SINCLAIR KNIGHT MERZ

Technical Evaluation of Transmission Network Reinforcement Expenditure Proposals by Licensees in Great Britain

DRAFT REPORT FOR PUBLIC RELEASE

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1. Executive Summary

1.1 Introduction

The Office of Gas and Electricity Markets (Ofgem) appointed Sinclair Knight Merz Ltd (SKM) to assist in the technical evaluation of proposed transmission reinforcement expenditure proposals by the Transmission Licensees[1] (TLs) in Great Britain to accommodate the expected additional renewable generation capacity in Scotland by 2009/10.

The TLs have produced expenditure forecasts totalling £804 million for transmission network reinforcements associated with the connection of circa 2,900 MW of renewables in Scotland, mostly wind sourced, and 700 MW in North West England. The following table summarises the expenditure forecasts by main project and TL with the geographic locations of all of the proposed works being presented in Figure 1 below.

Table 1 TLs reinforcement expenditure proposals (£ '000s)

	Summary by reinforcement	SHETL	SPTL	NGC	Total
1	Beauly-Denny related	254,270	77,658	0	331,928
2	England/Scotland Interconnectors	0	43,430	108,457	151,887
3	North East Ring	0	0	139,654	139,654
4	Heysham area reinforcements	0	0	65,158	65,158
5	Kendoon area connection infrastructure	0	90,049	0	90,049
6	Sloy area reinforcements (Stage 2)	7,100	13,863	0	20,963
7	Beauly to islands (Shetland/Orkney/W. Isles) [See Note]	4,137	0	0	4,137
8	Beauly / Keith reinforcement [See note]	282	0	0	282
	Total	265,789	225,000	313,269	804,058

Note: Initial Engineering and design works

We have reviewed the capital cost estimates provided by the companies, both for the overall scheme costs and also any early investigatory design and engineering works necessary to better determine the feasibility and costs of a project and generally we consider the budgetary costs figures submitted as reasonable at this stage. We also consider that prudent provisions have been included, given the uncertainties on the scope of works prior to undertaking detailed engineering and design works although specific issues with some of the indicated provisions are highlighted in the main body of the report.

[1] The Transmission Licensees in Great Britain are: Scottish Hydro Electric Transmission Ltd (SHETL) in the north of Scotland, SP Transmission Ltd (SPTL) in the south of Scotland and National Grid Company (NGC) in England and Wales.

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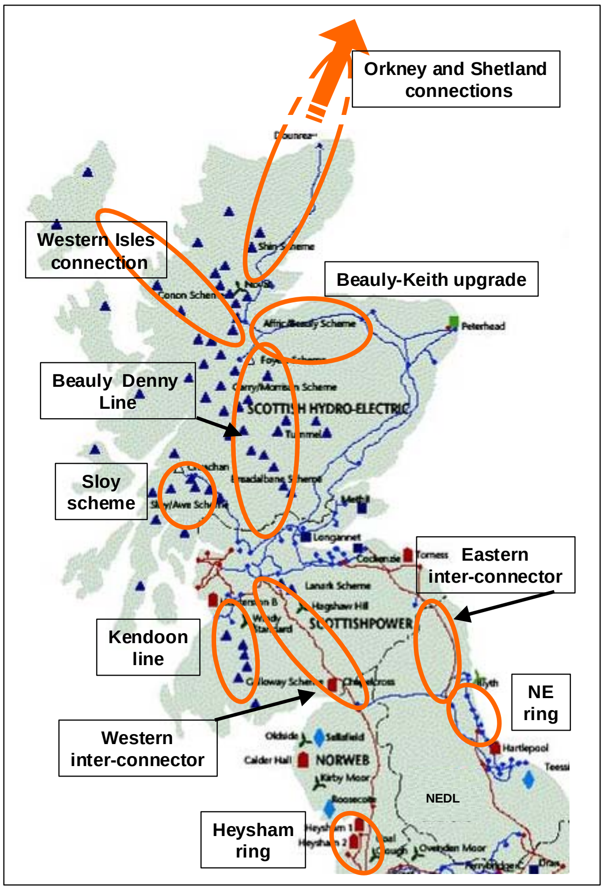
Figure 1 Geographic disposition of proposed RETS work



1.2 Connection activity

The connection of new renewable capacity in Scotland and elsewhere is the main driver behind the proposed transmission network reinforcements identified by the TLs. The renewable generation connections relevant to this work essentially include all renewables likely to connect within the interconnected parts of SHETL and SPTL licence areas and also, where relevant certain proposed generation connections to NGC's area. Overall GB renewable connections also need to be taken into account as total renewable generation connections within GB (if forecast to approach renewable targets) will tend to reduce the likelihood of individual connection applications proceeding through to commissioning.

The "High Wind" scenario of the 2000 DTI study indicated a wind installed capacity in Great Britain of 6.2 GW by 2010. Based on this study and geographical distribution estimates of wind by the BWEA, the RETS study created two scenarios, constrained and unconstrained, to take into account constraints in the distribution networks. For the unconstrained scenario the results indicate

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a split of 3.9 GW and 2.3 GW between Scotland and England and Wales respectively. In the case of the constrained scenario, the split is 1.7 GW and 4.5 GW between Scotland and England and Wales respectively.

During the course of the ongoing Distribution Price Control Review forecasts of Distributed Generation (DG) were also prepared by each of the DNOs and these are forecasting an increase of about 11 to 12 GW of embedded generation during the period through to 2009/10. These forecasts have been reviewed by Ofgem and their appointed consultants and the reasonableness of the forecasts confirmed. These forecasts indicates a total of 13 to 14 GW of embedded generation by about 2010, including about 2800 MW embedded within the Scottish distribution networks. It should be noted that the totals are inclusive of all embedded generation, including conventional generation, CHP as well as wind and other renewable generation. However, the"non-renewable/non-CHP" component is forecast to total only about 600 MW, indicating a forecast total of embedded renewables of more than 12 to 13 GW.

The analysis of connection activity within Scotland indicates around 4 GW of wind connecting in Scotland by 2010, which includes the 2.8 GW of embedded generation referenced above, hence about 1.2 GW of TL connections are indicated. This total capacity will be split roughly evenly between the north and south of the country with significant, presently "transmission constrained" generation, wishing to connect in the far north. In addition to these categories, there is also a significant volume of connection offers yet to be accepted and also a significant volume of connections at the feasibility stage. The 4 GW figure does not include connections in the Western Isles and also Orkney and Shetland, all of which will require costly submarine cable links to connect, and are currently at an investigatory stage with respect to determining the feasibility, consents and likely associated capital costs of such works.

NGC have also provided information with respect to wind farm connection in both the northern and southern area of England and Wales. Taken together these indicate 2 GW of contracted generation, with a further 500 MW of projects with DTI funding considered likely to proceed to connection. If connections in the "offer process" are included, the total volume of potential connections totals about 4 GW by 2010. It should be noted that the greater part of the NGC projections are associated with "offshore" wind farms. Taken overall, the DG and TL forecasts which total more than 16 to 17 GW are ahead of government targets for the same period, and in the light of underperformance to date with renewable connections, indicates a considerable degree of optimism. As a consequence it is considered likely that some of the higher cost, offshore and "island" wind farm projects may be shelved or delayed.

There is a perception that planning issues in Scotland are less obstructive than in England and Wales. Also, a significant proportion of the wind generation is Scotland, almost 3 GW is being developed by SHETL and SP Generation, with other major players also significantly involved. In contrast the DNO DG capacity will be largely made up of smaller developments with a more diverse developer base and as a consequence may be less likely to be developed at the same rate. On balance therefore we are satisfied that, somewhat above the DTI and BWEA forecasts, a projection of about 4 GW of wind generation by 2010 within Scotland is reasonable and can be used as a basis for assessing the shorter term network reinforcement issues. In the case of connections to the NGC transmission network, essentially offshore wind farm connections at Heysham which could drive some of the proposed transmission reinforcement, we are of the view that there is significant uncertainty on the likely outturn volumes and timing of these connections.

1.3 Transmission planning standards and wind intermittency

The TLs have an obligation to plan and reinforce the transmission network in accordance with Planning and Operational standards that are embodied in their license. These security standards establish the technical requirements that the network should meet to secure demand in case of specific network outages or contingencies.

The security standards are based on cost-benefit studies undertaken at the time of central planning that balanced the cost of additional security brought by network reinforcement against avoided unreliability costs derived from increased outages, weighted by their likelihood, if the network was not reinforced. The findings of these “probabilistic” cost-benefit studies were expressed in form of a set of “deterministic” rules that could be applied in a consistent way by network planners and system operators. There are some differences between the standards applicable to NGC, in England and Wales, and SHETL and SPTL in Scotland as well as the voltage levels regarded as transmission, however the security criteria can broadly be summarised as that the network must be secured at all times for the concurrent or overlapping outage of two network elements.

Network security is normally most stressed at times of peak demand, when maximum generation capacity is needed to meet demand. The network is planned such that demand is secured for the contingencies prescribed in the security standards assuming a likely output from generators. The generation output that can be expected at times of peak demand, or capacity credit, is a key consideration in any network planning security assessment. The standards define the proportion (or scaling) of the maximum generation capacity that can be assumed at times of peak demand for network planning purposes for each major type of conventional generator, e.g. thermal or hydro.

These generation “scaling factors” were based on generation planning assessments that took into account the generation reliability and the likelihood of demand exceeding generation at times of peak demand, also known as Loss of Load Expectation (LOLE). At the time of these assessments, intermittent generation sources such as wind, were not a feasible option for the bulk supply of the system. The capacity credit factors indicated in the security standards for conventional dispatchable generation, typically around 80 to 83 percent, are not applicable for intermittent generation sources such as wind as the reliability of such output levels at times of peak demand is very low. It is therefore necessary to establish appropriate “scaling factors” for wind generation.

This issue has been partly taken on board by the TLs, to the extent that they have undertaken and also commissioned studies which essentially conclude that the correlation between the outputs of wind farms in Scotland is expected to be around 60 percent. The TLs have then considered that the 83 percent used in the RETS study, which is consistent with the assumptions in the planning standards for conventional generation, was not applicable to wind generation and have used in their most recent assessments a 60 percent figure which they consider an appropriate value to use as a “scaling factor” for wind generation for the purposes of network planning. However this value is not necessarily the wind generation output which may be reasonably expected to occur at times of peak demand and hence may not be an appropriate driver for network reinforcement. Given the potential for significant increase in wind generation capacity in the future it will be important for transmission licensees, Ofgem and other industry participants to consider how best to reach a considered view on these matters and any necessary changes to the security standards. As a contribution to this debate SKM has undertaken, as part of this study, an initial assessment of the possible implications for security standards.

