



Moving towards a longer term SO incentive regime – review of NGET’s Phase 2 proposals for the constraint model

A REPORT PREPARED FOR NGET AND OFGEM

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Moving towards a longer term SO incentive regime – review of NGET’s Phase 2 proposals for the constraint model

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1 Introduction

In its role as System Operator (SO) NGET incurs balancing costs which can broadly be split into two categories:

- energy related costs such as margin, frequency response, energy imbalance, footroom, reactive power and related costs; and
- constraint costs incurred in different areas of the GB system (in Scotland, across the Cheviot boundary and in England and Wales).

A Balancing Services Incentive Scheme (BSIS) has been a feature of the regulatory framework for the SO since before the introduction of NETA in 2001. The intention has been to provide NGET with an incentive to reduce costs in areas over which it has significant influence for the benefit of the end consumer.

The BSIS is a bundled scheme with a single target for all categories of cost. The scheme has up to now been set for a single year. A target for the Incentivised Balancing Cost (IBC) has been agreed with Ofgem at the beginning of the year and then compared with the outturn cost. The difference between the target and outturn value of the IBC has then been shared using pre-agreed percentages between NGET and customers, subject to a cap and a floor value on the level of incentive (positive or negative) received by NGET. The target value was subject to a dead band to reflect cost uncertainty and a broad adjustment to reflect the fact that NGET has no control over system imbalance (the net imbalance adjustment or NIA).

In the face of rising SO costs, especially since the introduction of BETTA, Ofgem has sought to establish a longer term version of the BSIS in order to encourage actions with longer term payoffs, increase information discovery about the potential for cost reduction and to lower administrative costs. To this end, Ofgem launched a thorough review of the methodology and a programme of work with NGET to establish an appropriate methodology to enable multi year electricity schemes to be established. Frontier was appointed by the parties to undertake consultancy work in support of the review.

1.1 The review

As well as establishing an appropriate methodology for a multi year scheme, the review provides for collaboration to develop NGET's modelling tools to support setting scheme parameters for the given methodology. The intention is to apply the methodology for a new scheme to start in 2011, probably for a two year period, and to have tools prepared that can be used for future schemes.

The review is being undertaken in three phases.

- **Phase 1 (now complete):** related to the examination of NGET's current methodology, including its models and modelling approach, to put forward preliminary conclusions for the development of an SO incentive scheme covering at least two years. This work was undertaken by Frontier and the results were set out in our Phase 1 report and were supported in Ofgem's own Phase 1 report;
- **Phase 2 (now complete):** was undertaken by NGET in the light of the conclusions from Phase 1 and related to the production of NGET's proposed methodology, including its models and modelling approach, for the development and implementation of an SO incentive scheme covering at least two years. The output was a report from NGET, an Excel based energy model and a GB wide model of the transmission and generation system in order to assess the expected costs of constraints under given fuel price assumptions and other assumptions (the constraint model); and
- **Phase 3 (the current phase):** being undertaken by Ofgem, with the support of Frontier, relates to the examination of NGET's proposed methodology and models produced in Phase 2 to determine their appropriateness for application to an SO incentive scheme covering at least two years.

The present report focuses on NGET's proposal on constraint costs. As the process to develop the constraint modelling methodology was still ongoing at the start of Phase 3, Ofgem asked Frontier to report back on the methodology for energy costs and the associated model first. A separate report – *“Moving towards a longer term SO incentive regime – review of NGET's Phase 2 proposals for the energy model”* – presented the results of that review.

1.2 The new approach

Phase 1 recognised that an appropriate approach to incentivisation would focus the incentive on areas over which NGET has significant control and limit the scope for gains or losses due to factors that were substantially beyond NGET's control.

To implement this principle, the approach would not be to set a target value of IBC *prior* to the start of the scheme but to agree a set of parameters and relationships that could be used to derive the target. Parameters that could be forecast with some degree of certainty or over which NGET had control would be set *ex ante* but parameters over which NGET had no control or which were difficult to forecast would be defined as *ex post* variables entered once the outturn values were known on a monthly basis during the course of the scheme. In each month it would then be possible to derive the target value of the IBC and compare it with the actual value. At the end of the scheme, the cumulative target

and actual values for the whole period would be known. The difference would constitute the gain or loss for sharing between NGET and industry.

1.3 Structure of the report

As noted above, this Phase 3 report is focussed on the constraint model and associated methodology to determine constraint costs.

- Section 2 describes the scope of the report and the process we have followed to undertake the review.
- Section 3 provides an overview of NGET's approach for the modelling of constraint costs, including the econometric modelling of headroom replacement costs.
- Sections 4 to 6 describe the inputs to the constraint model. Specifically:
 - Section 4 focuses on the inputs to the unconstrained schedule;
 - Sections 5 and 6 focus on the inputs to the constrained schedule. Section 5 focuses on NGET's approach to defining the stylised transmission network within the model, while Section 6 considers alternative approaches for pricing constraints;
- Section 7 summarises the findings of our review of both the results of the constraint model and the performance econometric model of headroom replacement costs.
- Section 8 presents a summary of our findings and recommendations.

2 Scope and process

We briefly set out the scope of the review work addressed in this report and then go on to summarise the process we followed to undertake the review.

2.1 Scope of the review

As noted above, this report focuses on NGET's proposals for a constraint model. The purpose of the model is to calculate the optimal level of constraint cost, against which NGET's performance will be assessed.

Constraint costs are assumed by NGET to be made up of two components, with a different approach proposed for modelling each of them:

- **Direct constraint costs.** NGET has procured a GB wide model of the transmission and generation system. The model is based on Plexos, appropriately customised and calibrated for this purpose. This version of the model is known as the Plexos BSIS model. The model estimates constraint costs by comparing an unconstrained despatch schedule (calculated assuming no transmission constraints) with a constrained schedule, calculated by taking transmission constraints into account. The costs of resolving constraints are calculated using estimates of prices in the Balancing Mechanism. Therefore, the calculation of constraint costs hinges on:
 - the modelling of the despatch volumes, based on economic fundamentals and plant short run marginal costs; and
 - a pricing rule to define the Balancing Mechanism prices to be used in the modelling of the constrained schedule to calculate the cost of resolving transmission constraints.

With regards to the fundamentals modelling component, we have first considered the inputs to the model. Then we have assessed its performance by comparing the model results to actual volumes for the year 2009/10. On pricing, our work focused on considering, jointly with Ofgem and NGET, alternative pricing approaches and exploring the potential impact of each of them on NGET's incentives.

- **Headroom replacement costs.** In addition to direct constraint costs, NGET incurs headroom replacement costs whenever the free headroom provided by some generators becomes inaccessible due to transmission constraints. The current implementation of the Plexos BSIS does not model headroom replacement needs and therefore costs. This functionality may be introduced at a later stage. For the time being, NGET has proposed to forecast headroom replacement costs using an econometric model estimated

on historic data. We have reviewed this model using the same approach we used to review the econometric models underpinning the energy model.

2.2 Process

In addition to using the information contained in NGET's consultation document on the Initial Proposals for the electricity SO Incentives Scheme, we have based our review also on information provided by NGET subsequently.

Specifically:

- NGET provided initial draft documentation on the Plexos BSIS model in early December 2010;
- on December 10th 2010, NGET also provided the first set of unconstrained schedule outputs;
- on December 20th 2010, NGET – jointly with Redpoint – presented its proposed modelling approach in detail. Using this information, we prepared an initial note on unconstrained modelling schedule, providing NGET with some suggestions for modifications to the modelling approach;
- NGET refined its approach and further calibrated the Plexos BSIS model to produce an updated set of results, covering both the unconstrained and constrained schedule. These were provided on March 1st 2011. We reviewed these results and presented our assessment to NGET and Ofgem on March 11th 2011;
- Based on our review, NGET applied further calibrations to model and released a new set of results on April 4th 2011. Following a further review and adjustments to the modelling approach, NGET released a final set of results on June 3rd 2011, which we have reviewed for this report.

During this period, we had numerous discussions with Ofgem and NGET on the appropriate approach to pricing, and received a number of pieces of analysis from NGET on the potential windfall gains and losses associated with different pricing approaches.

On April 1st 2011, NGET also provided a final proposed econometric model of headroom costs.

Throughout this process, aspects of the constraints model were also discussed at a number of meetings at Ofgem and in our own offices. Finally, NGET has also responded to numerous questions about the models by phone and by e-mail.

Scope and process

3 Modelling approach

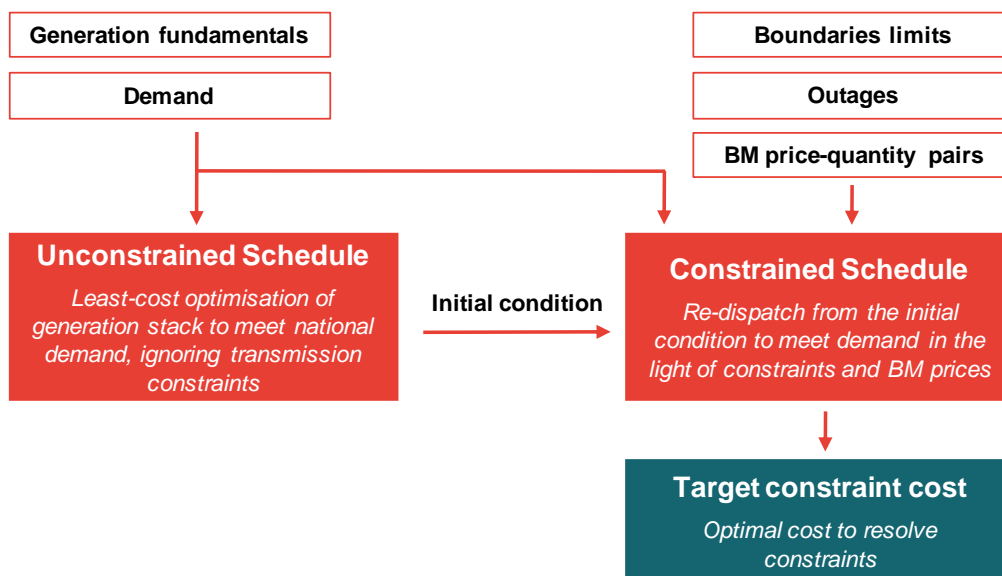
In this Section, we provide an overview of the modelling approach proposed by NGET, focusing on both the calculation of constraint costs and on the headroom replacement model. In the following Sections, we will discuss the inputs to the constraint cost model in detail.

The Section is divided in two parts. First, we provide an overview of the constraint cost model. Then we describe the econometric model that NGET has developed to estimate headroom replacement costs.

3.1 Constraint costs

Figure 1 provides an overview of the modelling approach to the calculation of constraint costs.

Figure 1. Constraint cost modelling approach



The key objective of the modelling approach is the estimation of optimal constraint management costs, which can then be compared with NGET's outturn costs, thereby assessing its performance.

The Plexos BSIS model calculates constraint costs in two sequential steps. First, the unconstrained schedule is calculated. This is the outcome of a least-cost optimisation of the generation stack, based on fundamentals, to meet national demand. This simulation ignores transmission constraints, thus representing the optimal dispatch that would naturally occur if network capacity was unlimited and plant running was based on generator SRMC.

The unconstrained schedule is then used as initial condition for the constrained schedule simulation. This is a re-despatch from this initial condition to meet national demand, this time considering boundary limits. The re-despatch is based on Balancing Mechanism price-quantity pairs. These represent the set of actions (combinations of prices and quantities) available to NGET to resolve transmission constraints near and during real time.

There are four different types of prices that the Plexos BSIS model needs to take into account. Specifically:

- **energy offer:** this is the price paid by NGET to move a generating unit (BMU), once synchronised, to move from its current output to any position up to its maximum capacity;
- **sync offer:** this is the price paid by NGET to move a de-synchronised BMU from standstill up to its minimum stable level;
- **energy bid:** this is the price paid by a BMU to move from its current output down to its minimum stable level, while remaining synchronised; and
- **de-sync bid:** this is the price paid by a BMU to move from its minimum stable level down to standstill, thus de-synchronising itself from the system.

3.2 Headroom replacement cost model

Free headroom is available whenever a BMU's declared availability (MEL) exceeds its notified output (FPN). Free headroom contributes to NGET meeting its reserve requirement. However, when there is a transmission constraint, part of this free headroom may become unusable. In these cases, NGET needs to replace the 'sterilised' free headroom no longer available to ensure it can still meet its GB-wide reserve requirement.

The current implementation of the Plexos BSIS model does not calculate headroom replacement needs and therefore costs. This functionality may be introduced at a later stage. For the time being, NGET has proposed to calculate headroom replacement costs using an econometric model. The model has been estimated on historic data.

The proposed model links monthly headroom replacement costs to three cost drivers, specifically:

- **season:** the time of the year affects the level of transmission constraints that NGET will face and hence the cost it will incur to replace sterilised headroom. This driver captures the combined effect of changes in demand and outages of transmission lines and generators according to the time of the year;

Modelling approach

- **constrained margin management (CMM) volume:** this driver represents the volume of the actions that NGET undertakes with the dual effect of procuring additional margin and replacing sterilised margin behind an export constraint;
- **margin price:** this is the price that NGET pays to synchronise additional generators whenever it procures additional margin. As such, it is directly connected to headroom replacement costs.

