imperial College's Stochastic Unit Commitment (SUC) model was used. The model was applied to analyse the impact of sub half-hourly wind generation volatility on the total generation operating costs.

2.6.2 Stochastic Unit Commitment (SUC) seeks to minimise the expected operating cost across all the possible realisations, taking into account changes in wind power output, demand and availability of conventional generation, over the time horizon considered. The full range of possible realisations is firstly discretised into a set of representatives, which then are used to build a scenario tree. An optimisation model is then implemented to calculate the commitment decisions for each individual scenario so that the expected costs are minimised. Since the realization is unlikely to follow any of the scenarios exactly, SUC must is used with rolling planning in order for its decisions to remain optimal over time. With rolling planning, only the here-and-now decisions are implemented, while the commitment decisions in future are discarded. Generally, SUC, with a time horizon of, say, 24 hours is performed every half hour or every hour (i.e. granularity of rolling planning is generally half-hourly or hourly[18].

2.6.3 As a first step, the SUC model was run for the Base Wind 2020 and 2030, and the generation cost results used to successfully benchmark the PLEXOS generation cost results. This benchmarking was conducted with half hourly data, consistent with the PLEXOS modelling.

2.6.4 The SUC was then run with 10min rolling planning using actual 10min wind generation data to assess the additional value of flexibility at more granular time resolution. The difference in total annual operating costs between the actual and linearised 10min scheduling indicates the increase in costs associated with the sub half-hourly wind volatility.

2.6.5 Figure 20 shows the change in total generation costs with 10 min and half hourly modelling. The cost of system operation are higher when 10 minute resolution is included, due to the additional challenges of meeting shorter term wind fluctuations. At both resolutions, as the capacity of SPG increases, system generation costs decrease. The rate of decrease in system costs slows as the total installed capacity increases, showing that there is a reducing marginal benefit to additional flexibility at large installed capacities

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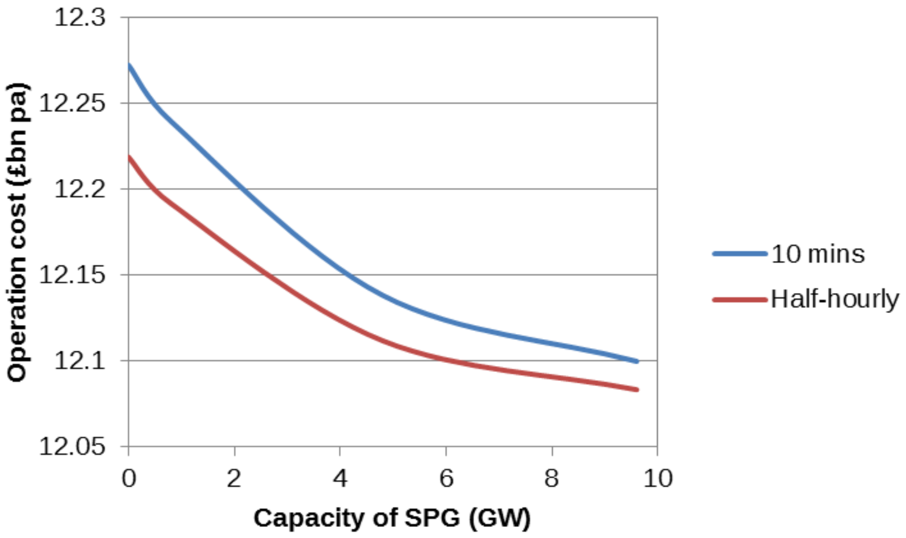
[18] A. Sturt, G. Strbac, "Efficient Stochastic Scheduling for Simulation of Wind-Integrated Power Systems", *IEEE Transactions* on Power Systems, Vol: 27, pp.323-334, Feb 2012

**Figure 20 - Total system generation cost with capacity of SPG (10 min vs. 30 min, 2020)**



2.6.6 In 2020, for 4.8 GW of SPG the system cost savings (over having no SPG) increase by 25% when the modelling is conducted at 10 minute resolution. In 2030, this value increases to 35%. This demonstrates that requirements for flexibility at a sub trading period level may significantly increase the overall value of flexibility.