Using data applicable to Scotland, we have correlated wind farms output with network demand. Our findings indicate that when the demand is between 85% and 100% of the peak, for half of the time the wind farms output is only about 25 percent of installed wind capacity or below (23% for the peak demand). In order to take into account the effect of generator availability we have further studied the capacity credit factor that is applicable to wind generation on the GB system using a LOLE approach with data for the complete GB generation/demand system. Our findings indicate that the appropriate scaling factor for wind generation corresponds to only about 20 percent of the total installed capacity. This observation is consistent with reported findings from similar assessments undertaken internationally.

In addition to the above security considerations, the transmission network should not unduly restrict power outputs from generators generally. If the network restricts the output of a generator then the generator is said to be “constrained” and the “constraint costs” can be evaluated and compared to the cost of the network reinforcement that would allow increased output from the constrained generation. Reinforcement of the transmission network to remove such constraints is consistent with the security standards, providing that it is subject to appropriate economic tests. In the case of wind generations, such analysis needs to takes into account the daily and seasonal variability of wind, the equivalent variations in electricity demand and the inevitable complementary variation in conventional generation output.

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1.4 Constrained generation costs

The penalty for not reinforcing the transmission system with increased renewable generation capacity is primarily the cost of modifying the generation dispatch on both sides of the network constraint, namely reducing generation output on one side of the constraint and increasing the output of other generation to the other side of the network constraint. It can be assumed that, in a correctly functioning electricity market, the generation set to meet demand prior to the network constraint was the most economic and hence the modification of the generation dispatch would result in increased generation costs.

Network reinforcement is justified when the savings in constrained generation costs relieved by the reinforcement, when capitalised, equal the cost of the proposed reinforcement. The savings in constraints should therefore consider the difference in constraints costs before and after the reinforcement, noting that under some operational conditions, a degree of constraints may still remain after the reinforcement.

In economic terms, constraint generation costs are generally made up of two components, a variable component, associated with the costs of fuel (including transportation etc.) and O&M, and a fixed component associated with the cost of providing replacement capacity.

The main variable cost component of the economic penalty associated with constrained generation is the increase in generation costs between the generator(s) constrained and the generators(s) that have to increase its output to the other side of the constraints in order to maintain the generation-demand balance. In the case of generating units of the same fuel and similar technology (e.g. old coal vs. old coal) these costs will mainly be attributable to the difference in efficiency and, based on published generation costs including recent reports to the DTI and Ofgem, this would typically amount to values of only about £1/MWh for the constrained energy volumes obtained in the cost-benefit studies. In the case of having to constrain higher efficiency units, for example constraining CCGT in Scotland and replacing this by old coal stations in England and Wales, these variable costs, based on published typical generation costs would amount to about £5/MWh.

A further economic penalty associated with generation constraint arises when at times of peak demand the system does not have access to generation capacity that could have been expected to assist in securing demand. As a result, it then becomes necessary to provide additional capacity to the other side of the constraint. Based on the “capacity credit” applicable for wind generation of about 20% discussed above, and the application of the security standards for network interconnectors, our studies indicate that capacity costs will only be applicable when the installed wind generation capacity in Scotland reach about 6000 MW.

In the case of constraining wind it has been considered appropriate to use a value of £45/MWh which includes the ROC buy-out price of about £30/MWh price and fuel savings for conventional fossil fuel generation of circa £15/MWh. It clearly follows that, from an economic point of view, it will always be cheaper to constrain conventional generation rather that wind generation.

The quantification of benefits from network reinforcement through the valuation of savings in constrained energy and losses can be undertaken using either economic (as outlined above) or market based valuation of constrained energy prices. Under a competitive generation scenario on both sides of a given network constraint, the market prices will tend towards the economic prices that represent the underlying generation production costs. Nevertheless, market forces may be such that generators tend to recover the costs of capacity across all their generation output, including when output increases because of a constraint. Prices under NETA for energy plus capacity have been around £25 MWh, but constraining a conventional plant off the system saves around £15 MWh giving a net cost of £10 MWh In undertaking the costs-benefit analysis of the proposed schemes involving the constraining on and off of conventional plant the TLs have valued the constraints at £25 MWh, essentially using prices consistent with constrained on costs of £40/MWh less £15 MWh for the fuel savings from constraining conventional plant off.

1.5 Approach

The general approach adopted in this evaluation is to review the costs and benefits of each of the reinforcements proposed by the TLs on its own in order to ensure that each reinforcement scheme is justified technically and economically on its own merits. It is also recognized that some of the reinforcement schemes proposed involve reinforcements in contiguous TL License areas.

In all cases the justification for a network reinforcement has been by reference to TL security planning and operational standards with cost-benefit analysis based upon comparison of the costs associated with the project set against benefits largely associated with reductions in generation constraint volumes and values, coupled with savings in transmission losses and other network betterment issues, e.g. advanced asset replacement. In addition to estimating savings associated with each project, we have also assessed the risk, if any of stranded assets should the new generation not connect or else other actions, e.g. closures or significant changes in the operation of existing generation take place.

1.6 Summary of views on proposed expenditure

The following table summarises our view on the TLs proposed expenditure. This table briefly identifies the proposed reinforcements and associated capital costs, the costs seeking regulatory sanction, the wind capacity needed to connect to justify the reinforcements, the risk of stranded assets should this not occur, or some other action eventuates (e.g. existing station closures) and our value judgement.

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Table 2 Summary of recommendations

	Reinforcement	Estimate costs of complete works (£'000s)	Costs seeking regulatory sanction (£'000s)	Wind installed capacity that justifies project (MW)	Stranded Assets Risks	Views
1	Beauly-Denny	331,928	331,928	1,200 MW	Low	Justified on the basis of savings in constraints costs and losses
2	England/Scotland Interconnectors upgrade.	151,887	151,887	3700 MW to 5,000 MW (Note:4000 MW of wind expected by 2010)	Sensitive to constraint costs, project staging and operation of conventional stations in Scotland	Further assessment required before the project could be deemed justifed, at this stage, proceed with initial design and engineering works £3.3 million (£2.8 m NGC, £1.5 m SPTL). Easier to be justified on a cost-benefit basis if staged (West uprating followed by East reconductoring). Also should follow 1 above (Beauly-Denny)
3	North East Ring upgrade.	139,654	139,654	6,200 MW to 6,800 MW (Note: 4,000 MW of wind expected by 2010)	Sensitive to assumptions on the operation of conventional stations in Scotland	Unlikely to be justified at this stage, proceed only with initial design and engineering works and should follow 2 above (Beauly-Denny plus E/S interconnector).
4	Heysham area reinforcements	65,158	65,158	As for 2 & 3 above plus also 500 MW local wind farms (offshore)	High, also lower cost alternatives should be investigated	Lower cost alternative should be investigated. Should follow 2 above (Beauly-Denny plus E/S interconnector)
5	Kendoon area connection infrastructure	90,049	90,049	350 MW (228 MW accepted/construction)	Medium, also lower cost/risk alternative should be investigated	Lower cost alternative should be investigated but in any case reinforcement circuits required. Justified Initial design and engineering works £2.3m
6	Sloy area reinforcements	45,963	20,963 (Stage 2)	150 MW (currently 300 MW under construction/contract)	Low	Justified on the basis of accepted connection offers and associated constrained generation costs
7	Beauly to islands (Shetland/Orkney/ W.Isles)	625,000 (SKM estimate)	4,137 [Initial engineering]	Not applicable. Specific connection driven assets with costs recoverable from customer	N/A	Initial design and feasibility work should be underwritten by developer. Outline "business case" indicates in favour of Western Isles and against Orkney/Shetland
8	Beauly / Keith reinforcement	158,449	282 [Initial engineering]	Circa 5000 MW north of Beauly	N/A	Well ahead of need, recommended to review at a later date
	TOTAL	1,608,090	804,058			

2. Introduction

The Office of Gas and Electricity Markets (Ofgem) appointed Sinclair Knight Merz Ltd (SKM) to assist in the technical evaluation of proposed transmission reinforcement expenditure proposals by the Transmission Licensees[2] (TLs) in Great Britain to accommodate in excess of 2,000 MW of additional renewable generation capacity in Scotland.

2.1 Background

In order to meet the Kyoto agreements, the UK government has set an annual target for the proportion of electrical energy supplied from renewable sources for the period up to the 31st March 2027. This annual target gradually increases by 1% year on year, up to year 2010/11[3] when it reaches 10.4% and, at present remains constant thereafter although the government announced at the end of last year its intention to extend these targets to 15.4% by 2015/16[4]. These targets translate into a requirement of up to 10 GW of additional renewable generation capacity by 2010, depending on the type of generation, and up to 15 GW by 2015. It is expected that a significant proportion of this renewable generation capacity will be wind sourced and located in Scotland.

2.1.1 Renewable Obligation

In order to implement these targets, a financial penalty scheme was introduced by the Government through the Renewable Obligation Certificates[5] (ROCs) that annually requires suppliers to source a certain proportion of the supplied electrical energy from certified renewable generators or to pay a fixed charge per MWh for the proportion of energy below the target. The ROCs were implemented starting on April 2002 and are scheduled to continue until 31 March 2027. Suppliers can “buy out” their obligation at a set price that increases annually with the Retail Price Index. The buy-out price was initially set at £30/MWh for 2002/03[6] however ROCs associated renewable energy have recently been traded close to £50/MWh. This higher value is the result of the re-distribution of the

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[2] The Transmission Licensees in Great Britain are: Scottish Hydro-Electric Transmission (SHETL) in the north of Scotland, SP Transmission Ltd (SPTL) in the south of Scotland and National Grid Company (NGC) in England and Wales.

[3] The Energy White Paper, UK Government, February 2003. 2010/11 refers to tax year from April 2010 to March 2011

[4] http://www.gnn.gov.uk/environment/detail.asp?ReleaseID=101781

[5] In Scotland, Scottish Renewables Obligation Certificates (SROCs)

[6] £30.51/MWh in 2003/04

buy-out fund among ROC holders with the latest auctions indicating a value of £20/MWh for the redistribution component as a result of the shortfall of renewable generated energy compared to the annual targets.