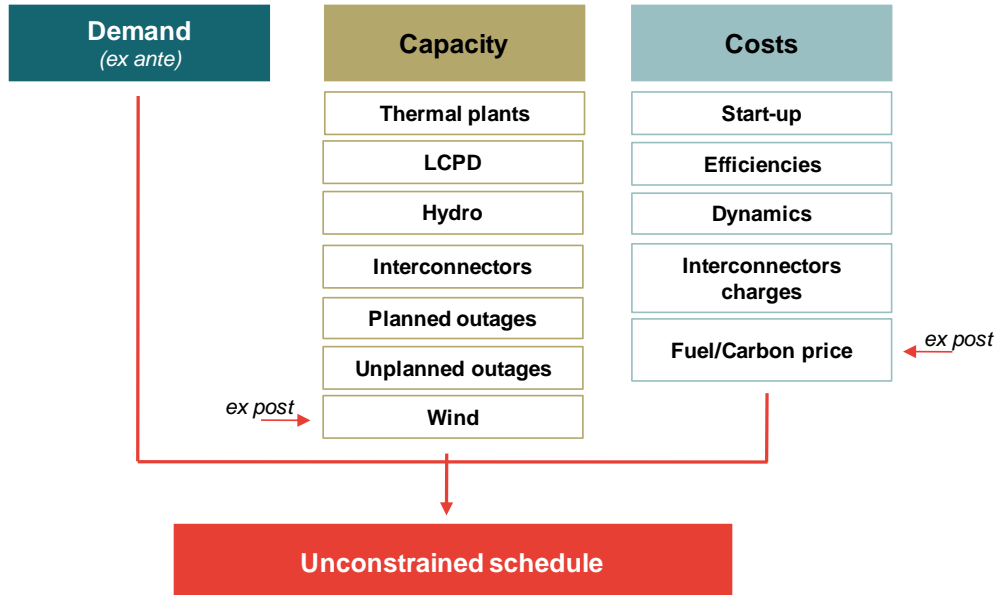
4 Constraint model inputs: unconstrained schedule

In this Section we review NGET's approach to define the main inputs to the unconstrained schedule. In addition, we consider in more detail three types of inputs where further refinements may be possible or have already been implemented since the Initial Proposals were published in December 2010. These are the treatment of LCPD opted-out plants, planned outages and the modelling of interconnector flows.

4.1 Review of main inputs

NGET's approach to modelling the unconstrained schedule is relatively standard. Figure 2 provides an overview of the key inputs used in the model. Most inputs are to be set *ex ante*, to provide NGET with adequate incentives in line with Phase 1 findings. In some cases, however, NGET has proposed to treat some inputs *ex post*, to limit the potential for windfall gains and losses. These are highlighted in the figure. We comment on these assumptions below.

Figure 2. Inputs to the unconstrained schedule



4.1.1 Demand

The model uses the demand forecasts already being prepared by NGET on a regular basis. Given its confidence in this methodology, NGET has proposed that demand is treated as an *ex ante* input. This assumption is also in line with what has been proposed in the energy modelling approach, for the modelling of

Frequency Response costs. The demand considered in the Plexos BSIS model is net of any pumped storage load (which is treated separately), station load or embedded generation.

4.1.2 Capacity

Most of the inputs used are defined ex ante. We review them below:

- **Thermal plants.** NGET uses the available ex ante generation background information, based on existing information on plant commissioning and decommissioning. The granularity of the information used in the model is monthly.
- **LCPD opted-out plants.** In its Initial Proposals NGET indicated that it was using a 35% annual load factor ceiling for all the affected plants, as a proxy for the running hours constraints that these plants face. Following further discussions, it has since modified this approach and switched to using ex ante plant-specific load factor ceilings. These have been calculated on the basis of the actual remaining running hours for each plant. We note however that a common 35% annual load factor ceiling has been used for the calibration of the model to 2009/10 outturn values. In the next section, we discuss this assumption in greater detail.
- **Hydro.** The treatment of hydro generation varies according to its source.
 - **Pumped storage.** In order to take into account the opportunity cost of despatching, the model optimises pumped storage generation across several days. Once ‘daily budgets’ have been defined, within-day despatch decisions are then made on the base of wholesale price differential between peak and off-peak.
 - **Reservoir.** Reservoir generation is modelled by assuming a monthly inflow into the head pond. Given this capacity constraint, the model optimises the release of water on a daily basis, with the additional condition that the annual load factor should be aligned with historically observed load factors for reservoir storage (about 36%).
- **Interconnectors.** The model takes into account available interconnector capacity, as interconnected markets can drive constraint levels in certain areas. In order to model the non-GB side of the interconnected market,

Constraint model inputs: unconstrained schedule

NGET uses a simplified generation stack¹, meeting a simplified demand profile.

- **Generation outages.** The treatment of generation outages is different for planned outages and unplanned outages.
 - **Planned outages.** NGET has proposed to use planned outages information (OC2). Despite the fact that planned outages are subject to some changes over time, we agree with NGET's proposal to define this input ex ante. This would provide NGET with incentives to attempt to influence generation outages in an efficient way. However, to mitigate the uncertainty associated with outage plans beyond the year ahead stage, NGET has proposed that information on generator outages is updated one year into the incentive scheme. To assess this proposal, we have considered the reliability of 2-year-ahead outage plans and discuss our findings below.
 - **Unplanned outages.** In the Initial Proposals, NGET indicated that it would treat this variable as an ex post input, to minimise the potential for windfall gains or losses. Following further discussions between Ofgem and NGET after the publication of the Initial Proposals, NGET has modified its approach. We understand that unplanned outages are now intended to be determined ex-ante, using a stochastic methodology². NGET proposes that outage rates will be set using recognised industry benchmarks.
- **Wind.** The output of wind generation is difficult to forecast in the time horizons considered and beyond NGET's control. For this reason, NGET has proposed to treat this input as ex post, using actual metered output for each generator.

4.1.3 Costs

NGET has proposed to define most of the cost inputs ex ante.

- **Plant efficiencies.** Direct information on plant efficiency is not publicly available. Therefore NGET has proposed to estimate plant efficiency ex ante. This estimation involves using generic efficiency levels by technology, adjusted to specific plants based on information on:

¹ Specifically, the French market is represented by a simple nuclear and gas stack. The Irish market is represented using a mixed coal and gas stack, while the Dutch market is modelled using a gas stack.

² We understand from NGET that Plexos takes as inputs parameters (which may be specific to technology type) to enable outages to be modelled stochastically. These include the expected outage rate by plant type and potential outage duration.

- generation age, as older units are less efficient than those more recently commissioned;
- historic running regime; and
- observed fuel consumption and emission patterns.

Going forward, the efficiency of new units will be calculated based on information available for existing ones.

- **Start-up costs.** NGET's approach to estimating start-up costs, treated as ex ante inputs, is very similar to that proposed for calculating plant efficiency. Generic start-up costs (made up by both a fuel component and a cash component) for each technology are used as starting point and adjusted to match observed data.
- **Plant dynamic parameters.** These parameters³ describe the running patterns of each generating unit and therefore the way in which the Plexos model can modify their output when determining the optimal despatch outcome. NGET has proposed to define this input ex ante, on the basis of actual plant dynamics obtained from historical submissions to the balancing mechanisms. The parameters for new units can be inferred from similar existing units.
- **Interconnector charges.** The proposed approach uses a price differential mechanism (effectively a wheeling charge) to calibrate interconnector flows. Flows on the interconnector will occur only if the price differential between the importing and the exporting market is larger than this wheeling charge. This ensures that the optimisation engine does not "over-use" the interconnector. We understand that this charge has been adjusted in the calibration process such that modelled outputs match annual historic interconnector flows.
- **Fuel and carbon prices.** NGET proposed approach is to use ex post spot fuel and carbon prices for each settlement period⁴ considered in the model.

We note that in defining the cost inputs, NGET have also calibrated the unconstrained model outputs to 2009/10 observed FPN levels, which can be

³ Plexos uses the following plant dynamic parameters: MEL (Maximum Export Limit: the maximum level at which a BMU can generate), SEL (Stable Export Limit: the minimum level at which a BMU can generate), MZT (Minimum Zero Time: the minimum amount of time that a BMU must remain off for), MNZT (Minimum Non-Zero Time: the minimum amount of time that a BMU must be on for), RUR (Ramp-up Rate: the rate at which a BMU can increase its output level) and RDR (Ramp-down Rate: the rate at which a BMU can decrease its output level)

⁴ In practice, daily prices instead of prices for each settlement period may be used.

Constraint model inputs: unconstrained schedule

assumed to represent each plant's potential output in the absence of transmission constraints. This is largely achieved through simple adders or subtractors to SRMCs (i.e. estimated fuel price is increased or decreased by a given value per MWh).

4.2 Review and further refinements

4.2.1 Review of NGET's approach and assumptions

In general, we believe that the approach adopted by NGET in relation to deriving an unconstrained schedule is appropriate for the purposes of estimating constraints. In particular, we believe the proposed *ex post* treatment of fuel costs and wind is appropriate since these inputs are volatile, difficult to forecast, and beyond NGET's control.

Generation outages are also beyond NGET's control, but their impact should on average be easier to forecast and hence it may be reasonable to model their input *ex ante* on a stochastic basis. Provided the industry benchmarks are reasonably calibrated to historic experience of outage rates for different technology types, this approach appears reasonable.

However, we note that for major long lasting outages, this approach may create the potential for windfall gains and losses (e.g. were there to be a prolonged outage on a plant which had a significant impact on constraint costs).

4.2.2 Further potential refinements

Planned outages

As noted above, NGET has proposed that planned outages are input in the model *ex ante*. However, to mitigate the uncertainty beyond the year ahead stage associated with the OC2 information, NGET has further proposed that the outage plan is updated after one year, to ensure that the model can be run using more up-to-date and, potentially, more accurate data. The benefits of doing so need to be weighed against the loss of some of the incentive provided by using fully *ex ante* data for both years at the start of the Incentive Scheme period.

For this assessment, we analysed the accuracy of outage plans for the year 2009/10. We compared OC2 submissions both two years ahead (Y-2) and one year ahead (Y-1) with the actual outages observed. NGET provided us with the data, which allowed us to consider the outage plans for about 200 generating units. Specifically, we considered the following possible outcomes:

- correct forecast for both Y-2 and Y-1;
- correct forecast only for Y-1;
- correct forecast only for Y-2; and

Constraint model inputs: unconstrained schedule

- forecast incorrect in both Y-2 and Y-1.

Table 1 summarises the results of the analysis, indicating the number of observed outcomes in each category. We note that each observation corresponds to an outage/week.

Table 1. Analysis of OC2: number of observed outcomes (outage/weeks)

Outcome	Number of observations
Total actual outages in 2009/10	1,314
Forecast correctly in both Y-2 and Y-1	293
Forecast correctly in Y-2 only	136
Forecast correctly in Y-1 only	354
Forecast incorrectly in both Y-2 and Y-1	531

Source: Frontier, using data provided by NGET

Based on these results, we observe that the number of successful forecasts in the Y-2 outage plan is 429 (the sum of successful forecasts in both outage plans (293) and the successful forecasts in Y-2 only (136)). To calculate the forecasting performance of the Y-2 plan, we need to consider the total number of outages (successful or not) included in it. As the Y-2 plan forecast 1,085 outages in total, its outturn success rate is 39.5%.

We then consider the accuracy of the Y-1 plan. In this case, the number of successful forecast is 647. This is given by the sum of successful forecasts in both outage plans (293) and the successful forecasts in Y-1 only (354). As the Y-1 plan forecast 1,127 outages in total, its outturn success rate is 57.4%.

Table 2 summarises these results.

Table 2. Analysis of OC2: relative performance of outage plans

	Number of successful forecasts	Total outages forecast	Success rate
Two-year ahead (Y-2)	429	1,085	39.5%
One-year ahead (Y-1)	647	1,127	57.4%

Source: Frontier, using data provided by NGET

This analysis shows that the Y-1 plan for 2009/10 was significantly more accurate than the Y-2 plan. We have carried out the analysis using only a year's worth of data and the relative performance of the outage plans may be different for other years. However, the analysis would appear to indicate that basing outage plans on two year ahead data given current levels of generator forecasting accuracy may result in material windfall gains and losses for NGET relative to a refresh of the outage forecast at the year ahead stage. This effect probably outweighs the benefits of an incentive on NGET (albeit that this might result in a change in arrangements leading to an improvement in forecast accuracy).

LCPD opted-out plants

In the Initial Proposals, NGET indicated that, to simulate the running hours constraint on LCPD opted-out plants, it was using a 35% annual load factor ceiling for all the affected plants. We noted that the FPN load factor for the plants was around 15% in 2009/10, significantly below this 35% cap. We also noted that it was unclear whether this situation would persist. In particular, as the time available to use remaining hours falls, significant increases in output may be reasonably expected.

Despite the fact that FPNs were below the level implied by the 35% cap, the review of the first set of complete results for the 2009/10 calibration found that the modelled load factor for coal plants was too low if compared with actual load factors calculated using submitted FPNs.