# 3 APPENDIX A – OVERVIEW OF SMART POWER GENERATION

## 3.1 Smart Power Generation (SPG)

3.1.1 One potential supply-side flexibility source is what we refer to as 'Smart Power Generation' (SPG), such as the Wärtsilä plant described below.

3.1.2 SPG offers high operational flexibility and high generation efficiency in the same product, a combination which has not been typically available in the past. Such a combination enables the high integration of renewable sources into the power systems at least cost, thus contributing to the transition to a sustainable, reliable and affordable power system. It is the missing piece of the low carbon power system puzzle.

3.1.3 Gas fired SPG can operate in multiple operation modes: from base load power generation to peaking; from load following to 'wind chasing'; and ultra-fast grid reserve (something important for the TSOs). Such plants can ramp-up rapidly when the wind calms down and the sun sets, and stop in just one minute when the wind starts to blow again. This enables full utilisation of valuable and green wind and solar energy. High energy efficiency (about 50%) enables SPG to be competitive in terms of generation cost and dispatch in power markets, particularly running cycles shorten in future.[19]

3.1.4 This is not to say that other spinning reserve such as CCGTs and coal plants should not play a role in providing flexibility to the system in 2020. On the contrary, SPG plants could allow a more stable operating regime these plants, thus maximising their efficiency. With a more fit-for-purpose flexible technology mix, the 'unused' capacity associated with part-loaded plants could be avoided, which could reduce the overall requirement for capacity on the system. In sum, even taking into account the potential increase in capital costs, such a technology mix could provide the required responsiveness at a lower total system cost.

## 3.2 Wärtsilä Power Plants

3.2.1 Wärtsilä Power Plants is a leading supplier of flexible power plants. We aim to provide superior value to our customers by offering decentralised, flexible, efficient and environmentally advanced energy solutions. Our technology enables a global transition to a more sustainable and modern energy infrastructure and our solutions are modular, tried and tested power plants.

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[19] The combustion engines used in SPG have the highest simple cycle electrical efficiency of any prime mover. Multi-unit configuration enables high net plant efficiency over a wide load range.

3.2.2 Our energy solutions offer a unique combination of:

- Energy efficiency
- Fuel flexibility
- Operational flexibility

3.2.3 We offer our customers competitive and reliable solutions that deliver high efficiency. Our power plants engines can run on liquid fuels, a wide range of gases and renewable fuels. Most of our products have multifuel capabilities and all can be converted from one fuel to another. Furthermore, the operational flexibility of our products enables high system efficiency, flexibility in operations with varying loads, low water consumption, as well as the possibility to carry out construction in phases according to the customer's needs. These key features, combined with the full lifecycle support we offer, create the basis for Wärtsilä's strong position within the Power Plants market.

3.2.4 With gas strengthening its potential to be the fuel of the future, our focus is on developing competitive solutions for the gas market. This focus supports our growth ambitions and enables a stronger presence in the broader markets.

3.2.5 Our business is divided into four customer segments

### Flexible baseload

3.2.6 Wärtsilä supplies flexible baseload power plants mainly to developing markets, islands, and remote locations. Energy consumption growth in these markets is driving a steadily increasing demand for new power generation solutions. Wärtsilä's customers in this segment are mainly Utilities and Independent Power Producers (IPP). Customer needs typically include competitive lifecycle costs, reliability, world-class product quality and fuel and operational flexibility, as well as operations & management services. Wärtsilä is in a strong position to cater to these needs. Flexible baseload power plants are run on both liquid fuels and gas.