The basis for the value indicated in the RO Order for the initial buy-out price of ROCs is unclear. In economic terms this value could have been expected to be representative of the “hidden” costs to the UK economy caused by conventional thermal generation in the form of its impact on the environment. These costs, present and future, are generally associated with increased global warming and blamed mainly on accumulated emissions of greenhouse gases, eg CO_2, and also other emissions. The buy-out value of the ROCs could then be interpreted as a proxy for the economic value that the society in Great Britain places on reducing the output from its conventional electricity generators, including the eventual decommissioning or replacement of part of its capacity. This type of economic analysis however is unlikely to have underpinned the buy-out value of ROCs due to the complexity in valuing the costs arising from the environmental impact of conventional electricity generation activities and the interdependencies with other industry sectors and even other countries.

A possible complementary interpretation of the buy-out price of ROCs is that it may represent the premium that consumers are willing to pay for the electrical energy generated from renewable sources albeit on the basis of it being a small proportion of the overall supply as indicated by the annual target. It should be noted that there are also ‘hidden’ additional costs as the penetration of intermittent renewable sources. However, a normally preferred possible interpretation of the buy-out price of the ROC is that it is simply a commercial incentive for renewable sources to improve its competitiveness in the marketplace against conventional fossil-fuel and other thermal generation. In this case, the fact that the ROC buy-out price is constant regardless of renewable generation source indicates a greater incentive to develop the “cheaper”, more developed renewable generation technologies (typically wind) rather than those using more “expensive” and less developed types e.g. tidal, photovoltaic etc

In this report the buy-out value of the ROCs will be used as a proxy for the “premium” economic value of renewable energy. The importance of the ROC buy-out value in the assessment of this report and its interpretation will become apparent in the economic studies presented later in this report.

As a direct consequence of the ROCs scheme and other activities by the Government to promote new renewable generation capacity, the Distribution Network Operators (DNOs) and the TLs, especially those in Scotland, have seen increasing interest from developers to connect renewable generators, particularly wind farms[7]. Dependent upon its geographic location, increasing levels of new renewable generation capacity may exhaust spare capacity existing in the transmission and distribution networks. It is clear that accommodating the ultimate levels of renewable generation connections implied by the Government targets in areas remote from demand centres may require significant network reinforcements in the existing transmission and distribution networks.

2.1.2 EU ETS and other legislation

In addition to the ROCs existing conventional power plants face limits in their carbon emission allowances resulting from the implementation of the EU Emissions Trading Scheme (EU ETS) due to start on January 1st 2005. The reduction values imposed on existing power plants is above the target levels for renewable source energy through a penalty on existing fossil-fuel stations to their emissions to the target level or to waive this requirement by purchasing an equivalent 'emission rights'. It is our understanding that the cost of these rights will be of similar or lower value than the ROC buyout prices.

Finally the Large Combustion Plant Directive (LCPD) will require power generation plant to meet more demanding emissions of SO_2 and NO_x by fitting Flue Gas Desulphuration equipment, use of cleaner fuels or reduce their running time to no more than 20,000 hours from 2008 to 2015.

These two environmental regulations will create added pressure to existing older fossil fuel fired power plant to consider their position in the market in the short/medium term and should be considered in the assessment of the benefits of reducing output from conventional thermal power stations to manage network constraints on wind generation that will be discussed later in this document.

2.1.3 TIWG Studies

In order to study the effects and requirements on the transmission networks, the Department of Trade and Industry (DTI) formed the Transmission Issues Working Group which included the three TLs in Great Britain.

This study, referred to as the RETS[8] hereafter, evaluated the impact of additional renewable generation in Scotland and identified reinforcements required in the transmission system of each of

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[7] It should be noted that 132 kV is regarded as transmission voltage in Scotland and therefore part of the TLs network of SHETL and SPTL whereas in England and Wales it is regarded as distribution voltage and is part of the DNOs networks. Larger renewable generation schemes tend to connect to higher voltage levels.

[8] Renewables Energy Transmission Study (RETS), Transmission Issues Working Group (TIWG) Final Report June 2003, http://www.dti.gov.uk/energy/renewables/technologies/transmission.shtml

the three TLs for 2 GW, 4GW and 6 GW of additional renewable capacity in Scotland. The RETS, although published in June 2003, was largely undertaken in 2002 and some broad assumptions had to be undertaken about the location of new renewable capacity and the nature of possible network reinforcement alternatives. Subsequent to the publication of this report a second study has been initiated by the TIWG, referred to as RETS2 hereafter, to study in greater detail the impact on the transmission network, being better informed, two years on by the actual and prospective location of additional renewable capacity extracted from the applications to the TLs in Scotland. This study is expected to be published in September.

2.1.4 Reinforcement Proposals

This report is concerned with the technical evaluation of the proposals associated with the first stage, referred to in the studies as Stage 1, which is associated with the connection of around 2000 MW of additional generation capacity in Scotland. The indicated costs of reinforcements for the three TLs under Stage 1, associated with 2,000 MW of additional renewable capacity in Scotland are as follows:

Table 3. Reinforcements indicated in RETS Study for 2 GW of renewables in Scotland

Transmission Licensee	Reinforcement proposals costs (2 GW Scotland)
SHETL	£190 million
SPTL	£160 million
NGC	£170 million
Total	**£520 million**

Further to the initiation of the Ofgem consultation of the proposals for transmission reinforcement to accommodate increased levels of renewable capacity, the TLs reviewed their proposals and indicated the following reinforcements[9] were required to accommodate stage 1 of the RETS.

[9] Transmission Investment for Renewable Generation, Second Consultation, May 2004. http://www.ofgem.gov.uk

Table 4. Reinforcements indicated in Ofgem's May 04 Consultation paper

Transmission Licensee	Reinforcement proposals costs (2.9 GW Scotland and 700 MW NW England)
SHETL	£240 million
SPTL	£225 million
NGC	£316 million
Total	**£781 million**

The revised proposals represent an increase of over £261 million (+50%) over the reinforcement estimates indicated in the earlier RETS however it should be noted that the more recent estimates correspond to a renewable generation capacity of 2.9 GW in Scotland (+45%), and over 700 MW of additional wind capacity in the North West of England that was not considered in the original RETS study.

2.2 Scope of work and objectives

The scope and objectives of this work are as follows:

- Extraction and validation of data inputs, generation/demand forecasts and planning scenarios from TLs submissions
- Review of reinforcement proposals and their costs
    - Transmission capacity
    - Sensitivity to data inputs and assumptions
    - Costs levels
- Works expected completion time and delay risks
- Quantification of volume of transmission constraints
    - If RETS stage 1 works were not carried out
    - During RETS stage 1 construction assuming summer 2004 start
- Evaluation of consistency between RETS 1, 2 and 3 Proposals

2.3 Approach

The general approach adopted in this evaluation is to review the costs and benefits of the reinforcements proposed by each of the TLs on its own in order to ensure that each reinforcement scheme is justified technically and economically on its own merits. However it is also recognized that some of the reinforcement schemes proposed expand beyond the License boundaries of the TLs involving reinforcements in several of the TLs networks.

Meetings have been held with each of the Transmission Licensees (TLs) to give them the opportunity to present and discuss of their proposed reinforcement proposals. During these meetings the TLs provided information to support the proposed reinforcements in their licensed area. In addition complementary information and clarifications were requested in those areas where it was considered necessary to augment or provide further details to the information made available to SKM.

Two joint meetings have been held with Ofgem and the three TLs and another two meetings have been held separately with each of the TLs. Ofgem personnel attended most of the meetings. A record of the information collected and submitted for our review is listed in Appendix A.

2.4 Structure of this document

This document is organised as follows:

- Section 1 contains the Executive summary
- Section 2, Introduction, is this section which provides an introduction to the regulatory framework and issues surrounding the connection of additional renewables
- Section 3, Brief review of the RETS report, undertakes a review of a study undertaken by the TL of required levels of reinforcement for several levels of installed wind capacity in Scotland.
- Section 4, Renewable connection forecasts, examines the renewables connection forecasts from information provided by the TLs and other sources.
- Section 5, Transmission reinforcement criteria, reviews the applicable network planning and operational standards in the assessment of required network reinforcements and its application in case of intermittent sources such as wind. It also provides an overview of the approach undertaken in the evaluation of constrained energy volumes.
- Section 6, Valuation of constrained generation costs, examines appropriate values to use for constrained generation energy, capacity and losses.

- Section 7, Review of reinforcement proposals, describes and reviews the proposed reinforcement proposals by the TLs.
- Section 8 details the expected costs associated with each of the reinforcements discussed in Section 7 for the period up to 2010.
- Section 9, Cost Benefit analysis, undertakes an evaluation of the benefits provided by each of the main reinforcements considered and a comparison to its costs to determine the level of additional renewable capacity required to justify the project for a range of constraint costs.
- Finally Section 10, Summary conclusions and recommendations, contains a summary of the main findings, conclusions and recommendations.

3. Brief review of RETS Report

3.1 Summary of assumptions, approach and description

As indicated earlier the DTI formed the Transmission Issues Working Group (TIWG) to study the effects of the forecasts levels of renewable generation in Scotland on the electricity network. The three transmission licensees in Great Britain at the request of the TIWG initiated a study (RETS) to identify and evaluate the network reinforcement requirements for increasing levels of installed wind generation capacity in Scotland.

The study investigated three levels (stages) of additional installed wind capacity in Scotland namely 2 GW, 4 GW and 6 GW or stages 1 to 3 respectively. The new renewable generation was spread evenly between SHETL and SPTL, and within each license area it was spread in clusters at selected nodes. Transmission planning standards were applied as appropriate for each of the TLs areas, a comparison of the main differences is provided in Section 4. Other assumptions for generation background and demand followed the same assumptions as those undertaken in the BETTA studies for Ofgem. A “diversity factor” of 83% of wind generation capacity was used by the TLs in accordance with the factor applicable with conventional generation for the purposes of assessing transmission capacity at winter peak demand as specified in the planning standards.

3.2 Identified reinforcements and costs

The following tables summarises the reinforcement costs indicated in the RETS report tabulated per company and per stage

Table 5 RETS reinforcement costs (£ million)

Network reinforcement per stage	SHETL	SPTL	NGC	Total	
				per stage	cumulated
Stage 1 (2 GW)	190	160	170	520	520
Stage 2 (4 GW)	160	155	400	715	1,235
Stage 3 (6 GW)	70	70	120	260	1,495
TOTAL	420	385	690	1,495	

It should be noted that the RETS work was a desktop scoping study and the indicated costs were based on initial estimates of required reinforcements without detailed design work.