NGET therefore re-ran the model eliminating the LCPD running hours restriction. In these runs, the only LCPD opted-out plant exceeding the 35% limit was Cockenzie. Therefore, NGET decided to recalibrate the short-run marginal costs of two other plants to ensure a reduction in Cockenzie's modelled utilisation. Specifically, NGET applied a £2/MWh reduction to Ferrybridge C2a's SRMC and a reduction of £3/MWh to Tilbury 8's SRMC. These adjustments are consistent with the NGET's general approach to model calibration. NGET then re-ran the model with this recalibration, while maintaining the 35% load factor restriction for all LCPD opted-out plants.

Constraint model inputs: unconstrained schedule

However, the results showed that for no-one of the LCPD opted-out plant the 35% running hours constraint was binding.⁵

Following this re-calibration, while the load factors of all LCPD opted-out plants were below their FPNs (a modelled load factor of 12% compared to an FPN load factor of 15%), NGET took the view that an acceptable level of modelling accuracy had been reached.

It would be possible for NGET to undertake more calibration to arrive at results for the LCPD opted-out plant which are closer to their 2009/10 FPNs. However, given that these 2009/10 FPNs need not bear any particular relationship to 2010/11 or future year outputs, it is not clear that such additional calibration would be valuable at this stage.

Going forward NGET has introduced load factor limits specific to each generating unit, according to their individual remaining hours. This approach is preferable as it should be better able to capture changes in the behaviour of individual LCPD plants as the number of available remaining hours fall.

Finally, we do note that the running of LCPD plant is inherently difficult to model given the multi-annual hours restriction and there is likely to be an ongoing need to review the model's performance in this area.

Interconnector flows

As noted above, modelled flows on the interconnectors will occur only if the price differential between the importing and the exporting market is larger than a pre-determined wheeling charge. NGET has calibrated the model by adjusting the wheeling charge to match annual historic interconnector flows.

At the moment, the wheeling charge is the main parameter that is modified to calibrate the interconnector flows in the model.

While this may be appropriate given explicit auctions on the interconnectors, in due course NGET may wish to consider the implications of implicit auctions. Specifically, the impact of implicit auctions may be worth considering now that BritNed has been commissioned, especially if it is found to have a material impact on interconnector utilisation and constraints. However, we note that prior to implicit auctions being implemented, there is little that can be achieved in this area.

We discussed these potential improvements with NGET. NGET agreed with our suggestion that the approach to modelling interconnector flows could be

⁵ We understand from NGET that the current version of the model includes a 35% annual load factor ceiling for all LCPD opted-out plant, ensuring that Plexos cannot generate non-compliant results.

reviewed once market coupling is live on BritNed and data on its impact become available. In the meantime, we believe that NGET's approach is appropriate.

5 Constraint model inputs: transmission network

In order to model a constrained despatch and hence define the volume and cost of constraints, NGET defines a model of the transmission system and provides this as an input to Plexos. In this chapter, we set out our understanding of NGET's approach to modelling the transmission system and then consider the extent to which it is fit for purpose and the areas where ongoing regulatory oversight is likely to be required.

It is important to note at the outset that our review has been undertaken from the perspective of considering what would be an appropriate methodology in terms of the final objective of defining the volume and cost of constraints. We have not undertaken a detailed engineering based appraisal of NGET's approach.

5.1 Our understanding of NGET's approach

The physical transmission system is composed of interconnected lines and transformers, and the flow of power around the system is governed by physical laws. While it is possible to define a rating for any individual piece of equipment, it is not possible to define the transfer capabilities between areas of the transmission system without also defining scenarios for the dispersion of generation and demand.

The most accurate approach to modelling the transmission system would be to characterise it in terms of physical pieces of infrastructure and the physical laws which govern power flow. However, this would result in a highly complex model.

NGET is proposing the adoption in due course of a model close to this, which would characterise the transmission system in terms of individual lines and nodes. However, for the purposes of the current scheme, given the time available to develop the model, they are proposing to adopt a simpler definition. This interim definition would characterise the system as a series of zones (groups of nodes) with fixed capacity limits across zonal boundaries (fixed in MW, irrespective of the broader flows on the system) between the zones. These boundary transfer limits would need to be estimated on the basis of credible scenarios for the overall dispersion of generation and load.

This simplification is often used in the modelling of power systems. For example, in defining the available capacities over interconnectors between countries in Europe, an approach which defines a MW transfer capability irrespective of system conditions is taken.

The impact of this simplification on accuracy clearly depends on two factors:

- the degree of aggregation of nodes into zones – the more aggregated the zones, the less accurately they will be able to reflect the realities of the transmission system as the model will assume that there are no constraints within zones; and
- the approach to estimating the transfer capabilities across zonal boundaries.

5.1.1 Approach to defining zones

NGET advised us that their approach to defining zones is largely based on the experience and judgement of its power system engineers, combined with calibration of the constraints predicted by the model to those observed over the year 2009/10.

5.1.2 Approach to defining transfer capabilities

NGET proposes to adopt a slightly different approach to defining transfer capabilities for the first and second year of the scheme.

First year transfer capabilities

In the first year of the scheme, the programme of transmission network outages is known with a reasonable degree of certainty (as the planning in relation to both construction and maintenance outages is well-advanced).

For non-derogated boundaries, there is no need to consider the non-outage transfer capabilities of the network, as the application of the Security and Quality of Supply Standard (SQSS) should mean that the network has been designed and built to ensure that there are no persistent constraints.

Therefore the key focus is on the transfer capabilities of derogated boundaries and the capabilities of boundaries during outage conditions. However, there are likely to be hundreds of outages on the transmission system over the course of a year, and wide range of system conditions to consider in relation to any potential derogated boundary or boundary with an outage. The power system study work required to estimate the transfer capability across a boundary for a given set of system conditions is reasonably resource intensive. NGET therefore has to define “representative conditions” to analyse, both in terms of the nature of the outage and the wider dispersion of generation and load.

Therefore, for each boundary, NGET considers conditions which it believes are likely to have the most significant effect on boundary capacity. For a non-derogated boundary, NGET considers the planned outage which is likely to have the most significant effect, and then examines in detail the system conditions for a chosen week of that planned outage (taking into account the estimated pattern of generation and demand during that week).

Constraint model inputs: transmission network

For the course of the chosen week, NGET analyses the maximum potential power flow with reference to the ability to restore the system to acceptable conditions after a fault. For example, in relation to a thermal limit, NGET:

- estimates the system operator’s ability to reduce power flow on overloaded circuits over time (using the most effective generator in relation to any particular circuit, irrespective of cost); and
- sets the boundary capability such that an overload on the relevant circuits can exist, but such that after a fault, the worst affected circuits can be reduced to a “normal” rating within 20 minutes.

The results of these analyses are then applied for the boundary as a whole during the outage conditions for which they are believed to be representative. In other words, the conditions for the representative week are applied to the whole outage, and the outage is then applied to any period of outage for that boundary. Where there are overlaps between outages, these are considered separately, as are individual plant output constraints to reflect specific fault level constraints or stability requirements.

Second year capacities

In the second year of the scheme, while the timings for outages for major construction works may be complete, those for maintenance outages will not be known in detail. Hence, there is not a full outage plan which can be evaluated.

Therefore, NGET estimates the impact of likely outages on the basis of previous outage experience. NGET relates likely outages to actual historic outages and then studies the impact of those historic outages on boundary capacity. These historic studies are then used to estimate, with a significant level of uncertainty, boundary capacity for the relevant periods of the second year. Inevitably, this approach is less robust than the approach used to estimate first year transmission capacities, which, as noted above, are estimated on the basis of work plans that have already been developed. However, in the absence of a concrete outage plan having been developed, it is not clear that there are any other ways in which to progress.

Given the uncertainty in relation to outages, NGET raises the issue of whether transmission boundaries should be set at the outset of the scheme for the second year, or whether there should be a “refresh” of boundary capacity estimates for the second year of the scheme ahead of the start of that second year.

5.2 Review and further refinements

5.2.1 Review of NGET's proposed approach

The overall approach taken by NGET to defining a simplified zonal model of the transmission system is relatively standard. NGET has an incentive to ensure that the zonal definition is not too aggregated as fewer zones would imply a smaller number of boundaries where constraints might arise. In turn, this might result in too low a target cost for constraints.

There are two other areas in relation to the definition of boundary constraints where NGET could use subjective judgements to attempt to bias the target cost upwards. We discuss these in more detail below.

5.2.2 Further potential refinements

We highlight three potential issues with NGET's approach which are worth further consideration by Ofgem.

Refresh of transmission capacities

In our Phase 1 report, we indicated that there were potential benefits to providing NGET with a longer term incentive in relation to the planning and scheduling of transmission outages. In particular, we noted that there was a trade off between incentivising outage scheduling in the short term (when much of the logistics around outage timing would already be fixed) and in the long term (when there may not be sufficient certainty as to the nature of outages required to allow informed decisions to be made). We indicated that the period between one-year and two-years ahead may be an important period to incentivise, as there might already be a reasonable level of certainty in relation to the need for outages, but also some flexibility as to their precise timing.

Relative to generation outages, NGET should have greater control over the timing of transmission outages, both through internal processes in relation to its England & Wales Transmission Owner business and through the effective operation of the SO TO Code in relation to the Scottish Transmission networks. To the effect that the SO TO Code processes do not work as effectively as they could, an incentive relating to transmission outages over the long term may incentivise NGET to bring forward proposed modifications to the Code to improve its effectiveness.

If boundary capacities are refreshed for the second year of the scheme, the incentive for NGET to reschedule outages to minimise the impact on constraint costs would be reduced or removed. This is because NGET's target for constraint cost would take into account the updated schedule of outages reflecting any rescheduling undertaken between the year ahead and two year ahead stage.

Constraint model inputs: transmission network

Provided both Ofgem and NGET agree that the information on which NGET is estimating transmission boundaries in the second year of the scheme is sufficiently robust, we therefore believe there could be material benefits to setting transmission boundaries for both years of the scheme at the outset (i.e. avoiding the second year refresh).

Choice of representative outages

For reasons of practicality, NGET is required to identify both representative outages and representative weeks within outages in order to define boundary capacities.

There is inevitably a degree of subjectivity in **choosing the outage which best represents the likely level of outage boundary capacity** for the year in question.

Due to the large number of outages to be considered, it is difficult to envisage any alternative process. However, Ofgem will need to be comfortable that the exercise of subjectivity does not bias the results.

In this area, Ofgem is likely to face a considerable information asymmetry. The impact of outages on boundary capacity is highly complex to estimate, as it relates to the detail of the outage itself and the broader dispersion of generation and load at the time of the outage. Without a detailed understanding of the engineering of the power system, Ofgem is likely to find it difficult to form an ex ante view as to the reasonableness of NGET's analysis.

This leaves two options available to Ofgem. The first would be to contract independent power system engineers to review NGET's analysis and to verify whether any bias could have been introduced. This process could involve a significant delay. The second would be to put in place ex post monitoring of the impact of outages on boundary capacities and to monitor whether (with hindsight) NGET's exercise of judgement was reasonably unbiased. Ex post, this can at least initially be evaluated on a statistical rather than engineering basis. In the event that it were found to have introduced bias at a level which it is believed could reasonably have been anticipated ex ante, Ofgem could consider the imposition of penalties or other sanctions (e.g. clawback of incentive gains) on NGET. However, such penalty scheme should be mindful of genuine reasons for changes such as uncontrollable factors and mistakes.

Given the significant effort already undertaken to establish broader arrangements for this first two year scheme, the first approach is unlikely to be practical. Therefore, we believe it will be important for Ofgem to ensure there is sufficient ex post monitoring in place (along with a clear process in terms of potential penalties) to allow any significant bias in the exercise of NGET's judgement to be identified.

Constraint model inputs: transmission network

Equally, the process of **estimating the boundary capacity for any given outage** involves a requirement for the exercise of subjectivity.

In terms of process, NGET proposes to estimate boundary capacity based on the system operator's ability to reduce power flow on overloaded circuits over using the most effective generator in relation to any particular circuit, irrespective of cost. This should ensure an estimate of boundary capacity which is optimistic, as in reality this generator may not be available or may only be available at a high cost, in which case generators which were less effective at reducing boundary flows would need to be called on (resulting in a lower effective transfer capacity). In other words, the process should tend to over-estimate transfer capacity and under-estimate the extent of constraint.

However, there is still scope for the exercise of discretion in relation to the choice of week during the outage which is believed to be representative.

Again, there are two options which Ofgem could follow to verify whether the use of discretion has introduced bias – an ex ante engineering audit or ex post monitoring. As with the choice of representative outages, we believe that at this stage, for the first two year scheme, an ex post monitoring process is likely to be the most practical approach.

6 Constraint model inputs: constraint pricing

To determine which generators are re-despatched to manage constraints (and hence to evaluate the cost of constraints), the constrained schedule requires prices for each generator on the system. Using these prices, the Plexos model can be used to value the volume of congestion estimated and hence to provide an overall cost target for NGET to be incentivised against.

Therefore, in this chapter, we:

- First, describe the approach envisaged in Phase 1 for valuing constraint volumes, known as the **ex ante approach**, and set out some of the problems that have emerged with this methodology.
- Second, we consider other pricing options, using **ex post** prices. These were not considered at the time of Phase 1, but were developed more recently, in light of the results of NGET's analysis in Phase 2. We then go on to analyse the advantages and disadvantages of variants of ex post regimes.
- Finally, we set out **our recommendations**.