### Grid stability and peaking

3.2.7 Wärtsilä's grid stabilising power plants enable the growth of energy solutions based on wind, solar and hydro power. We offer dynamic solutions used for systems support, reserve power, peaking needs, and in regions with rapidly growing wind power capacity. Customers in this segment are mainly Utilities and IPP's. The strengths of Wärtsilä's products include rapid start and ramp up to full speed, the ability to operate at varying loads, competitive electricity generation and capacity costs, as well as 24/7 service. Grid stability and peaking plants are mainly fuelled by gas.

### Industrial self-generation

3.2.8 Wärtsilä provides power plant solutions to industrial manufacturers of goods in industries such as cement production, mining, and textiles. Customers are mainly private companies and reliability, reduced energy costs, and independence from the grid are among the key factors in their decision making. Power plants in this segment are run on either gas or liquid fuel, depending on fuel availability.

### Solutions for the oil & gas industry

3.2.9 Wärtsilä provides engines for mechanical drive, gas compression stations, and for field power and pumping stations to the oil and gas industry. Typical customer needs include maximum running time, reliability, long term engineering support and 24/7 service. The solutions we offer run on natural gas, associated gas and crude oil.

### Power Plants and sustainability

3.2.10 The world is currently seeking more sustainable solutions for energy infrastructure. This development is driven by climate policies, energy security and economics. Carbon intensive energy sources are being replaced by low carbon fuels, such as natural gas and renewable solutions. Energy savings and efficiency improvements are being encouraged, and even legally enforced, at every level.

3.2.11 Wärtsilä's energy solutions offer a unique combination of flexibility, high efficiency, and low emissions. Many different fuels, including bio-fuels, can be used efficiently, which helps in reducing greenhouse gas emissions. The flexibility of Wärtsilä's solutions enables the development of a reliable energy infrastructure, wherein most of the sustainable characteristics are already known.

### Efficiency development

3.2.12 We continuously seek improvements in the present engine portfolio, and are developing new engine concepts for the future. As a power plant contractor, we develop our power plants in parallel with the engines. This enables us to optimise both the performance and the reliability of our power plant offering. We offer high efficiency, single cycle solutions and focus on improving efficiency even further through the use of e.g. combined cycle solutions. Power plant net efficiency can be further improved by plant design and by optimising internal power consumption. Such solutions minimise not only fuel and water consumption, but also the emissions per unit of energy, thereby providing major environmental benefits.

### Flexibility

3.2.13 Flexibility is one of the main features of Wärtsilä's power plant solutions. The high modularity of our products makes it easy for our customers to construct an optimally sized plant, and to later expand its size to meet future needs. Fuel flexibility has many advantages for our customers, notably the lowering of energy production costs by using low cost fuels, minimising CO2 emissions, and the ability to convert from one fuel to another based on fuel availability.

3.2.14 The unique operational flexibility of our products comprises:

- Very fast plant starts and stops
- High ramp rates
- High part-load efficiency
- A broad load range

3.2.15 Frequent starting and stopping does not affect the operational costs of the plant. This is unique, no other competing technology offers the same

Towards an optimally sustainable power system

3.2.16 The power generation system of the future will contain a significant percentage of wind power capacity. Such capacity is non-dispatchable and intermittent, which creates potential for other power units to balance the system. Wärtsilä is in a good position to meet this need, as the operational flexibility of our products makes them easily adaptable to the needs of the grid.

Reducing emissions

3.2.17 Wärtsilä places high priority on developing diverse and flexible emission reduction techniques. Since emission requirements and the fuels used differ widely, a comprehensive range of products is required in order to offer competitive solutions.

Mitigating the effects of climate change will call for substantial reductions in greenhouse gases (GHG). We believe that the importance of natural gas will increase in the future. Consequently, the multi-fuel capability of our power plant solutions becomes an increasingly significant competitive advantage, as it enables the utilisation of all liquid and gaseous bio-fuels that may become available on a wider scale. Wärtsilä focuses on developing decentralised energy solutions that emit fewer GHG emissions.