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3.3 Results obtained

The volumes of constrained generation energy obtained in the RETS report for the existing network and for the network with the reinforcements considered for each stage and level of installed wind capacity are shown in Table 6.

Table 6 Constrained Energy from RETS study

Installed Wind	Existing System	Stage 1	Stage 2	Stage 3
2 GW	2.3 TWh	0.6 TWh		
4 GW	5.0 TWh	2.4 TWh	0.6 TWh	
6 GW	9.1 TWh	5.6 TWh	2.6 TWh	0.9 TWh

The net benefit of the reinforcements associated with each stage is calculated from the difference between the capital cost of the proposed reinforcements and the ‘capitalised’ constrained generation energy. The calculations in the RETS study were undertaken using a value for the constrained energy of £25/MWh, assuming a 40 year typical life for transmission assets and an interest rate of 6.25%. The net benefits and capital costs for each stage are calculated and presented in the RETS report in cumulated form for each combination of wind installed capacity and network reinforcement stage. The results obtained, presented in Table 2 in the RETS report, are reproduced in Table 7:

Table 7 Net benefit of network reinforcement from RETS study (£ millions)

Installed Wind	Stage 1 Cost: £520M	Stage 2 Cost: £1,235M	Stage 3 Cost: £1,495M
2 GW	75		
4 GW	425	387	
6 GW	736	1,132	1,480

The report therefore concludes that the identified projects show a positive benefit for all the identified reinforcements when compared to the costs of constraining generation.

3.4 Analysis of the results obtained

The analysis undertaken in the RETS report of the proposed reinforcement schemes showed positive benefits when the avoided constraints costs were compared to the capital costs on a cumulated basis (Table 7) for all the three reinforcement stages considered. The proposed staged reinforcements are progressive with the amount of installed wind capacity. The following table presents the benefits on a per stage basis using the values of constrained energy presented in the

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RETS report and using the same assumptions for the capitalisation of constrained generation energy costs (£25/MWh).

Table 8 Net benefit of network reinforcement from RETS study per stage

Stage	Installed Wind Capacity	Capital network reinforcement cost per stage (£ million)	Net constrained energy benefit per stage (TWh)	Net benefit in capital terms per stage (£ million)	Maximum capital expenditure justifiable (£ million)
1	2 GW	520	1.6	75	595
2*	4 GW	715	1.9	-38	677
3*	6 GW	260	1.7	348	608

*Assumes network reinforced with the works identified for all previous stages

The analysis shows that the benefit for stage 2 is in fact negative and that presenting the results on a cumulated basis may lead to the conclusion that all stages produce positive benefits when it may not necessarily be so.

It also follows from the above that presenting the results on a GB basis may produce misleading results as the various network reinforcements in the TLs areas may provide various degrees of benefits. High benefit to cost ratios associated with certain reinforcements may mask low or even negative benefit to cost ratios for proposed reinforcements in other areas if all the costs and benefits are lumped. It is therefore necessary to consider in the evaluation of the benefits provided by the reinforcements through the difference in constrained energy before and after each proposed reinforcement taking into account that some reinforcements may involve works in more than one of the TLs areas.

The balance between demand and generation with increase in wind generation capacity indicated in the RETS study was achieved through the offloading of units behind the constraints in the England and Wales system. An alternative to the provision of additional network capacity through network reinforcement is to reduce the output of certain power stations in Scotland. This would allow the export of further energy from renewable generators at a cost that, in economic terms, would broadly be the difference between the heat rate of the unit in Scotland that is displaced and has to reduce its output, and the unit(s) in the E&W system that increases its output to pick up the balance. These issues are further considered in Section 4.

3.5 RETS2 studies

In December 2003 the three TLs started a new RETS study, RETS2, that would study the effects on the network of renewables in Scotland in much greater detail taking into account the developments since the conclusion of the RETS2 study and the actual network location of existing, contracted and forecast wind capacity. The studies will be undertaken using the ASSESS tool jointly developed by NGC and Electricité de France. The study will focus on three key years 2005/6, 2007/8 and 2010.

The objectives of the revised studies are to:

1) Review 2005/6 System Security and Quality of Supply to:

a) Identify how much additional generation can be accommodated by April 2005 (based on dates new generation is likely to connect)

b) Determine the constraint volume, (based on dates new generation is likely to connect) if all 2005 contracted generation was to connect for both

i) Normal prevailing conditions
ii) Consideration of outages required to accommodate reinforcements identified for 2007/8

c) Determine what, if any, mitigation could be undertaken to reduce the constraint volume identified in b) above.

2) Identify reinforcements to accommodate contracted (and ‘quoted’ generation) by 2007/8

a) Identify reinforcement requirement required to connect to cases, a low case of 2.3GW (based on signed agreements) and a central case of 4.6 GW (based on signed agreements and 50% of unsigned agreements proceeding) of renewable generation. This generation will be assumed to comply with the proposed Grid Code requirements, particularly with regard to fault ride-through.
b) Identification of the constraint volume for both low & central cases.
c) Identify outage requirements for 2007/08 reinforcements.

3) Review of System Security and Quality of Supply for year 2010. Based on a range of scenarios to be consistent with 2007/8 (i.e. 4, 6 and 8 GW of renewable generation). The 8GW study has been included, as there is currently more connection activity than envisaged in the 2002 RETS studies.

This study is expected to be concluded by the Autumn 2004.

3.6 Conclusions

This brief review of the RETS has indicated the following:

- The positive benefit to costs ratios indicated for each of the three stages considered (2 GW, 4 GW and 6 GW in Scotland respectively) become negative for Stage 2 (which assumes that Stage 1 has been implemented) if the incremental costs and benefits provided by each stage are considered.
- High benefit to cost ratios associated with certain reinforcements may mask low or even negative benefit to cost ratios for proposed reinforcements in other areas if all the costs and benefits are lumped
- It is therefore necessary to consider in the evaluation of the benefits provided by the reinforcements through the difference in constrained energy before and after each proposed reinforcement taking into account that some reinforcements may involve works in more than one of the TLs areas.
- Critical aspects in the evaluation of the benefits from reinforcement are:
  - The assumption on the conventional generation dispatch
  - The assumption on the contribution of wind generation to the peak (treatment of wind generation under the planning standards)
  - The evaluation of constraint volumes
  - The assumptions in the valuation of constrained energy and capacity.

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4. Renewables connection forecasts

4.1 Introduction

The connection of new renewable capacity in Scotland and elsewhere is the main driver behind the proposed transmission network reinforcements identified by the TLs that are presented and discussed later in this document.

The renewable generation connections relevant to this work essentially include all renewables likely to connect within the interconnected parts of SHETL and SPTL licence areas and also, where relevant certain proposed generation connections to NGC’s area. In the case of the two Scottish businesses, connection to both the transmission (132 kV and above) and also the distribution networks are relevant and the Scottish TLs responses include connection activities at all voltage levels. However, in the case of NGC we have only requested data on direct connections to the NGC network, although we recognise that certain renewable generation connections to both the United Utilities and the Northern Electric distribution networks will impact on transmission network power flows, albeit by essentially netting off a proportion of the Grid Supply Point (GSP) demands.

In addition, when considering the impact of renewable generation connections on TL power flows and on the operational patterns of existing conventional generation, overall GB renewable connections also need to be taken into account. In addition, through the ROC regime, renewable generation connections in total within GB (if forecast to approach ROC limits) will tend to reduce the likelihood of individual connection applications proceeding through to commissioning

The following sections examines overall GB connection forecasts and forecast by each of the TLs based on data from renewable connections, applications and other relevant developer activity in their areas

4.2 GB Renewable Generation Forecasts

The DTI published in 2000 the document “New and Renewable Energy: Prospects for the 21st Century” which presented 3 scenarios for renewable generation by 2010. The RETS report used the “High wind” scenario which indicates a wind installed capacity by 2010 in Great Britain of 6.2 GW (Table 9). In addition a second scenario was created replacing the contribution from waste incineration (13%) by wind which results in a total wind installed capacity of 8 GW (Table 9).

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Table 9 High wind scenarios from the DTI 2000 study / RETS

	2010 with Waste Incineration	2010 w/o Waste Incineration
Maximum Demand (MW)	74,300	74,300
Demand factor	67%	67%
Energy delivered (GWh)	432,827	432,827
Target renewables	10%	10%
Renewable energy required (GWh)	43,283	43,283
Wind Proportion	44%	57%
Wind Energy (GWh)	19,044	24,671
Wind Generation Factor	35%	35%
Equiv. Capacity (MW)	**6,211**	**8,047**

The results shown in Table 9 indicate therefore a maximum installed wind capacity for the whole of Great Britain of between 6.2 GW and 8.0 GW by 2010. Based on geographical distribution of wind generation based on British Wind Energy Association (BWEA) estimates two scenarios are considered in RETS. The first scenario (unconstrained) is based on BWEA estimates of suitable land areas for wind generation and a second scenario (constrained) takes into account constraints in the distribution networks. For the unconstrained scenario the results indicate a split of 3.9 GW and 2.3 GW between Scotland and England and Wales respectively. Most of the additional renewable capacity in Scotland is expected to be wind sourced. In the case of the constrained scenario, the split is 1.7 GW and 4.5 GW between Scotland and England and Wales respectively. Table 10 summarises these results and also indicates the resulting capacity estimates for the "no waste incineration" scenario (Table 9) also used in RETS.

Table 10 Scotland/E&W split. Installed wind capacity forecasts DTI/BWEA/RETS

Unconstrained Scenario	2010 with waste incineration	2010 w/o waste incineration
Scotland	**3,913**	**5,069**
England & Wales	2,298	2,977
Constrained Scenario		
Scotland	**1,739**	**2,253**
England & Wales	4,472	5,794

The driver for the installation of renewable capacity is the annual target level and the ROC penalty scheme affecting the whole of GB. It is therefore important to appreciate that this effectively creates a competition between suitable locations across the whole of GB for developers who will consider a multitude of sites for renewable projects on a "first consented, first develop basis". In the consideration of the likely renewable capacity in Scotland by 2010 it is therefore important to consider also the levels of activity in England and Wales as the overall capacity indicated by connection applications for renewable generation is likely to exceed the levels indicated by Table 9. However there is no incentive to install capacity over the annual target and hence this will tend to slow down projects if the targets are close to being met. These issues are reviewed in the following sections with particular reference to the levels of installed renewable capacity affecting Scotland for each of the three TLs.