6.1 Ex ante approach

6.1.1 Phase 1 approach to pricing constraints

Our Phase 1 report recommended that the expected volume of constraints for the period of an incentive scheme be established on the basis of a fundamentals model. As described in previous sections, the inputs to this model would either be:

- ex ante, if the parameter was considered to be within NGET control or predictable (for example the level of transmission capacity). Setting this ex ante would incentivise NGET to outperform relative to the agreed parameter, which would result in reduced costs to customers; or
- ex post, if the variable was considered unpredictable and outside of NGET's control. For example, fuel prices would not be a parameter that NGET should potentially be incentivised against as there is little it can do to influence the level of such costs.

Based on the model, these inputs would be used to then derive an overall level of constraint volume. The Phase 1 report suggested that this volume of constraints would be valued on the basis of a forecast of prices that were specific to each power station. We considered that these prices would be a function of fuel prices and wholesale prices, although the exact nature of the relationship was to

be investigated in Phase 2. Our expectation was that the relationships between power station bids and offers in the balancing mechanism and the other variables (such as fuel prices) would be set ex ante. However, the actual prices to be used to value the volume of congestion would be derived ex post when the value of inputs deemed outside of NGET's control (such as fuel prices and the prevailing wholesale price) were known.

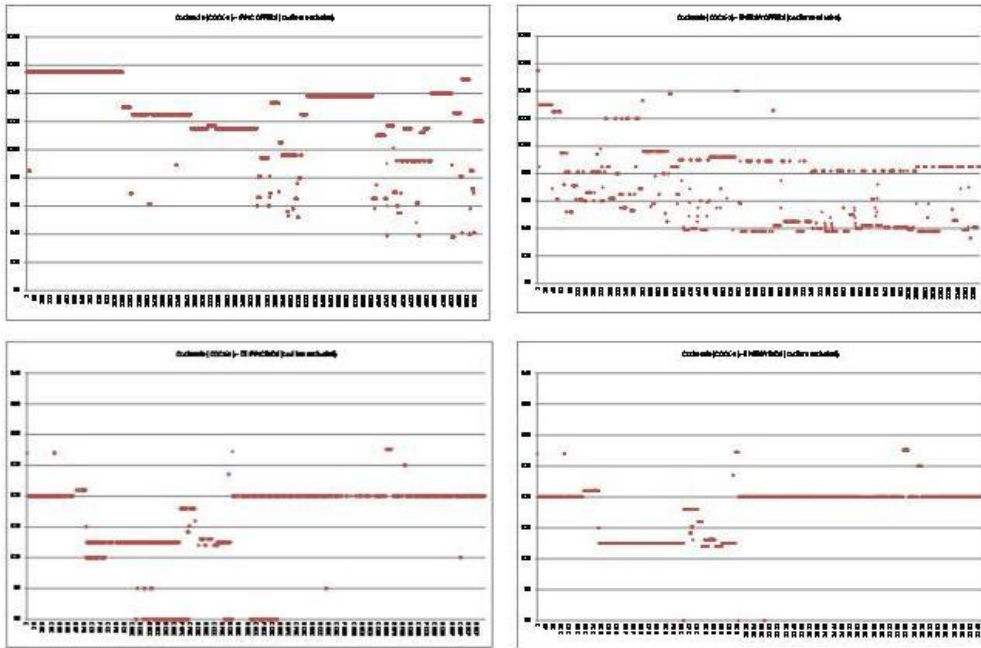
This approach would have led to an overall monetary value of congestion that, although established ex post, would have been determined on the basis of relationships established ex ante. In this way, NGET would have been appropriately incentivised to operate in a manner that rewarded it for minimising the overall level of constraint costs.

6.1.2 Phase 2 findings

As part of its work in Phase 2, NGET considered the variables that might be used to forecast the level of bid and offer prices that would be used to value the volume of congestion. Its findings were that, for a large proportion of plant, there was no discernable relationship between bid and offer prices and other underlying drivers of price such as fuel prices or the wholesale prices.

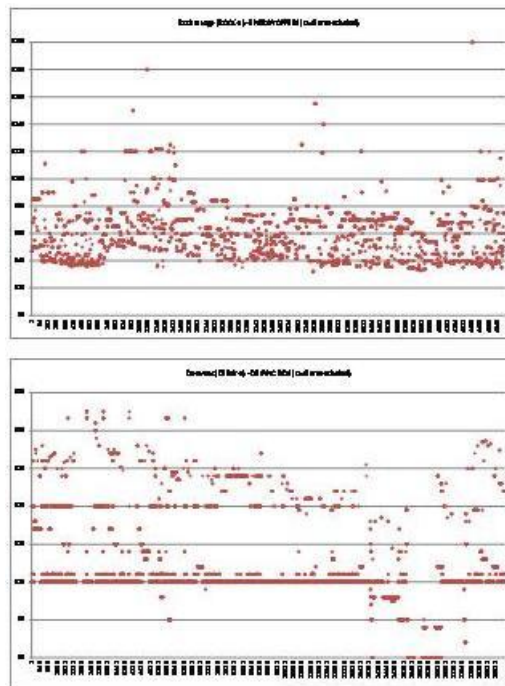
Figure 3 below shows the sync offer, offer, desync bid and bid prices for Cockenzie. Figure 4 shows the BM prices of two other plant – namely Rocksavage and Derwent.

Figure 3. Cockenzie: Actual Bid and offer prices



Source: NGET

Figure 4. Selection of other bids and offers



Source: NGET

Constraint model inputs: constraint pricing

The data presented above show BM prices submitted by these plants in the 2009/10 period. As is evident from the figures, the prices submitted into the BM appear to follow no discernable trend. NGET has tested to see whether there is a relationship between the prices submitted above with a large number of possible explanatory variables such as underlying fuel prices and prevailing wholesale prices.

In the cases set out above, no such relationship could be defined. Moreover, this is the case for the majority of BM units submitting prices – only about 30% appear to follow some type of (even relatively loose) trend with other explanatory variables. For the majority of plant, submitted prices either tend to vary sporadically or stay the same for extend periods of time. One possible reason for this cited by NGET is that BM bidding behaviour is impacted more by plant specific considerations (such as staff availability to manage possible outages caused by the plant operating under unusual conditions as a result of BM participation or stock levels and type of some fuels (e.g. coal)) rather than more market-wide considerations such as prevailing fuel prices.

Furthermore, there is no particular subset of plant type that exhibits “predictable” pricing behaviour. For example, the bids and offers submitted by some CCGTs are equally unpredictable as those submitted by coal plant. This is also true of plant by location.

An implication of this result is that, were this approach to be adopted in setting an overall financial target for the incentive scheme, NGET could potentially be exposed to very significant windfall gains and losses. These would arise to the extent that NGET was exposed to the difference between the expected BM prices (howsoever determined) and the actual prices prevailing in the BM. NGET have reported that the overall outturn of constraint costs are, perhaps not surprisingly, very sensitive to assumptions on BM prices. It has estimated that a +/- £2.50/MWh price difference in the bids and offers of thermal plant would lead to a £50m windfall gain or loss under the incentive scheme

In light of these findings, it would appear that to set the overall target on the basis of ex ante price relationships would risk exposing NGET (and customers) to the possibility of very large windfall gains and losses. In theory, this might not inhibit the setting of a multiyear scheme for constraints. If the risk of positive and negative exposure was equal and the accuracy of the forecast was constant over time (i.e. proximity of the period being forecast to the start of the incentive scheme period did not improve the accuracy of the forecast) then the windfall gains and losses may offset each other over time.

However, in practice, this is unlikely to be the case – proximity to the forecast period is likely to improve the forecast accuracy, and it is very unlikely NGET would wish to be exposed such uncontrollable costs over the longer term without the possibility of a reopener.

Constraint model inputs: constraint pricing

Therefore, were the ex ante pricing approach to be adopted, the incentive scheme may need a relatively large deadband and relatively low sharing factors to dampen the effects of possible gains and losses in the scheme outside of its control.

Since the intention is to have a single incentive scheme operating across energy and constraints, this would reduce the strength of incentive on NGET across all categories of cost as a result of an issue forecasting just one of those categories.

6.2 Ex post approach

In light of the possible issues in using ex ante prices in the evaluation of the overall level of constraints that NGET should be incentivised against, consideration has been given to using ex post prices.

Under this approach, the actual prices submitted by plant in the BM would be used to value the volume of constraints identified. These bids and offers would be used in the valuation process irrespective of whether the bids and offers are actually called by NGET in the BM to resolve congestion (or for any other reason). The rationale for this might be that, by not exposing NGET to the apparently inherently unpredictable prices of the BM, the overall objectives of a longer term scheme in which NGET with significant sharing factors might be more achievable.

Therefore in this section we briefly describe how the ex post regime would operate and then go on to examine potential problems and possible solutions to aspects of the regime.

6.2.1 Using ex post prices to value congestion.

Under an ex post pricing regime, the actual prices submitted by plant would be used to evaluate the congestion volumes identified in the model. On the face of it, such an approach would still provide NGET with strong incentives to operate in an efficient manner. For example:

- were it to select a plant in the BM to resolve a constraint that, turned out, was less effective than one identified by the model given the prevailing prices in the BM and system conditions, then NGET would be exposed to the financial consequences of its decisions; and
- NGET would still have an incentive to contract with market participants to reduce the volumes of congestion. The output from the modelling would identify a volume of congestion that would be evaluated at the prices prevailing in the BM. This would set the target amount of revenue that NGET can use to resolve the constraint. If NGET chose to, it could incur costs in striking a contract with a specific plant to reduce its intended output (its physical notification) so

that, in practice, there would be no constraint to resolve at the time of gate closure. The cost of this contract would, assuming NGET had made the correct decision, be more than covered by the target cost evaluated in the incentive scheme.

6.2.2 Issues to consider if using an ex post pricing regime

Although under this approach the incentive scheme appears still to incentivise NGET to operate efficiently whilst not exposing it to the potential of unforecastable windfall gains and losses, a number of issues have been identified. These are:

- the treatment of prices for plant experiencing an unexpected outages;
- the potential for windfall gains from contracting for volume limits with plant; and
- the treatment of contracts that NGET might undertake that seek to limit its exposure to prices in the BM (rather than contracts that limit physical notification volumes at gate closure).

We discuss each in turn, and highlight options for the potential resolution of each issue.

Treatment of unexpected outages

On occasion, plant will be unavailable on an unplanned basis. This means that it will not be operating and therefore will not submit a bid and/or offer in to the BM. This creates two issues:

- first, in calculating the volume of congestion, the model will not know that this plant is unavailable. Hence, if the plant would normally cause congestion, then the model would overestimate the volume of congestion as, in practice, that plant would not be actually be available to cause the congestion; and
- second, as the plant is unavailable there would be no submitted BM prices, and therefore no price that could be used to value the congestion identified by the model.

NGET's proposed solution to the first problem is to make ex ante assumptions on the likelihood of a plant be on an unexpected outage in any given period. That is, it will treat unexpected outages stochastically, as discussed in section 4. It is the intention that the benefits and costs of outages will therefore "even out" over the forecast period. In other words, there will be occasions when the model assumes that plant is available when in practice it is not, in which case NGET would accrue a financial gain under the scheme. However, there will be other

Constraint model inputs: constraint pricing

number of times when the model assumes a plant is unavailable when, in practice it is, in which case NGET would incur a financial loss under the scheme.

For the second problem, NGET has suggested that a proxy rule is applied so that prices used by Plexos are determined on the following basis of the following set of rules:

- first, the last relevant price submitted by the unit; or (if this not available)
- second, the average of all units of the same fuel type at the node; or (if this unavailable also)
- third, the average of the same fuel type at neighbouring nodes or the average of all units at the node can be used; or
- alternatively, the average price of the same fuel type within the country can be used.

NGET has stated that it has no preference between approaches three and four. Our view is that it appears preferable to link the missing price to that of a plant of the same fuel type as that might reasonably be expected to be a better proxy for BM prices than plant of different technologies (notwithstanding the observations noted in the ex ante approach discussion above). In which case, we suggest that:

- the third ranking rule is the average price of the same fuel type of neighbouring nodes; and
- then (finally) the average price of the same fuel type within the country be used.

Overall this approach appears reasonable. It is worth emphasising that the choice of pricing approach does not, in this case, affect NGET behaviour in any way as the outage of the plant is unexpected and, by definition, not subject to possible influence by NGET.

Treatment of volume based contracts

As already noted, under an ex post approach, NGET would be fully incentivised to contract with generating units to alter their final physical notification volumes submitted at gate closure. This would have the impact of alleviating the overall volume of congestion to be resolved in the BM by NGET.

This practice has been adopted extensively by NGET for a number of years under the existing incentive schemes. It is recognised by both NGET and Ofgem to have yielded significant cost savings to one in which congestion was resolved only in the BM.

Therefore, an approach in which the overall modelled volume of congestion were valued solely on the basis of BM prices, would be likely to result in a material overvaluation of the “efficient” level of revenue that NGET requires to resolve congestion volumes.

We understand that both Ofgem and NGET agree that under an ex post pricing regime a “discount factor” would need to be applied to the overall value of congestion determined by Plexos to account for efficiencies that NGET is likely to achieve through contracting.

Ofgem and NGET have discussed the approach to determining the discount factor to be applied to the cost of congestion identified by Plexos.