In addition to the information presented above which reflects and interprets the DTI and BWEA forecasts during the course of the ongoing Distribution Price Control Review (DPCR4) forecasts of Distributed Generation (DG) were also prepared by each of the DNOs in their Business Plan Questionnaire responses (DG-BPQ). These responses[10] are presented in tabular form below and it can be seen that the DNOs are forecasting an increase of between about 9.7 to 10.9 GW of embedded generation during the period through to 2009/10.

Table 11 Extract (and development) from Summary of DG-BPQ Information

DNO	DG Additional Connected Capacity (MW)		
	Historical 1 April 00 – 31 March 03	Interim 1 April 03 – 31 March 05	Future 1 April 05 – 31 March 10
Aquila	93.5	19.5	69.7 – 309
EME	67.3	22.6	865.0
EPN	502.2	43.5	807.8
LPN	101.5	4.9	335.4
SPN	541.5	15.0	472.0
WPDSW	46.7	37.5	175 – 315.8
WPDSWa	70.9	134.7	261.4 – 455
NEDL	52.7	5.6	1152.9
YEDL	211.4	6.0	1097.4
SSESthn	51.1	128.5	248.0
SSEHydro	80.5	293.1	866.7
SPDistr	76.8	84.1	1437.0
SPManweb	111.8	173.1	987.0
UU	122.7	59.3	987 – 1530
Total additions	2131	1027	9762 - 10879
Cumulative total	2131	3158	12920 -14037

[10] Ofgem, Electricity Distribution Price Control Review, Update October 2003.

The forecasts presented above have been reviewed by Ofgem and their appointed consultants and the reasonableness of the forecasts confirmed. With specific reference to this review it should be noted that the two Scottish DNOs, SSEHydro and SPDistr forecasts equate to total embedded generation of 1240 MW and 1598 MW respectively.

The growth in generation presented in Table 11 above is almost solely generation which can be classified as New and Renewable generation and, of this forecast growth in generation, about 5,700 MW comprises onshore and offshore wind. Comparison of the total DNO connected wind generation levels reflected in Table 11, i.e. 5.7 GW with the wind capacity forecast given in Table 10, namely between 6.2 and 8.0 GW it is clear that the headroom for additional, TL connected capacity lies between about 0.5 GW and 2.3 GW. The expectation is therefore that there will be a degree of competition between alternative renewable generation projects, both within and between technologies with an implicit risk that projects may be abandoned or delayed should projected capacity exceed or approach RO target levels. In addition, with respect to distribution or transmission connections, the expectation is that from the developer viewpoint, distribution connections will be somewhat cheaper than transmission connections, which is a correct signal in net importing areas of the country.

Beyond 2010, with the Governments stated RO targets growing at about 1 percent per year, equivalent of about 1 GW of additional wind generation, or somewhat less if higher load factor renewable generation is available, there will obviously be a continuing market for such generation, albeit growing at a lower rate than is the case with the 2010 target which, at the present time requires renewable generation development at a rate of about 2 GW/year.

4.3 Scottish Hydro Electric Transmission Ltd

Scottish Hydro Electric Transmission Ltd (SHETL) has provided specific information on wind farm connections, construction and applications/quotes which confirm significant wind farm connection activity in their licence area. This information has been provided in the form of a detailed schedule indicating proposed wind farm location, capacity, developer, project status and likely project time lines. This information is summarised in Table 12 from which it can be seen that over 7000 MW of connection activity is indicated, with only a minimal amount, circa 250 MW having lapsed at this point in time. It should be noted that these projections also include distribution network connections, indicated from Table 11 above to total about 877 MW by 2009/10.

Table 12 SHETL: Renewable generation activity by geographical area

Project Status2	Shetland	Orkney	Skye & Western Isles	Highlands	North East	Mid West	South West &Argyll	South East	Grand Total
Connected	4	16		27		20	100	14	179
Under Construction			56	261	119	4	3	104	547
Quote Accepted		17	32	407	146	165	200	275	1,241
Quote Issued	556	90	1,150	117	89	35		112	2,149
Quote Process		35	5	651	63	20	7	78	860
Initial inquiry/budget quote	5	1	33	1,468	60	30	148	288	2,032
Quote Lapsed		4	6	110	74	44	19	0	257
Grand Total	564	163	1,282	3,040	551	317	478	870	7,266

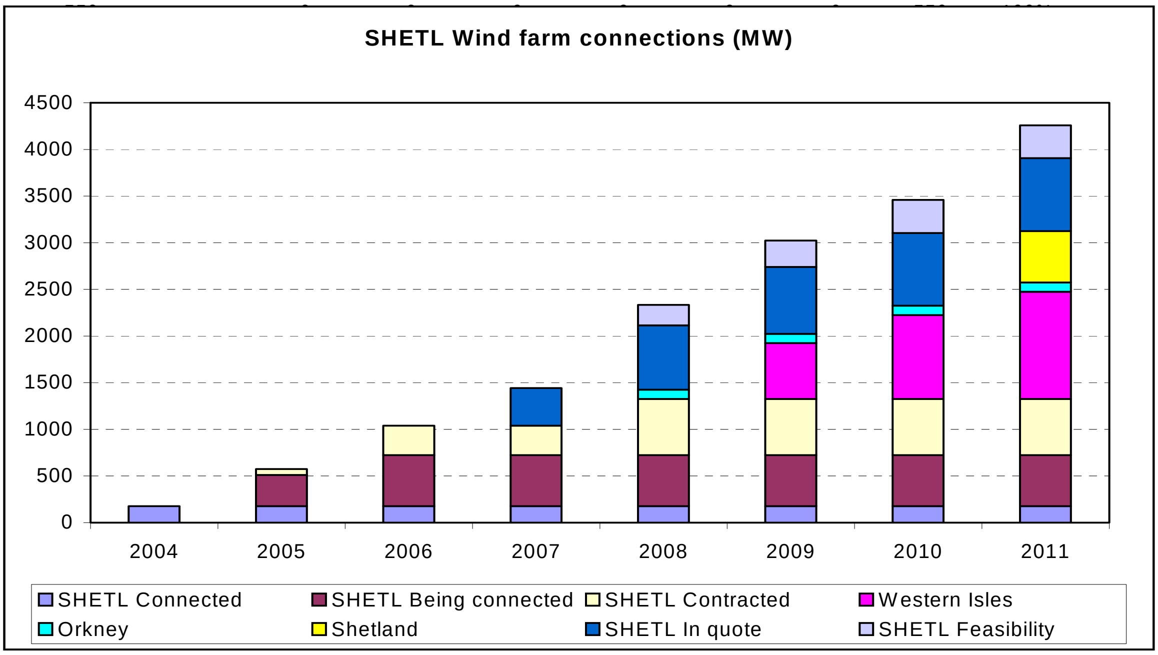
It can be seen from the table above that over 700 MW of wind farms are actually connected, or under construction with a further 1,200 MW of connection quotations having also been accepted by the connecting parties.

The geographic location of the SHETL connections is important with respect to the need or otherwise for the proposed SHETL network reinforcements, principally the Beauly – Denny line which will be driven by the level of generation connections in the north of the country, regionally Shetland, Orkney, Skye and Western Isles and the Highlands. At the present time a total of about 360 MW are either connected or under construction in these areas, with quotations in place for almost a further 2000 MW.

The other geographic area of relevance to specific reinforcement proposals is the South West and Argyll which at present has a total of about 300 MW of wind generation either connected, under construction or which has accepted a connection offer, with a further 150 MW of connections currently under investigation. This area of the SHETL network, which includes the Sloy hydro-electric power stations is presently restricted by 132 kV transmission bottlenecks, and SHETL propose the establishment of a 275/132 kV connection with SPTL in this area, essentially the 275 kV circuits connecting with the Scottish Power Generation's Cruachan pump storage power station.

Based upon information from such connecting parties, either formally through the connection procedure, or otherwise informally with respect to ongoing investigations, SHETL have presented information indicating the desired connection dates of such projects. This information is presented graphically below and it can be seen that a progressive increase in connections to about 1,300 MW of contracted connections by 2010/11, with a further 1,500 MW being associated with major schemes on Lewis, Orkney and Shetland, although such schemes will themselves require major reinforcements to the main grid systems and also submarine cable transmission before they can connect. Such schemes are also dependent upon completion of the proposed Beauly – Denny line as this will be the main conduit for them to the demand centres.

Figure 2 SHETL Expected Phasing of Wind Farm connections 2004-2011



It can be seen from Figure 2 that up to about 1,500 MW of plant may be confidently forecast to connect by about 2008. At the present time it appears that further connections up to about 4,000 MW may eventuate. However, actual outturns will be very dependent upon consenting issues, both with respect to the wind farms themselves and also the rate at which the main SHETL transmission network can be expanded and reinforced to connect with these projects.

The likelihood of such projects proceeding will also be influenced by ROC related issues, in particular the degree of confidence that such projects will be able to receive full ROC incentives, an issue which will be dependent to a large degree upon the volume of renewable generation connecting in GB generally. Based on the above we consider a reasonably optimistic view would be that about 2,500 MW may connect by 2011, but that this may easily be in error by +/- 1,000 MW.

4.4 SP Transmission Ltd.

SP Transmission Ltd (SPTL) has provided information in similar detail to SHETL. This information is presented in summary form in Table 13 and it can be seen that a total of about 720 MW of generation is either connected, under construction and/or has accepted a connection offer. A further 1,850 MW of generation capacity is presently in the Offer process, with about 4,800 MW of projects being in the earlier, feasibility stage.