The methodology that Ofgem and NGET have considered involves taking the ratio between the aggregate contract costs actually incurred and what it terms the aggregate “equivalent BM costs”. The latter are the costs that NGET has estimated it would have incurred if it had not entered into these contractual agreements. To calculate the equivalent BM cost, NGET has used the information provided in the sanction papers that were used internally by NGET at the time to decide whether to enter into the contract.

We have assessed NGET’s methodology. In summary, we found that:

- estimating the share of total constraints addressable by contracts using historic data since BETTA Go-live tends to bias this estimate downwards as the share of constraints resolved by contracts then was smaller; and
- in calculating the discount factor, NGET have chosen to exclude a particular contract on the grounds that under the methodology used, the sanction paper would imply an unrealistically large saving as a result of the contract.

Based on the findings of our review we would recommend that:

- only the last three years of contracting strategy are used to inform the overall level of the discount factor.
- assuming that Plexos included the network conditions underpinning the need for the excluded contract, the contract should be included in the calculation of the discount factor.

Treatment of price based contracts

The most significant problem with the introduction of an ex post pricing regime for valuing congestion relates to the treatment of contracts that have a price based term within them.

Under an ex ante regime, NGET is incentivised to limit its exposure to prices in the BM through contracts with particular generators. For example, if it was

Constraint model inputs: constraint pricing

unsure whether a constraint would be active then it might seek to limit its exposure in the BM by paying an upfront option fee to a particular plant so that it submits more beneficial BM prices than those which NGET otherwise anticipated. Hence, although NGET incurred the cost of an upfront fee in striking the contract, it would receive the benefit of having certain prices in the BM for that generating unit.

However, under an ex post scheme constraint volumes will be valued on the basis of prices submitted in the BM (albeit with a discount factor applied to the aggregated value). As a result, there exists no incentive for NGET to enter into contracts that influence BM bids and offers. If, for example, it entered into a contract to limit the price a generator might submit in the BM, it would incur the cost of the option fee. However, the (now more beneficial) prices would also feed in to the overall value of the target – providing no scope for NGET to be rewarded for the benefits of striking the contract.

In practice, NGET have reported to us that pure price based contracts have so far only very occasionally been struck for use in the resolution of congestion, although we note that in future such instrument could become more attractive to deal with volume uncertainty caused by wind. However, blended contracts that have price and volume terms are more common. For example, for the period 7 August – 29 October 2010 NGET struck a contract with Peterhead the terms of which included a capped volume of physical notification but also capped offer and floored bid prices.⁶

NGET has argued that assessing the value of the price element in blended volume and price contracts is typically not straightforward. As a result, price data are typically not used by them in the evaluation of which contract terms to strike and nor are price limits specified in contract tender documentation. Rather, it is data that market participants may or may not choose to submit.

Nonetheless, price data is present in contracts struck by NGET. This creates the concern that NGET's incentives in relation to contracting may be distorted relative to a pure ex ante scheme.

On the face of it, this may not be a substantive issue. As we have noted above, including the prices struck in the contract (at the cost of an upfront option/ fixed fee) in the formulation of the overall target amount of revenue, negates the incentive for NGET to undertake such contracts (as it would not recover the costs the upfront fee).

There may be a concern in relation to alignment of incentives between NGET and generators (i.e. that NGET might strike a contract with a generator against customer's interests). Given NGET's tendering process, where there is effective

⁶ See http://www.nationalgrid.com/NR/rdonlyres/0B9E1C37-B1C1-44A7-A49E-E873BEC005DA/42239/Constraint_Requirement_Open_Letter3_July10_Final.pdf

competition for contracts among generators, this is unlikely to be an issue. And where generators have a degree of locational market power, it is not clear why they would be in a better position to secure a higher payoff through a contracting route than through the BM itself⁷.

However, the fact that prices can be quoted in contracts with NGET creates the possibility that NGET are in a position to “lock in” prices which influence costs to customers but to which they are indifferent.

There are three possible approaches to this problem:

- First, ignore the issue. On the basis that the ex post pricing regime simply nullifies the incentive for NGET to consider price based contracts, the issue could be ignored and recognised as a “cost” of not being able to use ex ante prices; and
- Second, prevent NGET entering into price based contracts. If there was a concern that allowing NGET to enter into price based contracts might, in some way, distort decision making in relation to congestion management decisions, Ofgem could choose to prohibit NGET from entering into congestion management contracts that included price terms through a licence condition; and
- Third, establish a counterfactual rule. Under this approach, a rule in the scheme would be established that uses a proxy price in the evaluation of the overall level of congestion rather than the price submitted by the generator (that was subject to influence under the terms of the contract). This price would attempt to mimic the price that the generator would have submitted in to the BM had it not entered into the contract.

Of these options, a counterfactual rule may appear the most attractive. However, this approach could itself create the risk that NGET chooses plant to contract with on the basis of the output of the counterfactual rule.

Unlike the rules developed by NGET for the treatment of plant not bidding because of unexpected generator outages, NGET can influence whether a plant is subject to these rules (by contracting with them). Hence, Ofgem would need to be aware that NGET would be incentivised to enter in to contracts with price elements in them not on the basis of efficiency, but on expected BM pricing were significantly different from that suggested by the counterfactual rule.

⁷ We note that price contracts do not guarantee any level of calloff of BM bids or offers for generators – they merely constrain submitted prices which may be then accepted or rejected by NGET.

That said, in our view there is merit in undertaking analysis to understand whether a suitably robust counterfactual rule can be established in order to place some incentive on NGET in relation to price contracts.

In the interim we believe Ofgem should consider prohibiting contracts relating to constraints with a price component through a licence condition on NGET⁸. We recommend this course of action in the short term for two reasons:

- First, NGET has stated that price based contracts are of very limited use to it in the resolution of constraints, and it has only very rarely entered into them. In relation to blended volume and price based contracts, as assessing the value of the price component is not straightforward, NGET has stated that it does not use the price caps and floors submitted in its decision on which contracts to accept. On this basis, the practical impact of preventing the use of price data in contracts for constraint resolution would be minimal; and
- Second, allowing price based contracting to continue allows NGET to lock in prices which impact customers while they are indifferent to their level. We have not identified any instances in which NGET would have a perverse incentive to act against the interest of customers (they should be indifferent to price levels). However, it is not clear why there is a benefit in allowing NGET to lock in prices which could be against customers' interests when they have no financial interest in them themselves.

6.3 Overall recommendations

We now briefly summarise our recommendations in this chapter. These are that:

- the ex ante approach to setting prices used to evaluate congestion as suggested in Phase 1 should not be adopted given the high degree of apparent unpredictability of BM bids and offers from generating units and the low incentive power on NGET which would need to accompany it;
- Instead, an ex post pricing regime should be adopted. Although this is second best in many respects it appears the only viable approach given the inherent unpredictability of BM bids and offers;
- The ex post pricing regime requires a number of “fixes”. We recommend the following:

⁸ We note that careful thought would need to be given as to the formulation of such a prohibition, as it should not preclude the conclusion of contracts for energy balancing services with price components.

- rules are used to formulate proxy prices for plant that are on unexpected outages;
- a discount factor is applied to the overall value of congestion estimated by Plexos on the basis of ex post prices to take account of NGET contracting; and
- in the short term, Ofgem may consider prohibiting NGET from entering into contracts containing price terms relating to congestion; but
- in the longer term, the introduction of a counterfactual rule in relation to BM prices for contracted generators should be considered. This might be either at the behest of Ofgem or NGET if either believes that allowing contracts might introduce material efficiencies.

7 Review of model outputs

Having considered the proposed methodology, we now set out the results of our review of the performance of NGET's proposed models (the constraint model and the headroom replacement cost model).

7.1 Constraint volumes

NGET provided us with the back-cast modelling result for both the unconstrained and constrained schedule (calculated using ex-post BM prices) for the year 2009/10. To allow us to assess the performance of the Plexos BSIS model, NGET also provided actual data for the same period. Specifically, it provided FPN⁹ (to be compared with the unconstrained schedule) and metered output (to be compared with the constrained schedule) by settlement period.

7.1.1 Considering the impact of contracts

Prior to assessing the back-cast modelling, it is important to understand the basis on which the modelling has been carried out. Ideally, the model would have been calculated to a 2009/10 pre-contract position (i.e. the despatch of the model prior to NGET striking any contracts to manage the cost of constraints). The modelled output could then have been used as one of the inputs to an assessment of the discount factor (reflecting contracting efficiency) by comparing modelled output to actual constraint costs.

However, we understand that for reasons of practicality, NGET has calibrated to a mix of pre- and post- contracts.

There were three sets of contracts struck in relation to management of constraint volumes in 2009/10:

- contracts relating to the output of Longannet;
- contracts relating to the output of Peterhead; and
- a range of intertrip contracts which facilitated greater transfers over key boundaries than would otherwise have been the case.

The model calibration has been carried out using actual submitted Maximum Export Limit (MEL) for all plants. For Peterhead, the MEL in 2009/10 was capped. This has been taken into account in the calibration. The intention is that this MEL cap should be removed for subsequent years, and so future runs of the model can again be considered to be with a "without contracts" position.

⁹ After NGET contracts.

The situation in relation to the intertrip contracts is more complex. The intertrip contracts increase the effective boundary capabilities assumed between key zones. To assess the level of boundary capacity without the intertrip contract would require a material number of system studies to be carried out by NGET (in the same way that system studies are required to forecast the transfer capabilities going forward for the scheme).

Within the time available, therefore, it is not realistic to model the “without contracts” position in relation to the intertrip contracts. These contracts only impact the constrained schedule – they should not change the unconstrained schedule. This needs to be taken into account when considering the accuracy of the modelling of constraint costs, an issue to which we return below.

7.1.2 Approach to assessing modelling

We have focused our review on a selection of key plants.

- **Scottish plants.** We have considered the model performance on forecasting the running patterns of Peterhead, Longannet and Cockerzie. Given the characteristics of the GB transmission network, these plants are often central to the volume of constraints and the cost of their resolution. The accuracy of the model for these plants is therefore essential.
- **Coal plants.** To assess Plexos’ performance when predicting the behaviour of coal plants, we considered two large generators in detail (Kingsnorth and Drax).
- **Gas plants.** We considered Plexos’ performance when modelling the running patterns of Rocksavage and Great Yarmouth. We chose to consider Great Yarmouth because, based on the comparison between FPN and metered output, it was the most constrained off plant in 2009/10.
- **Pumped storage.** As noted above, the modelling the behaviour of pumped storage is complex, as it requires optimising despatch over the medium term to fully take into account its opportunity cost. For this reason we have considered Plexos’ performance when predicting Dinorwig’s behaviour.

To carry out this assessment, using Plexos’ outputs we have calculated the following indicators:

- **Net modelling error:** for each week in 2009/10, we compared the series of actual values (FPN or metered as appropriate) with Plexos’ output. We then calculated a net modelling error as the sum of the modelling errors in each period (Predicted generation minus Actual generation) divided by the total Actual generation.

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- **Load factors by plant:** we also compared the modelled load factor for each plant with actual load factors. This provided an indication of whether Plexos captures the overall annual running pattern of generators.
- **Load factors and load duration curves by technology.** In addition to considering individual plants, we also considered the overall model performance by calculating load duration curves and load factors at the technology level. This indicator allowed us to assess whether Plexos' simulation captures the behaviour of the whole system correctly.

7.1.3 Results

We have grouped the results of the analysis by type of plants considered. We present them below, while the next subsection we provide our overall conclusions of our review of the constraint model.

Scottish plants

Table 3 compares the net modelling error for Peterhead, Longannet and Cockerzie. We have calculated the modelling error for both the unconstrained and constrained schedule, considering peak and off-peak times separately.

Table 3. Scottish plants – summary of net modelling error

	Peterhead	Longannet	Cockerzie
Unconstrained – Peak	3.9%	-4.1%	0.5%
Unconstrained – Off-peak	-7.1%	-16.6%	-3.5%
Constrained – Peak	7.1%	-9.2%	-0.6%
Constrained – Off-peak	-4.8%	-20.7%	-6.0%

Source: Frontier, based on Plexos modelling results and NGET data

These results show that the Plexos BSIS model captures the actual running patterns of these plants with relatively good degree of accuracy. The model appears to be less accurate in simulating Longannet's behaviour.

Plexos's accuracy relative to the Scottish plants we considered is confirmed by the small differences between modelled and actual load factors, as shown in Table 4 for both the unconstrained and constrained schedule.

Table 4. Scottish plants – comparison of modelled and actual load factors

	Peterhead		Longannet		Cockenzie	
	<i>Plexos</i>	<i>Actual</i>	<i>Plexos</i>	<i>Actual</i>	<i>Plexos</i>	<i>Actual</i>
Unconstrained	54.0%	54.7%	38.4%	42.2%	27.1%	27.3%
Constrained	53.7%	53.0%	34.9%	40.5%	25.4%	26.1%

Source: Frontier, based on Plexos modelling results and NGET data

Coal plants

Table 5 shows Plexos's net modelling error for Kingsnorth and Drax. The model's performance is mixed. With regards to Kingsnorth, the model tends to underestimate the plant's actual FPN and metered output during peak times. The opposite occurs during off-peak times, when the modelled results are higher than actual data. On the other hand, generally Plexos models Drax's FPN and metered output accurately. Overall, it has a slight tendency towards overestimation, which is more pronounced for off-peak periods.