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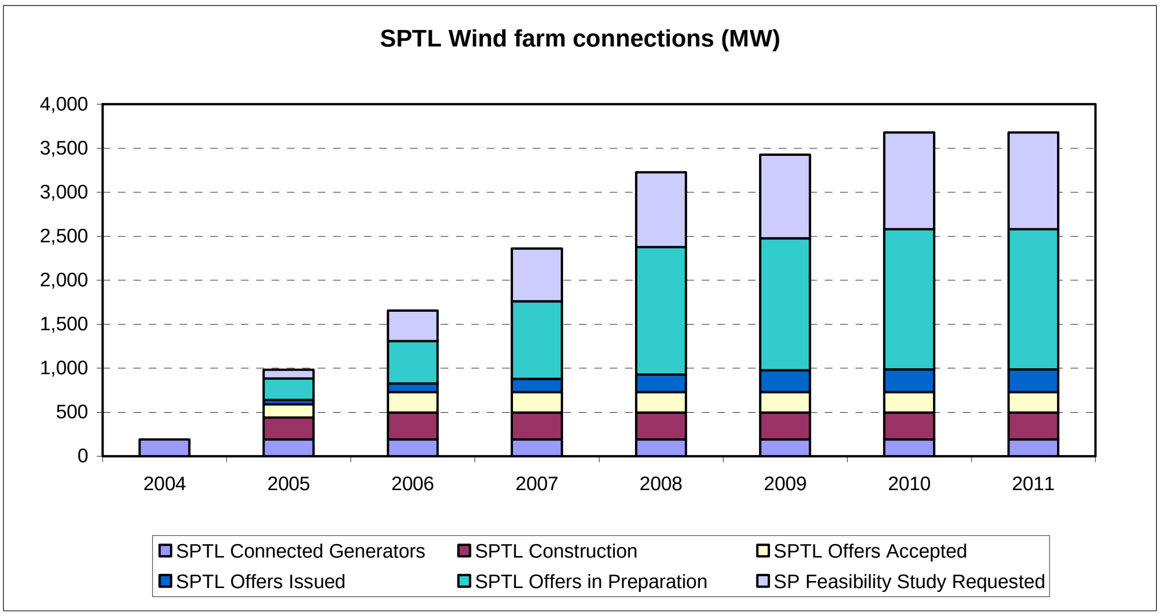
With respect to geographic location, and hence associated network reinforcement requirements the more critical area is the South-West where, although only about 225 MW are committed, about 1250 MW of generation capacity is in the Offer process or else at the early feasibility stage. It is this level of interest which has encouraged SPTL to consider a major network reinforcement into the Galloway region, potentially as a first stage to a third pair of "Scotland-England" interconnection circuits.

Table 13 SPTL: Renewable generation activity by geographical area

Project Status	Ayshire	Borders	Central	Fife	Glasgow	Lothian	North Ayrshire	South	South West	Grand Total
Connected	31	49	17			55			36	188
Under Construction			141						166	307
Quote Accepted		39				14		153	26	232
Quote Issued	68	50	35					38	69	260
Quote Process		47	297	30	48		155	920	96	1,593
Feasibility Studies	30	169	419					179	300	1,097
Concept Enquiries	328	431	316	170	70	254		1,384	796	3,749
Grand Total	457	785	1,225	200	118	323	155	2,674	1,489	7,426

The information submitted by SPTL has also been sorted in likely connection date order, and this is presented in graphical format in Figure 3.

Figure 3 SPTL Expected Phasing of Wind Farm connections 2004-2011

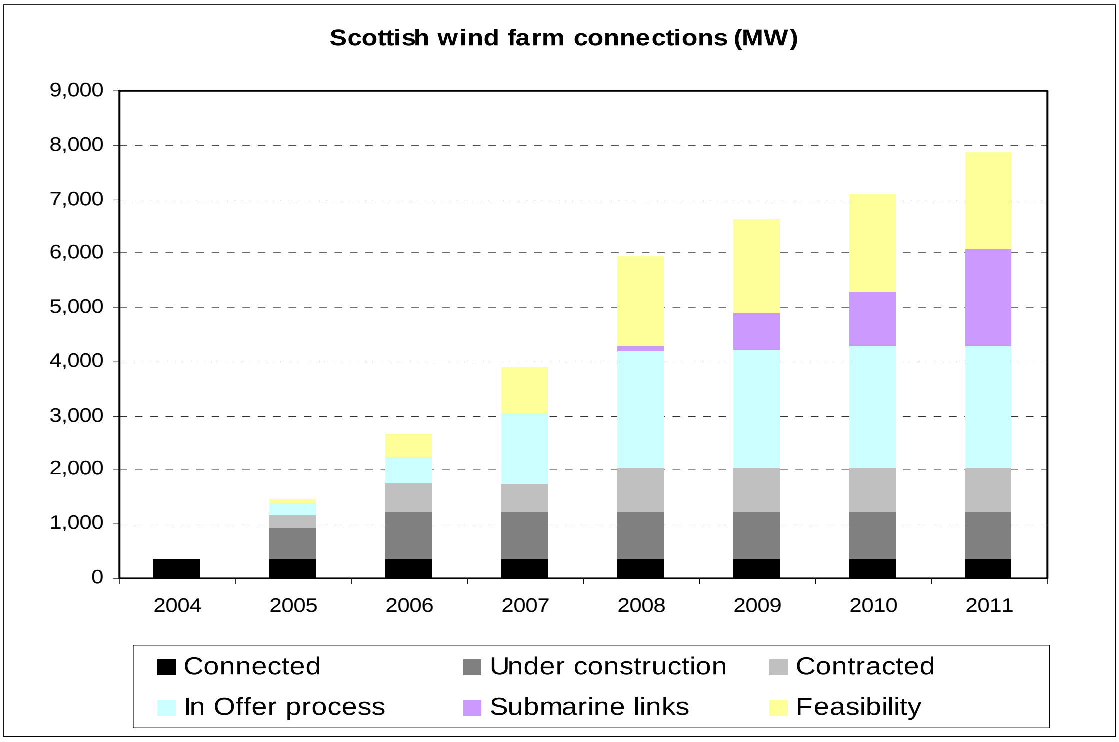


It can be seen from the graph above that a total of about 700 MW of generation connections are reasonably in process, either connected, under construction or having formally accepted a connection offer. A further 260 MW of connection offers have been issued and a significant volume of connection work is indicated to be in process, or else requesting feasibility studies. As in the case of the SHETL connections, a reasonably optimistic view would be that a total of about 2,000 MW of capacity may be connected by 2011, although this must be similarly caveated as being subject to a potential variation of +/- 1,000 MW.

4.5 Scottish connection activity summary

The information presented in Sections 4.3 and 4.4 above has been collated together into equivalent categories and is presented in Figure 4. We have attempted to indicate the degree of firmness of the project by the colouring, albeit that actual outturn may be somewhat different with the possibility that a submarine connection to Orkney may proceed ahead of projects currently in the Offer process. The ranking of prospects has therefore taken cognisance that schemes such as those in the Western Isles and the prospects in Shetland will require expensive, and consents challenged, overland and submarine interconnections. In addition they will also need to be timetabled behind the actual construction of the Beauly-Denny line.

Figure 4 Summary of wind farm connections (MW) phasing forecast in Scotland



It should be noted however that a significant proportion of the connection applications are from major electricity energy suppliers, including both Scottish and Southern Energy and Scottish Power Generation, both of which are obligated to self generate, or else purchase, renewable sourced energy generation in proportion to their significant energy sales. Such developers, who also own significant conventional generation, will be expected to develop, or otherwise procure, an appropriate generation portfolio balance consistent with their renewable obligations. They will therefore have a strong incentives and also significant financial and project delivery capability. However, it is expected that consenting issues associated both with the individual projects, and also with the provisions of suitable connections thereto may well slow the developments. In the case of other players, a degree of uncertainty with respect to consents and constraint issues can act as a significant brake on developments, particularly if opportunities are presented elsewhere in GB, refer to Table 11. In summary therefore we are of the view that although there is considerable connection activity and interest at present, actual project delivery is more likely to be in the centre of the range indicated by Figure 4, rather than at the higher levels.

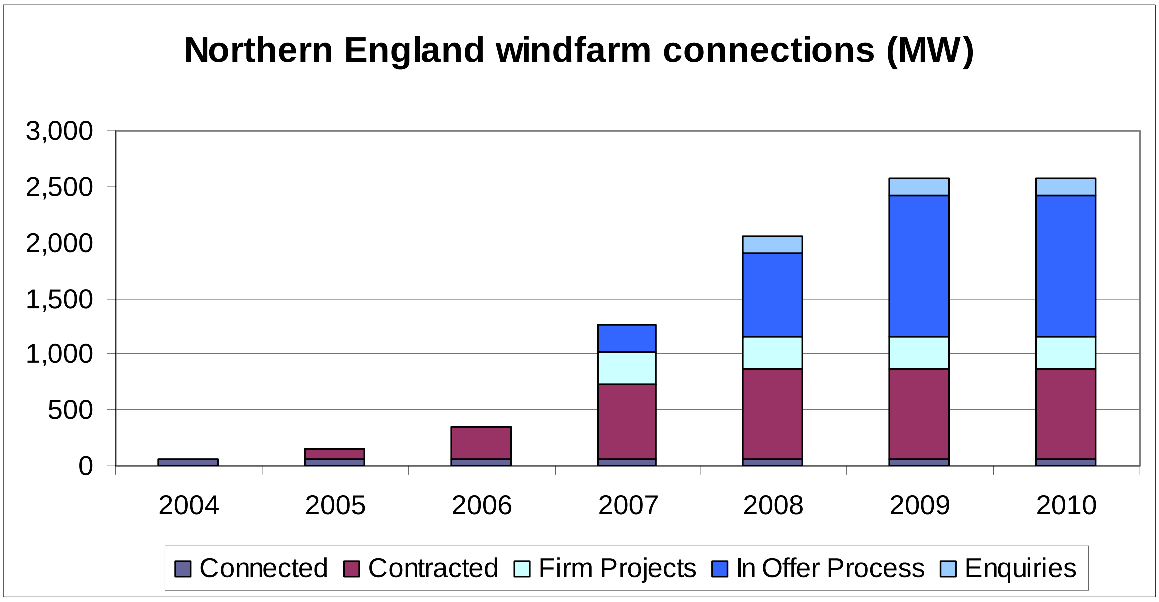
4.6 National Grid Company

NGC have provided information in a similar format to the two Scottish TLs with respect to wind farm connection in both the northern (Figure 5) and southern area of England and Wales.

4.6.1 Northern England connections

In the case of developments in the north-west relevant to the proposed network reinforcements, existing connected windfarms and those with firm contracts are forecast to total almost 900 MW by around 2008/09, and further projects with DTI funding are considered likely to proceed to connection which will bring the total “firm” connections to about 1,150 MW before 2010/11. As in Scotland, if connections in the “offer process” are included, the total volume of potential connections can be seen from the graph below to more than double by 2010/11.