NGET told us that the calibration of Kingsnorth has been complicated by the fact that its output was particularly volatile in 2009/10. For this reason, they do not expect to be able to improve the model's performance further for this plant. We note, however, that given Kingsnorth's low load factor, the absolute modelling error is relatively small. In comparison, the model calibration to match Drax running pattern was significantly less problematic, partly because the Drax's output profile is very simple.

Table 5. Coal plants – summary of net modelling error

	Kingsnorth	Drax
Unconstrained – Peak	-39.4%	4.3%
Unconstrained – Off-peak	35.6%	17.1%
Constrained – Peak	-44.8%	15.6%
Constrained – Off-peak	9.6%	15.6%

Source: Frontier, based on Plexos modelling results and NGET data

The model's performance for the two plants is reflected by the modelled and actual annual load factors shown in Table 6.

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Table 6. Coal plants – comparison of modelled and actual load factors

	Kingsnorth		Drax	
	<i>Plexos</i>	<i>Actual</i>	<i>Plexos</i>	<i>Actual</i>
Unconstrained	8.6%	11.3%	80.1%	73.2%
Constrained	8.6%	12.8%	79.9%	71.3%

Source: Frontier, based on Plexos modelling results and NGET data

Gas plants

Table 7 summarises Plexos's net modelling error for Rocksavage and Great Yarmouth. In both cases, the model appears to be able to track the plant's actual running patterns with a high level of accuracy, perhaps with the constrained schedule for Great Yarmouth being the only exception. Even in this case, however, the error is not very large.

Table 7. Gas plants – summary of net modelling error

	Rocksavage	Great Yarmouth
Unconstrained – Peak	2.3%	3.0%
Unconstrained – Off-peak	8.3%	4.9%
Constrained – Peak	3.4%	7.5%
Constrained – Off-peak	7.5%	20.1%

Source: Frontier, based on Plexos modelling results and NGET data

Overall, the model tends to overestimate the plants' actual FPN and metered output. This is confirmed by the annual load factors – modelled and actual – shown in Table 8 below.

Table 8. Gas plants – comparison of modelled and actual load factors

	Rocksavage		Great Yarmouth	
	<i>Plexos</i>	<i>Actual</i>	<i>Plexos</i>	<i>Actual</i>
Unconstrained	71.7%	68.3%	78.5%	75.5%
Constrained	72.2%	68.5%	78.5%	69.2%

Source: Frontier, based on Plexos modelling results and NGET data

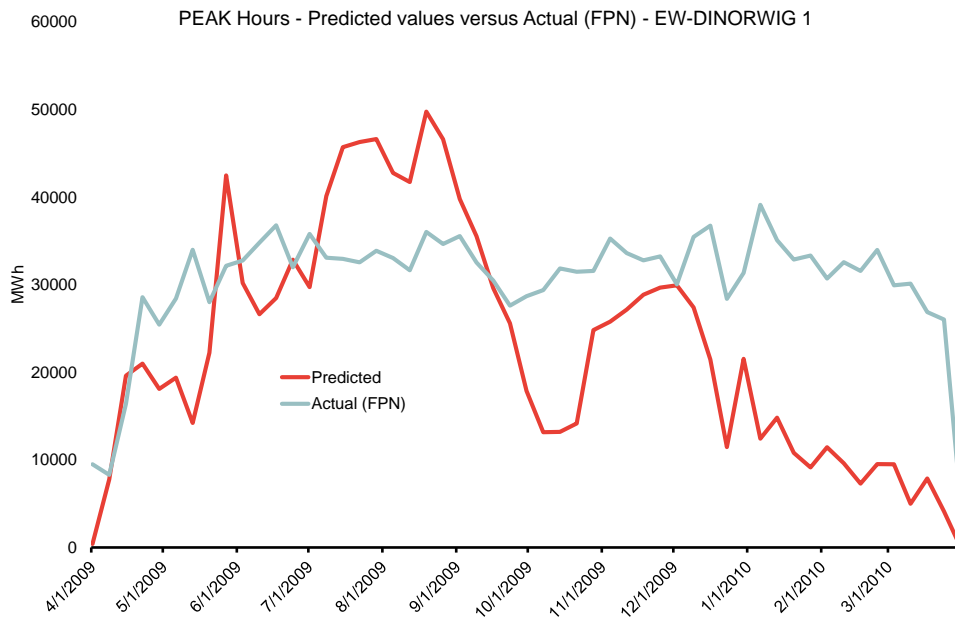
Pumped storage

Figure 5 and Figure 6 show the model's accuracy when predicting Dinorwig's running pattern. Specifically, the charts show the Plexos's performance when modelling Dinorwig's behaviour during peak times, both for the unconstrained and the constrained schedule.

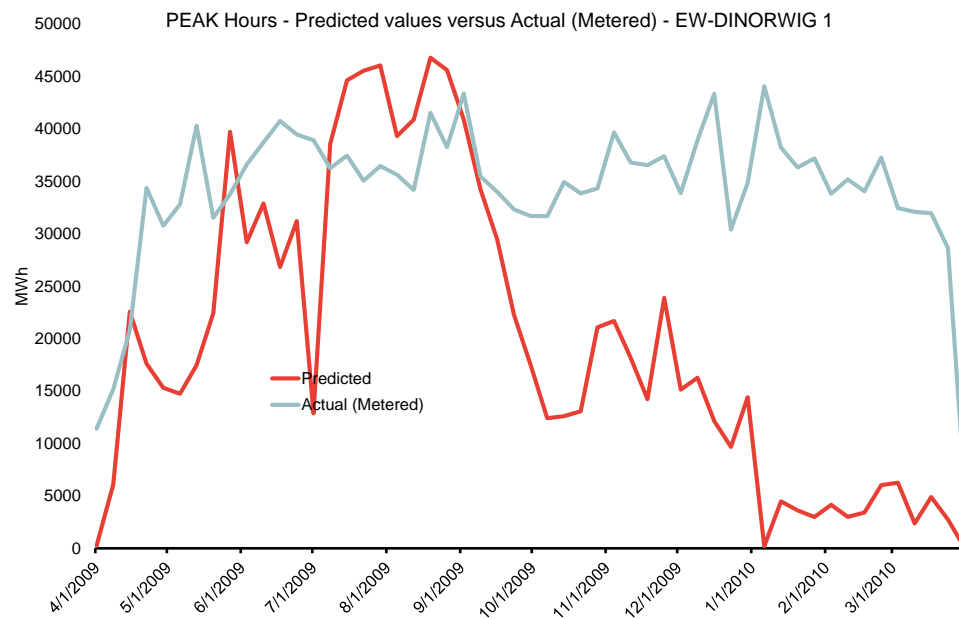
In both cases, the model appears to track Dinorwig's running patterns relatively well during the first part of the year (Summer), but it tends to systematically underestimate its output during the Winter months. The net modelling error for the unconstrained schedule is -24.0%, while it is -32.7% for the constrained schedule.

We discussed the modelling of Dinorwig with NGET. NGET told us that, due to the complexity of the output profile of pumped storage and the broader energy balancing reasons for its despatch, the calibration of the model is particularly problematic. It is therefore unlikely that model's accuracy could be improved any further. We do not believe it would be appropriate to devote further resources to calibrating the model in relation to Dinorwig's output at this time.

Figure 5. Dinorwig – comparison of predicted and actual unconstrained despatch



Source: Frontier, based on Plexos modelling results and NGET data

Figure 6. Dinorwig – comparison of predicted and actual constrained despatch

Source: Frontier, based on Plexos modelling results and NGET data

System

In addition to considering the Plexos's accuracy in modelling the running patterns of specific plants, we have also considered whether it models the entire system accurately.

Table 9 compares the annual load factors by technology calculated using Plexos's output with those calculated using FPN (for the unconstrained schedule) and metered output (for the constrained schedule).

Table 9. System – comparison of modelled and actual load factors

	Unconstrained		Constrained	
	<i>Plexos</i>	<i>Actual</i>	<i>Plexos</i>	<i>Actual</i>
Coal	34.3%	38.6%	34.1%	37.4%
Gas	65.3%	63.0%	65.5%	60.6%
Oil	0.04%	0.06%	0.04%	0.23%
Hydro (including Pumped Storage)	12.6%	14.0%	11.3%	15.4%
Nuclear	73.9%	78.4%	73.9%	74.2%

Source: Frontier, based on Plexos modelling results and NGET data

Overall, the model shows a good level of accuracy. The model tends to slightly underestimate the actual coal output, and to overestimate gas despatch.

A significant part of this issue relates to the treatment of LCPD plants, and the fact their modelled output is below their FPNs, as discussed in section 4. This can be seen by a comparison of the LCPD opt-out and other coal plant load factors shown in Table 10.

Table 10. Coal generators load factors (LCPD vs. non-LCPD)

Generator	Plexos load factor	Actual load factor
Coal	44%	45%
Coal LCPD Opt-out	12%	15%

Source: NGET

It is worth noting that this aggregate position for the non LCPD opt-out plant masks significant variations in forecast accuracy. An analysis of modelled and actual unconstrained load factors for a further nine randomly selected coal plant is shown in Table 11.

Table 11. Plexos performance with coal plants – Unconstrained schedule

	SYS Zone	Load factors		Net modelling error	
		<i>Plexos</i>	<i>FPN</i>	<i>Peak</i>	<i>Off-peak</i>
Eggborough	Z8	5.4%	32.8%	-85.0%	-80.5%
Fiddlers Ferry	Z9	53.7%	36.0%	25.6%	99.9%
West Burton	Z10	56.3%	36.3%	20.6%	162.8%
Cottam	Z10	39.4%	53.0%	-17.4%	-37.3%
Ironbridge	Z11	12.4%	11.4%	-5.5%	70.2%
Ratcliffe	Z11	31.9%	46.0%	-32.1%	-28.5%
Rugeley	Z11	26.2%	56.5%	-52.3%	-55.8%
Tilbury	Z15	25.7%	27.1%	-9.9%	4.9%
Aberthaw	Z15	11.9%	41.0%	-69.8%	-72.7%
Aggregate		31.0%	39.0%	-24.4%	-11.7%

Source: Frontier based on NGET data

This analysis shows some plants for which Plexos models load factor well, and others where there is significant modelling error. However, the implications of these modelling issues for constraints may not be that marked, as a result of the locational clustering of many of the plants in an area where transmission constraints are not severe.

Table 12 shows the comparison of modelled and actual unconstrained load factors for a further nine randomly selected gas plants. That table shows that, with a couple of exceptions, the model captures the plants' FPNs reasonably accurately.

Table 12. Plexos performance with gas plants – Unconstrained schedule

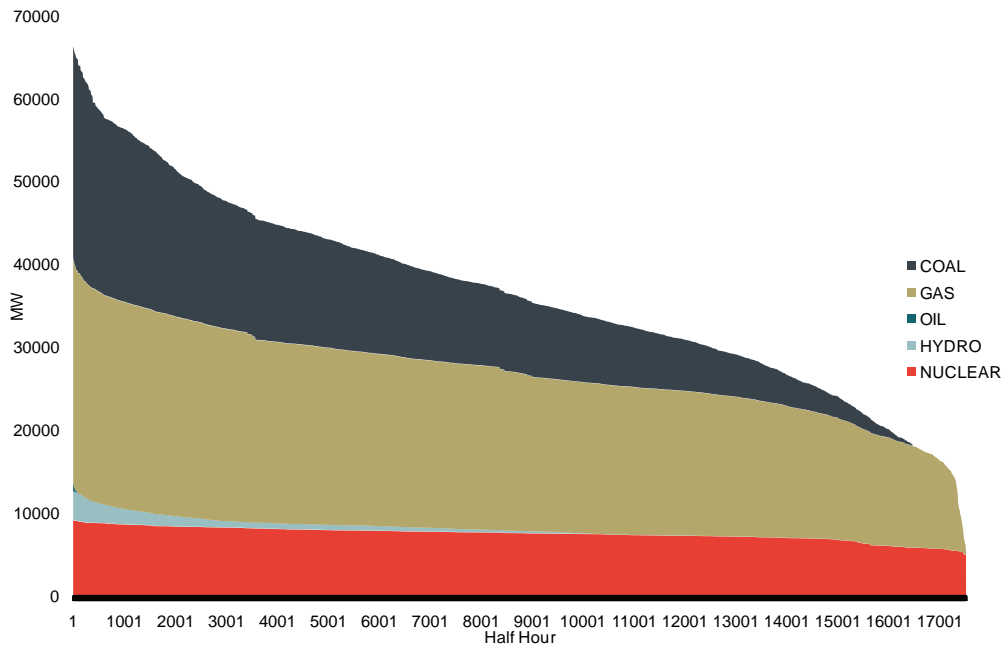
	SYS Zone	Load factors		Net modelling error	
		<i>Plexos</i>	<i>FPN</i>	<i>Peak</i>	<i>Off-peak</i>
Teesside	Z7	39.6%	51.8%	-1.7%	-54.2%
Deeside	Z9	70.8%	76.5%	1.8%	-18.3%
Corby	Z12	41.7%	44.5%	8.4%	-35.5%
Baglan Bay	Z13	39.5%	42.5%	-6.6%	-7.6%
Barry	Z13	67.2%	43.6%	37.7%	79.7%
Coryton	Z15	93.0%	82.3%	5.5%	21.8%
Medway	Z15	55.9%	62.6%	-4.8%	-16.8%
Shoreham	Z16	83.9%	80.4%	3.1%	5.8%
Langage	Z17	19.4%	28.4%	-33.9%	-29.6%
Aggregate		51.8%	55.8%	-0.5%	-15.3%

Source: Frontier based on NGET data

At the overall system level, the model also underestimates hydro output (both reservoir and pumped storage). This is probably due to the complexity of hydro generation behaviour, which is difficult to capture. Finally, the model captures nuclear running patterns accurately.

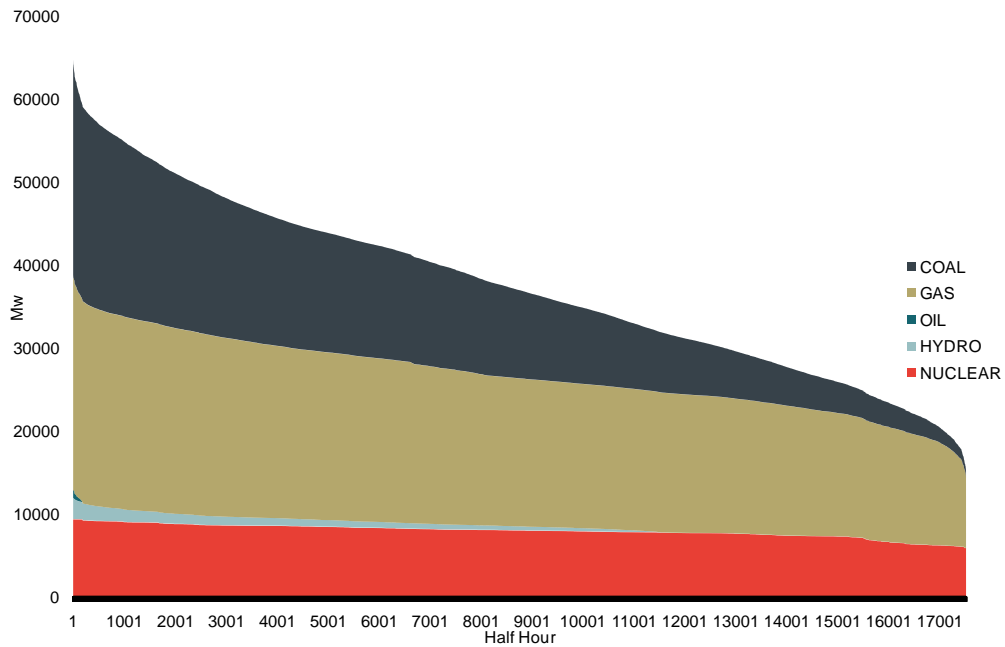
Figure 7 and Figure 8 compare the annual load duration curves for the Plexos simulation and the actual FPN for the unconstrained schedule. Figure 9 and Figure 10 provide the same comparison for the constrained schedule. Overall, the chart shows that Plexos simulates the behaviour of the entire system reasonably well.

Figure 7. Plexos unconstrained schedule - load duration curves by technology



Source: Frontier, based on Plexos modelling results and NGET data

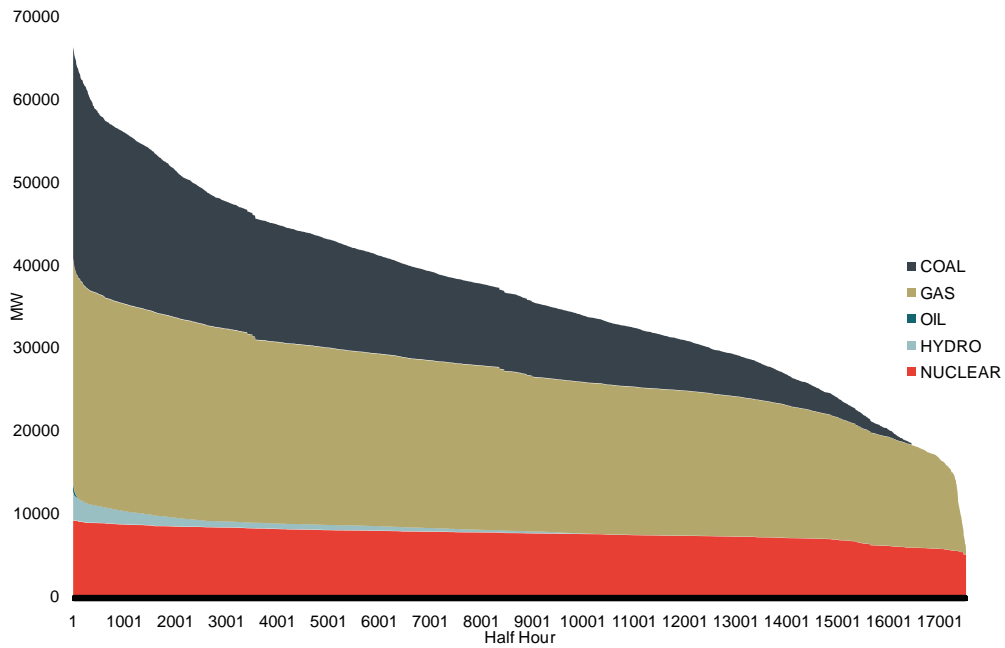
Figure 8. FPN unconstrained schedule - load duration curves by technology



Source: Frontier, based on Plexos modelling results and NGET data

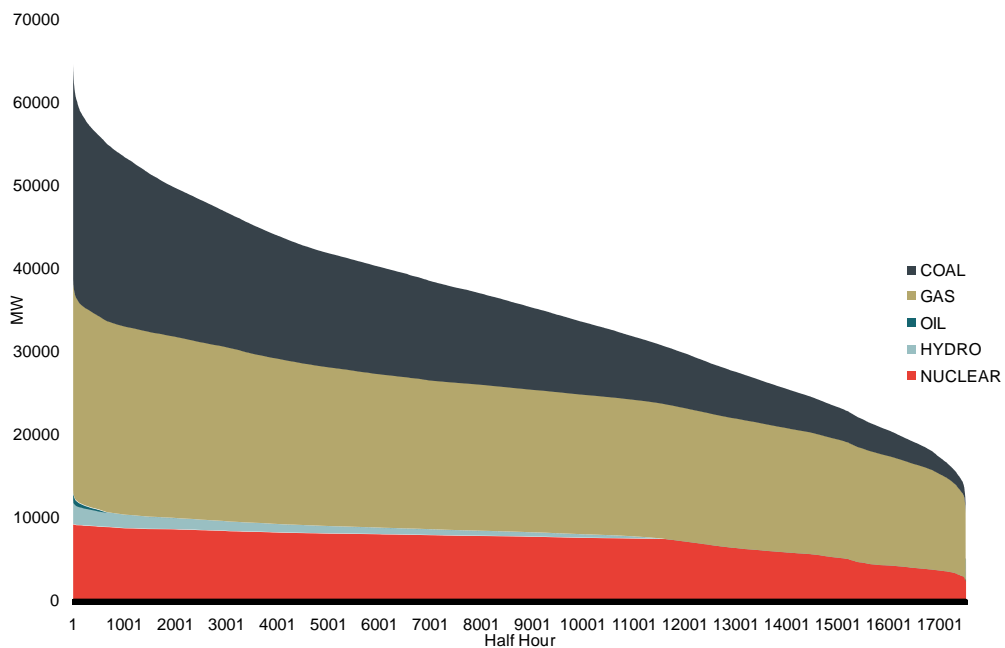
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Figure 9. Plexos constrained schedule - load duration curves by technology



Source: Frontier, based on Plexos modelling results and NGET data

Figure 10. Metered constrained schedule - load duration curves by technology



Source: Frontier, based on Plexos modelling results and NGET data

7.1.4 Constraint costs

Based on the ex post pricing approach described in section 6, NGET has run the model to estimate outturn constraint costs for the year 2009/10.

NGET told us that actual costs (excluding headroom) were equal to about £128m. This total is the combined outcome of constraint management actions undertaken via the Balancing Mechanism and contractual arrangements which NGET entered with specific generators.

To compare the results of the model with the actual constraint management cost incurred in 2009/10, NGET ran the model including the impact of all contracts in place. These included a volume cap on Longannet, intertrip arrangements and a cap on Peterhead's MEL. NGET obtained a modelled cost of £74m. However, this value refers exclusively to the cost of resolving the remaining constraints via the Balancing Mechanism. In other words, while it does include the impact of existing contracts on constraints, it does not include their cost.

To obtain a value that can be compared with NGET's actual 2009/10 expenditure, the contract costs need to be added to the modelling result. Based on information that NGET provided, the cost for contracts in 2009/10 was £27m. This implies a "modelled" constraint cost of £101m. If compared with NGET's actual expenditure of £128m, this result suggests an overall modelling error of about -21%.

7.1.5 Conclusions

We have reviewed performance of the constrained model by comparing its output for both the unconstrained and constrained schedule for 2009/10 to actual volume data for the same period. We have compared the unconstrained schedule to submitted FPN and the constrained schedule to actual metered output.

Overall, the model appears to be able to simulate key generators' running patterns relatively well. The model's accuracy is similar for both the unconstrained and the constrained schedule.

We note that the model's performance is slightly uneven with regards to some generators, especially those with more volatile running patterns such as Dinorwig. We discussed these results with NGET and reviewed intermediate calibrations. We believe that, given the characteristics of these plants, further refinements to the calibration may lead only to marginal improvements.

In terms of the modelled value of constrained cost, the results of the backcasting analysis for the period 2009/10 show that the BM cost calculated by Plexos is lower than the actual cost that NGET incurred in the same period. However, we note that the actual modelling outcome for 2009/10 depends on the specific conditions that were in place in that period. Therefore, we believe that, going

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forward, it would be appropriate to apply a discount factor to the results of the model, calculated using the methodology discussed in the previous chapter. However, given the modelled underestimate of constraint costs, we would also recommend that the performance of the model is monitored on an ongoing basis to ensure that the application of a discount factor does not set unrealistic targets for NGET.

7.2 Headroom replacement cost model

As discussed above, the headroom replacement cost model that NGET has proposed is an econometric model. To review it, we have applied the same approach we used to assess the econometric analysis underpinning the energy model. Specifically, we have assessed:

- the quality of regression relationship as indicated by the statistical results reported; and
- the predictive power of the model based on comparison with the actual values for the same period (the fit) and by using regression coefficient estimates from a shorter period to forecast known results from the end of the period to the present.

In reviewing the statistical results for the different models, we have considered a number of different attributes of the relationship. Table 13 lists these attributes and explains their meaning.

Table 13. Attributes used to describe the regression models

Attribute	What it means and values used in assessment
Adjusted R²	This measures the % of variance explained by the model – no specific thresholds, although the higher the better. We have given 1 star to R-squared below 50%, 2 stars if below 75% but above 50% and 3 stars if above 75%.
F-test	They measure the significance of each individual coefficient – using the same threshold as F-test below
p-values of coefficients	This assesses the overall significance of the model specification – threshold values are 0.05 (for 95% confidence, 1 star), 0.01 (for 99% confidence, 2 stars) or 0.001 (for 99.9% confidence, 3 stars).

Table 14 below set out the key diagnostic statistics for the regression model. The overall statistics indicate that the model explains a large proportion of the variance, as indicated by the high R² statistic. The specification of the model, as represented by the F statistic, has a high degree of statistical significance.

Table 14. Headroom replacement cost model – diagnostic statistics

Statistic	Value	Assessment
Adjusted R-squared	85.6%	***
F-statistic	~0	***

Source: Frontier based on results provided by NGET

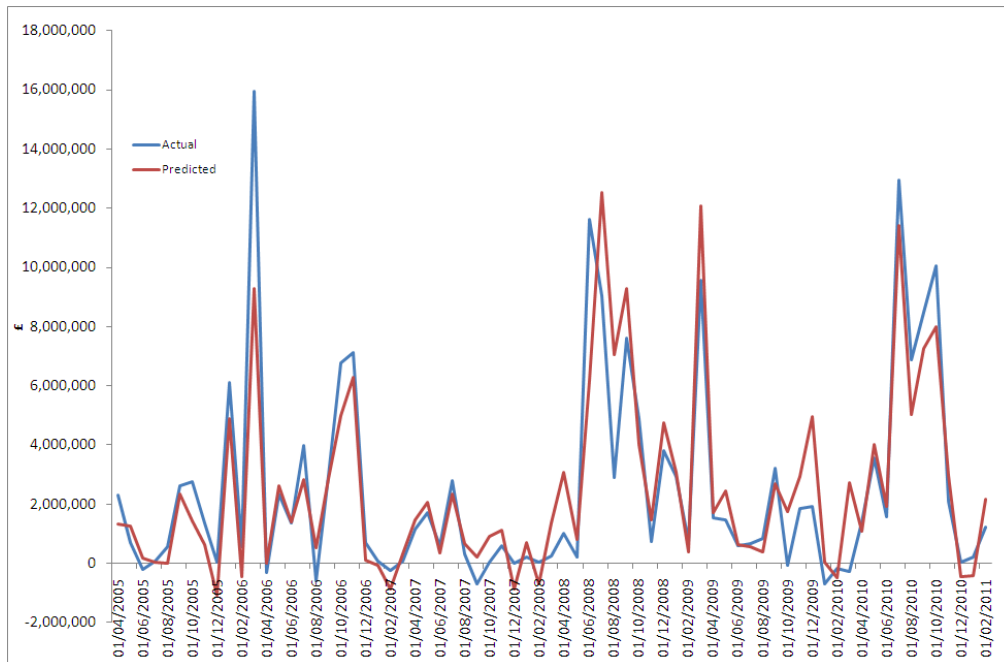
Of the parameters included in the model, three are statistically significant as shown in Table 15. However, one of the intercept seasonal dummy variables is not significant. This may be due to the fact that the two seasonal dummies complement each other, thus leading to some correlation between them. This notwithstanding, as the model specification has no constant, we believe it is appropriate to include both dummy variables.