Figure 5 NGC: Northern England windfarm connections (MW)

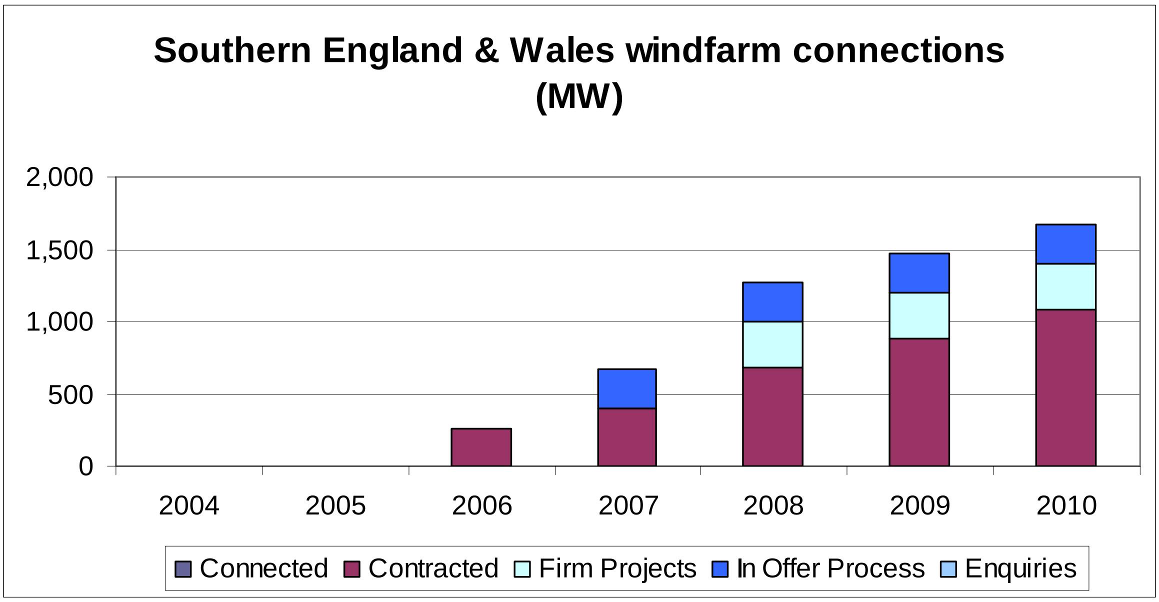


It should be noted however that the greater part of the NGC projections are associated with large "offshore" wind farms. As a consequence, particularly with the present uncertainty with respect to licence requirements, and also the inherently higher specific costs (£/kW) of such projects we are of the view that it is this sort of project which may be slipped rather than competing "onshore" developments.

4.6.2 Overall Connections "Health check"

As a general "health check" on connection activities, NGC have also provided information on connection applications in the southern part of their licence area. The "firm" element of these applications/contracts can be seen from the graph below to total about 1,000 MW by 2008/09 increasing to about 1,400 MW by 2010/11. Again, all of these projects are associated with offshore developments.

Figure 6 NGC: Southern England & Wales windfarm connections (MW)



Information obtained from the GB Distribution Network Operators has been presented in Section 4.2. This information indicates a total of 13 to 14 GW of embedded generation by about 2010, an increase of more than 11 GW over the corresponding 2003 totals. Of this total the DG figures indicate only about 600 MW is non-renewable or CHP. It should be noted that these totals include about 2.8 GW embedded within the Scottish distribution networks, capacity which is already included in the Scottish TL totals referenced earlier.

When taken together with the wind generation totals referenced earlier, i.e. about 1.2 GW of TL connected generation in Scotland (i.e. netting off 2.8 GW of distribution connected plant) and 2.5 GW of "contracted/firm" projects connecting to the NGC network, the embedded/renewable generation capacity by 2010 is forecast to total more than 16 to 17 GW, about 9.5 GW of which is wind generation. The level of wind generation outlined above are significantly greater than those presented in Table 9 and Table 10 of Section 4.2,.

In total, the above levels of renewable generation would indicate that the RO targets may be exceeded with this level of connection activity, rather than the presently indicated shortfall on the same targets. This indicates either considerable optimism in the submitted figures or, conversely that the prospect of exceeding the RO targets will invariably increase the perceived risk associated with some of the later and higher cost projects proceeding, namely offshore wind projects, and also wind projects on the Scottish offshore islands. This observation tends to support the view that totals of about 4 GW of wind generation in Scotland is unlikely to be significantly exceeded prior to 2010 and also that the levels of forecast offshore wind connections onto the NGC system may also be somewhat optimistic.

Somewhat in contradiction with observation presented above with respect to Scotland, is the perception that planning issues in Scotland are less obstructive than in England and Wales, and also that a significant proportion of the wind generation in Scotland, almost 3 GW is presently being developed by SSE and SP's respective generation businesses, with a number of other major players also significantly involved. In contrast, the DNO connected DG capacity in England and Wales will be largely made up of smaller developments, with a more diverse developer base. These projects may be expected to experience greater problems with planning issues in England in particular and, as a consequence may be less likely to be developed at the same rate. On balance therefore we are satisfied that a projection of about 4 GW of wind generation within Scotland is reasonable and can be used as a basis for assessing the shorter term network reinforcement issues.

In the case of specific generation connections at Heysham, NGC have identified a number of projects which may impact upon the main transmission reinforcement requirements. These are all associated with offshore wind farm connections and at the present time only one of these developments, a 99 MW project is under construction. We are of the view that other onshore projects are likely to slip back somewhat with regard to their presently contracted connections dates, as has been the case with the London Array project. In part this is due to some uncertainty with respect to submarine connection licence issues, they also reflect technical concerns associated with essentially prototype offshore wind farm equipment. Whilst the same issues may also affect onshore plant, access for maintenance, repair and replacement are much simpler and less expensive. In addition, as indicated above if inherently less expensive onshore projects in Scotland and DG connected generation in England and Wales progress as indicated in the respective forecasts, an element of increased ROC income risk (due to oversubscription) may also discourage the development of such projects.

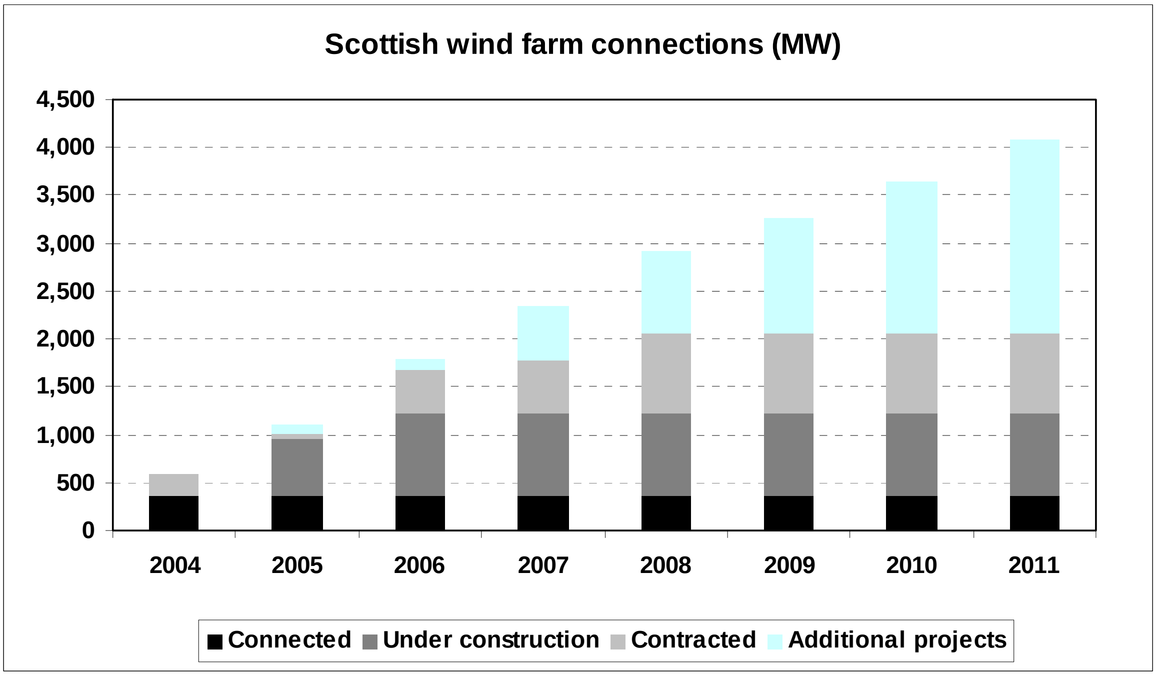
4.7 Conclusions

On balance we are satisfied that based on the evidence of the total generation capacity under construction or with connection contracts and signed agreements provided by the TLs, a forecast of about 4 GW of installed wind generation by 2010/11 within Scotland is reasonable. The 4GW level is also considered as a plausible scenario for 2010 against the background of overall GB connection activity and with meeting government targets. As a consequence we are of the view that a capacity of about 4 GW, split roughly 50/50 between the SHETL and SPTL areas, should be used as a basis for assessing the associated shorter term network reinforcement requirement discussed later in this report.

In the case of connections to the NGC transmission network which may impact on the needs for the proposed RETS network reinforcements, essentially offshore wind farm connections at Heysham, we are of the view that there is significant uncertainty on the likely outturn volumes and timing.

In summary therefore, the generation connection volumes considered appropriate drivers behind the network reinforcements associated with increased renewable in the north of GB may be taken to be those presented in Figure 7 below.

Figure 7 – Central forecast for Scottish Wind Farm connections.



5. Transmission reinforcement criteria

5.1 Introduction

The transmission security planning and operating standards establish the technical requirements that the network should meet in order to secure demand in case of forced network outages. They are expressed in the form of a set of deterministic rules that ensure that the network meets certain technical criteria post-fault for a concurrent or overlapping outage of two network elements. These standards are based on the results from historic cost-benefit studies that balanced the costs of additional security (additional network capacity) against the unreliability costs (costs derived from an outage weighted by its probability) to arrive to a set of deterministic rules that can easily and consistently be applied by network planners and system operators.

A key element of the security standards is the requirement to secure the system under peak demand as historically there was an implicit assumption that a system that can satisfy peak annual demand has the flexibility to secure demand at other times of the year. The standards indicate assumptions to make about the output of power plants at times of peak for network planning purposes. The security standards however do not explicitly recognise novel generation technologies such as wind that have a number of fundamentally different characteristics (most notably intermittency) when compared to conventional generation.