Table 15. Headroom replacement cost model – parameter significance

Parameter	Sign	p-value	Signif.
Summer	-ve	0.826	
Winter	-ve	0.012	*
Summer * CMM_MWH * Margin_Cash_Price	+ve	~0	***
Winter * CMM_MWH * Margin_Cash_Price	+ve	~0	***

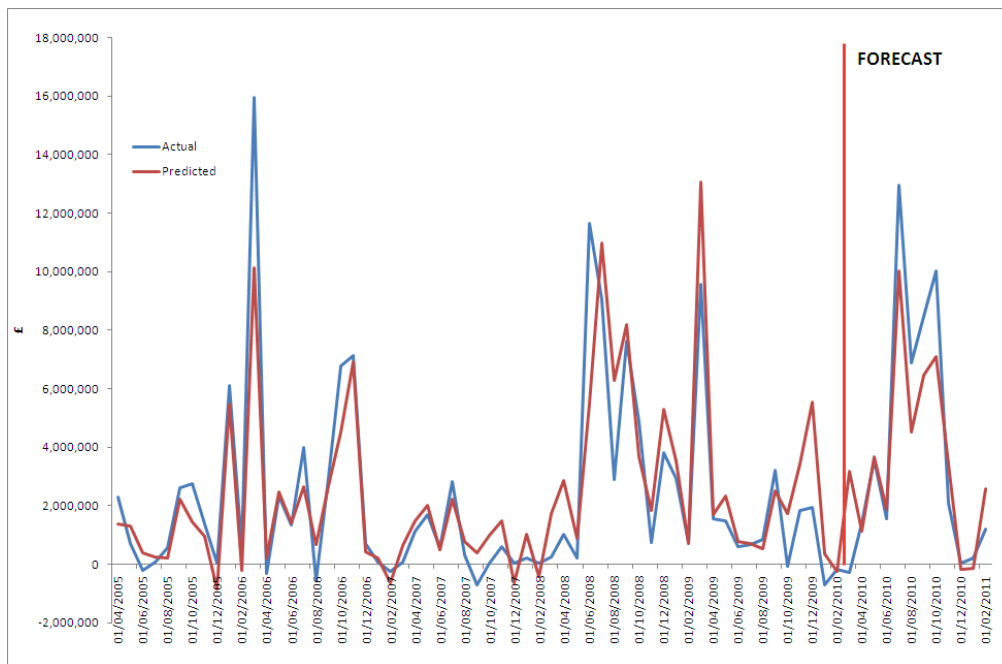
Source: Frontier based on results provided by NGET

A graphical view of the explanatory power of the model can be obtained by plotting the modelled and actual values for the whole period. The results are shown in Figure 11, which covers the period between April 2005 and February 2011 inclusive. As already suggested by the R-square statistic, the quality of fit is good. The model appears to be able to track the actual values accurately, matching the peaks and trough of the historic series.

Figure 11. Headroom replacement cost model – Quality of fit

Source: Frontier using NGET data – model estimated using data from April 2005 to February 2011

We have also assessed the forecasting power of the model by looking at the results of the regression when estimated over a shorter period (April 2005 to March 2009) and then forecasting the headroom replacement costs over the remaining period for comparison with the actual values recorded by NGET. Figure 12 shows the forecasting performance of the model remains good. During the forecasting period, the model continues to track the actual series accurately.

Figure 12. Headroom replacement cost model – forecasting power from March 2010

Source: Frontier using NGET data – model estimated using data from 2005 to 2009

Finally, we have also tested the forecasting power of the model using different estimation and forecasting periods, as shown in Table 16. The table shows the average monthly error as a percentage of the average monthly actual values. These results show that the model performance is better for the first year than for the second one. In particular, the 12-month ahead forecast show a small average monthly error. To use all the historic data available for the 2005-09 model estimation, we have also calculated a 14-month ahead forecast, up to February 2010. We note that in this case the model's error is at its lowest.

The average monthly error is larger, in percentage terms, for the 18-month and 24-month ahead forecasts. We note however that these results have been obtained using a model estimated on a shorter sample (up to March 2008), which does not include more recent variations in headroom replacement costs, specifically the sharp increases in costs in the Summers of 2008 and 2010.

Table 16. Headroom replacement cost model – forecasting power

Months ahead	Average monthly error (£m)	Average monthly error (as % of monthly actuals)	Total annualised error (£m)	Model used
6 months	-£0.43m	-12.9%	£5.67m	2005-09
12 months	-£0.37m	-9.4%	£4.53m	2005-09
14 months	-£0.25m	-7.5%	£3.04m	2005-09
18 months	£1.23m	41.1%	£14.8m	2005-08
24 months	£1.26m	44.0%	£15.1m	2005-08

Source: Frontier based on results provided by NGET.

8 Summary

In this section we summarise the findings of our review as well as our recommendations. Following the structure of this report, we consider:

- the inputs to the Plexos BSIS model, addressing separately the modelling approach of the unconstrained schedule, the specification of the transmission network and the constraint pricing methodology; and
- our review of the model outputs, considering separately the modelling of direct constraint costs and the treatment of headroom replacement costs.

8.1 Model inputs

In this section, we summarise our findings regarding the inputs to the Plexos BSIS model.

8.1.1 Unconstrained schedule

In general, we believe that the approach adopted by NGET in relation to deriving an unconstrained schedule is appropriate for the purposes of estimating constraints. In particular, we believe the proposed *ex post* treatment of fuel costs and wind is appropriate since these inputs are volatile, difficult to forecast, and beyond NGET's control.

Generation outages are also beyond NGET's control, but their impact should on average be easier to forecast and hence it may be reasonable to model their input *ex ante* on a stochastic basis. Provided the industry benchmarks are reasonably calibrated to historic experience of outage rates for different technology types, this approach appears reasonable.

However, we note that for major long lasting outages, this approach may create the potential for windfall gains and losses (e.g. were there to be a prolonged outage on a plant which had a significant impact on constraint costs).

We also consider some further potential refinements to the approach, specifically:

- **Refresh of generator outage plans.** Our analysis would appear to indicate that basing outage plans on two year ahead data given current levels of generator forecasting accuracy may well result in material windfall gains and losses for NGET relative to a refresh of the outage forecast at the year ahead stage.
- **Interconnector flow.** In the current modelling approach, modelled flows on the interconnectors will occur only if the price differential between the importing and the exporting market is larger than a pre-

determined wheeling charge. NGET has calibrated the model by adjusting the wheeling charge to match annual historic interconnector flows. At the moment, the wheeling charge is the main parameter that is modified to calibrate the interconnector flows in the model. While this may be appropriate given explicit auctions on the interconnectors, in due course NGET may wish to consider the implications of implicit auctions. Specifically, the impact of implicit auctions may be worth considering after the commissioning of BritNed, especially if it is found to have a material impact on interconnector utilisation and constraints. However, we note that prior to implicit auctions being implemented, there is little that can be achieved in this area.

8.1.2 Transmission network

The overall approach taken by NGET to defining a simplified zonal model of the transmission system is relatively standard. NGET has an incentive to ensure that the zonal definition is not too aggregated, as this would result in a target cost for constraints which was too low.

There are a number of other areas in relation to the definition of boundary constraints where NGET could use subjective judgements to attempt to bias the target cost upwards. We highlight three potential issues with NGET's approach which are worth further consideration by Ofgem.

- **Refresh of transmission capacities.** Relative to generation outages, NGET should have greater control over the timing of transmission outages, both through internal processes in relation to its England & Wales Transmission Owner business and through the effective operation of the SO TO Code in relation to the Scottish Transmission networks. To the effect that the SO TO Code processes do not work as effectively as they could, an incentive relating to transmission outages over the long term may incentivise NGET to bring forward proposed modifications to the Code to improve its effectiveness. If boundary capacities are refreshed for the second year of the scheme, the incentive for NGET to reschedule outages to minimise the impact on constraint costs would be reduced or removed. This is because NGET's target for constraint cost would take into account the updated schedule of outages reflecting any rescheduling undertaken between the year ahead and two year ahead stage. Provided both Ofgem and NGET agree that the information on which NGET is estimating transmission boundaries in the second year of the scheme is sufficiently robust, we therefore believe there could be material benefits to setting transmission boundaries for both years of the scheme at the outset (i.e. avoiding the second year refresh).
- **Choice of representative outages.** For reasons of practicality, NGET is required to identify both representative outages and representative weeks

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within outages in order to define boundary capacities. However, there is inevitably a degree of subjectivity in:

- choosing the outage which best represents the likely level of outage boundary capacity for the year in question; and
- estimating the boundary capacity for any given outage.

To address both issues, we believe it will be important for Ofgem to ensure there is sufficient ex post monitoring in place (along with a clear process in terms of potential penalties) to allow any significant bias in the exercise of NGET's judgement to be identified. While other more sophisticated solutions may be identified, we believe that at this stage, for the first two year scheme, an ex post monitoring process is likely to be the most practical approach.

8.1.3 Constraint pricing

The results of NGET's econometric modelling in Phase 2 suggest that the ex ante approach to setting prices used to evaluate congestion as suggested in Phase 1 should not be adopted given the high degree of apparent unpredictability of BM bids and offers from generating units and the low incentive power on NGET which would need to accompany it.

Instead, we recommend that an ex post pricing regime is adopted. Although this is second best in many respects it appears the only viable approach given the inherent unpredictability of BM bids and offers.

However, the ex post pricing regime requires a number of "fixes". We recommend the following:

- rules are used to formulate proxy prices for plant that are on unexpected outages;
- a discount factor is applied to the overall value of congestion estimated by Plexos on the basis of ex post prices to take account of NGET contracting; and
- in the short term, Ofgem may consider prohibiting NGET from entering into contracts containing price terms relating to congestion; but
- in the longer term, the introduction of a counterfactual rule in relation to BM prices for contracted generators should be considered. This might be either at the behest of Ofgem or NGET if either believes that allowing contracts might introduce material efficiencies.

8.2 Review of model outputs

In this section we summarise the conclusions of our review of model outputs, first discussing the results of the Plexos BSIS direct constraint model and then turning to the headroom replacement cost model.

8.2.1 Plexos BSIS constraint model

We have reviewed performance of the constrained model by comparing its output for both the unconstrained and constrained schedule for 2009/10 to actual volume data for the same period. We have compared the unconstrained schedule to submitted FPN and the constrained schedule to actual metered output.

Overall, the model appears to be able to simulate key generators' running patterns relatively well. The model's accuracy is similar for both the unconstrained and the constrained schedule.

We note that the model's performance is slightly uneven with regards to some generators, especially those with more volatile running patterns such as Dinorwig. We discussed these results with NGET and reviewed intermediate calibrations. We believe that, given the characteristics of these plants, further refinements to the calibration may lead only to marginal improvements.

In terms of the modelled value of constrained cost, the results of the backcasting analysis for the period 2009/10 show that the BM cost calculated by Plexos is lower than the actual cost that NGET incurred in the same period. However, we note that the actual modelling outcome for 2009/10 depends on the specific conditions that were in place in that period. Therefore, we believe that, going forward, it would be appropriate to apply a discount factor to the results of the model. We would also recommend that the performance of the model is monitored on an ongoing basis to ensure that the application of a discount factor does not set unrealistic targets for NGET.

8.2.2 Headroom replacement cost model

The headroom replacement cost model that NGET has proposed is an econometric model. To review it, we have applied the same approach we used to assess the econometric analysis underpinning the energy model. Specifically, we have assessed:

- the quality of regression relationship as indicated by the statistical results reported; and
- the predictive power of the model based on comparison with the actual values for the same period (the fit) and by using regression coefficient estimates from a shorter period to forecast known results from the end of the period to the present.

Summary

The overall diagnostic statistics indicate that the model explains a large proportion of the variance, as indicated by the high R^2 statistic. The specification of the model, as represented by the F statistic, has a high degree of statistical significance. Moreover, the model appears to be able to track the actual values accurately, matching the peaks and trough of the historic series.

We have also assessed the forecasting power of the model by looking at the results of the regression when estimated over a shorter period (April 2005 to March 2009) and then forecasting the headroom replacement costs over the remaining period for comparison with the actual values recorded by NGET. We have also tested the forecasting power of the model using different estimation and forecasting periods.

We have found that the model performance is good, and, as expected, it is better for the first year than for the second one. In particular, the 12-month ahead forecast show a small average monthly error. To use all the historic data available for the 2005-09 model estimation, we have also calculated a 14-month ahead forecast, up to February 2010. We note that in this case the model's error is at its lowest.

The average monthly error is larger, in percentage terms, for the 18-month and 24-month ahead forecasts. We note however that these results have been obtained using a model estimated on a shorter sample (up to March 2008), which does not include more recent variations in headroom replacement costs, specifically the sharp increases in costs in the Summers of 2008 and 2010.

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