There is therefore scope for differing interpretations in the application of the security standards when dealing with intermittent generation sources. In this section, a possible application of the current security standards when considering large-scale penetration of wind generation is presented. However, recognising that this interpretation is not definitive and that there are a number of issues that need to be considered which would go beyond our scope, we have carried out some sensitivity analysis later in this document to indicate the potential range of answers. It is recommended that the appropriate treatment of intermittent generation sources in the transmission security standards, particularly of wind generation, is subject to a consultation process within the industry.

5.2 Security Planning and Operating Standards

The three Transmission Licensees (TLs) are presently planning and operating against two different security standards, namely NGC's Security and Quality of Supply Standard (SQSS) and, for the two Scottish TLs, NSP 366 with respect to the planning of their transmission systems and with operation in accordance with their respective system operational standards, essentially identical. In the case of security of supply to demand groups, the two Scottish TLs include ER P2/5[11] as an appendix to NSP 366 and in the case of NGC essentially embody its recommendations within the NGC's SQSS.

5.2.1 Planning Standards

In the case of the respective transmission security planning standards, these are essentially identical insofar as they require the network to be planned to be secure against a single or double circuit outage at times of maximum demand. In both the NGC SQSS and the Scottish TLs NSP 366, there is a requirement to undertake an assessment of the generation available to meet that demand, in the case of the NSP 366 reducing power station sent out capacities in accordance with expected plant availability and in the case of SQSS, scaling down available generation on a pro rata basis such that the capacity matches demand. In NGC's case, in order to obtain some clarity at times of apparent surplus generation capacity, due to new plant connecting or planning to connect ahead of any indicated consequential plant closures, the SQSS allows NGC to undertake a generation "merit order" ranking exercise to determine likely generation capacity that will be available at any future date, including identification of the need for the additional of new (or previously mothballed) generation capacity to meet forecast demand.

To date the application of the generation ranking and capacity scaling procedure has largely been associated with "conventional" thermal plant, all of which is reasonably dispatchable and not subject to the same degree of operational constraints as may be imposed on hydro-electric generation and/or wind farm generation. However, with the projected growth in wind generation capacity nationally, and also following "BETTA go-live", greater transparency of Scottish generation, particularly hydro-electric generation, the capacity scaling issues needs to be addressed in somewhat greater detail if a correct "security weighting" of the different technologies is to be reflected in network capacity requirements.

In the case of the NGC SQSS, there is also an explicit procedure associated with determining the interconnection allowance associated with the provision of mutual support between contiguous parts of the network. This procedure is based upon the reflection of past interconnection flows into a stylised form suitable for deterministic application. This calculation procedure and the applicable assumptions for determining interconnection allowance requirements were not updated following

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[11] Engineering Recommendation P2/5, System design and development committee, October 1978. The Electricity Council, Chief Engineers Conference, Security of Supply. This document is currently undergoing review, in part to improve the way in which embedded wind, and non-wind generation is considered when considering security of supply. If considered relevant, differences between ER P2/5 and P2/6 may then be incorporated within the TL standards.

the vastly changed "post privatisation" environment. Nevertheless this procedure is embodied in NGC's SQSS and hence needs to be given due recognition when investigating the need or otherwise for network reinforcements.

The SQSS criteria for the main interconnected transmission system essentially scales generation to equal demand to derive a planned transfer condition and then adds an interconnection allowance to cover expected variabilities in demand and generation. SQSS Appendix C requires that **ALL** embedded large power stations are scaled equally. However, when plant margin exceeds 20% it is possible to discount generation that is less likely to operate. The assumed output from wind generators can therefore be interpreted as lying in a range between 0 and 83%. This wide range is unhelpful for a study of transmission reinforcement requirements associated with wind generation and therefore this report has attempted to narrow this range based on our interpretation of the principles that underlie the SQSS. Sensitivity analysis is also included for differing interpretations.

In addition to examination of network power flows at times of system Maximum Demand, both NSP 366 and NGC's SQSS require investigation of network power flows at other times. In the case of NSP 366 these are defined as at 75 % of Maximum Demand and also under Other Conditions. However, in both these cases NSP 366 also makes specific reference that at times other than peak demand, all available generation will be used, irrespective of merit order to secure demand[12]. In the case of the NGC SQSS consideration of reselection of generation units in order to satisfy the minimum security standards is also allowed, provided such measures are economically justified.

5.2.2 Operational standards

A noticeable differences in the security standards applicable to NGC and those applicable to the two Scottish TLs, is the explicit requirement for the NGC network to be operated secure against a double circuit event at all times other than in specific cases[13]. In the case of the Scottish TLs however, the main system should be operated, under normal and outage conditions, so that it can

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[12] The requirement to use all available generation does not apply at times of 100% maximum demand. This is considered to be reflective of the era when the security standards where drafted, i.e. during the "central planning era", when it would reasonably be presumed that all available generation (allowing for plant forced outages) would need to be employed in securing demand, i.e. no evident surplus generation (as was the case shortly after GB "privatisation" and also negligible intermittent generation.

[13] NGC Transmission System Security and Quality of Supply Standard (November 2000), page 3.4. In specific cases, where there is significant economic justification, relaxation to a single circuit fault risk may be allowed having due regard to the potential risk of loss of demand.

withstand the loss of any one circuit other than where there is significant risk of a double circuit overhead line fault, e.g. due to a risk of lightning strike or other adverse weather[14].

5.2.3 Transient stability criteria

A second area of difference between the NGC SQSS and the Scottish TLs equivalent standards relates to transient stability requirements. In the case of NGC's SQSS, the fault outage shall be taken to include a three phase fault (or faults) with clearance times consistent with the fault location and an assumed failure of a relay communication channel. In application this represents a three-phase double circuit fault with delayed clearance. In the case of the Scottish TLs, the fault condition is less severe, being the occurrence of any three phase fault (although relaxation to the less severe two-phase-to-earth fault is allowed if found limiting[15]) affecting only a single circuit and with fault clearance being affected within 140 ms or such other time as is appropriate to the actual equipment involved.

5.2.4 BETTA security standards

In the case of the present interconnector circuits between NGC and SPTL, the British Grid System Agreement (BGSA) requires that the assessed capability of such circuits to be determined by the more restrictive standard[16]. In the past this BGSA requirement has been interpreted as requiring the capacity of the inter-connector circuits to be determined on the basis of those applicable to NGC's MITS, essentially corresponding to an outage of a Double Circuit Overhead Line. Subsequent to "BETTA go-live", it is proposed that the inter-connector circuits will become part of the MITS, and also that there will be some harmonisation of the respective TL security standards. The expectation is therefore that the outage of a Double Circuit Overhead Line will still be

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[14] SPTL Operational Standards of Security of Supply and also SHETL System Operation Memo No. 3 require that during normal weather conditions the Supergrid system shall be operated, under both normal and outage conditions, so that it can withstand satisfactorily the loss of any single circuit, but that when weather conditions are such as to make the loss of a double circuit overhead line likely, the Supergrid system shall be operated, wherever possible, so that it can withstand satisfactorily such a loss.
Whichever of the two criteria above applies, the standard can be secured by the use of out-of-merit generation or imports if possible. The extent of such generation must be authorised by a level of staff appropriate to the cost involved.

[15] The Scottish TLs advise that this relaxation is only applied when significant blocks of generation and demand are not at risk.

[16] BGSA Clause 1.3.1. Each Party shall apply its own Licence Standards in calculating the Interconnection Capability. and also Clause 1.3.2. Where a difference in Licence Standards causes a difference in the value of Interconnection Capability between the relevant Parties, the application of the Licence Standard which is more restrictive of Interconnection Capability shall prevail in respect of those Parties.

employed as a basis for assessing the security of circuits connecting the Scottish and the England and Wales transmission systems.

Notwithstanding the above, it should be noted that NGC SQSS operational criteria states "In specific cases, where there is significant economic justification, relaxation to a single circuit fault risk may be allowed having due regard to the potential risk of loss of demand[17]."

5.3 Deterministic planning standards

In considering the application of deterministic planning standards it should be noted that the security standards are essentially concerned with dimensioning the interconnected system such that "under outage conditions… the transmission network should not restrict unduly the contribution that any generation may make to satisfying the demand at the winter peak" and also, "The provisions are intended to ensure security at the winter peak, and do not cover off-peak conditions"[18]. In the light of the above it is appropriate to consider the contribution that "conventional generation" and "wind generation" may make to satisfy the winter peak demand.

5.3.1 Conventional generation

As identified in Section 5.2.1 above, NGC's SQSS provides a methodology for determining the level of capacity to be assumed from individual generators on the basis that the total in merit generation available to the network would be expected to exceed demand at all times. At times of system maximum demand, one of the key states with respect to security of supply issues, the expectation is that under normal conditions on the England and Wales system available generation will equate to about 1.2 times forecast maximum demand. Under such conditions it is appropriate to scale such generation down by a factor of 1/1.2, i.e. 0.83, in order to establish a credible generation dispatch profile against which system security can be assessed. The underlying principle in this approach is that the historical generation planning margin of the England and

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[17] NGC SQSS continues "…This relaxation may be employed when favourable weather conditions prevail, and are forecast to prevail for a time not shorter than the time required to resecure the system in accordance with paragraph 3.13. During such cases of relaxation to a single circuit risk, a fault on a Double Circuit overhead line shall not cause:-

- Unacceptable overloading of any primary transmission equipment
- Unacceptable high or low frequency conditions
- Unacceptable voltage conditions; or
- System instability.

[18] These are arguments referenced by NGC when responding to a 1995 complaint to OFFER alleging that NGC was in breach of its Transmission Licence with respect to its approach when investigating the need or otherwise for the "2nd Yorkshire Line". Professor SC Littlechild, Director General of Electricity Supply, 19 March 1996

Wales system has been of this order, and it is reasonable to assume that all such generation is available to meet demand, subject of course to forced and planned outages, with the latter being negligible at times of system maximum demand, and of course subject to fuel being available to the generator, generally taken as a given with conventional plant.

As stated in Section 5.2.1 above, it is proposed that there will be a harmonised GB SQSS following "BETTA go live". In developing a draft GB SQSS consideration has been given to the way in which the contribution from hydro-electric generation is assessed based on the established procedures of the two Scottish TLs which is to assume that the capacity is in line with the historic longer term availability of such units. In practice this corresponds to about 80 percent of nominal capacity which equates to the maximum hydro-electric generation usage at times of typical winter peak demand.

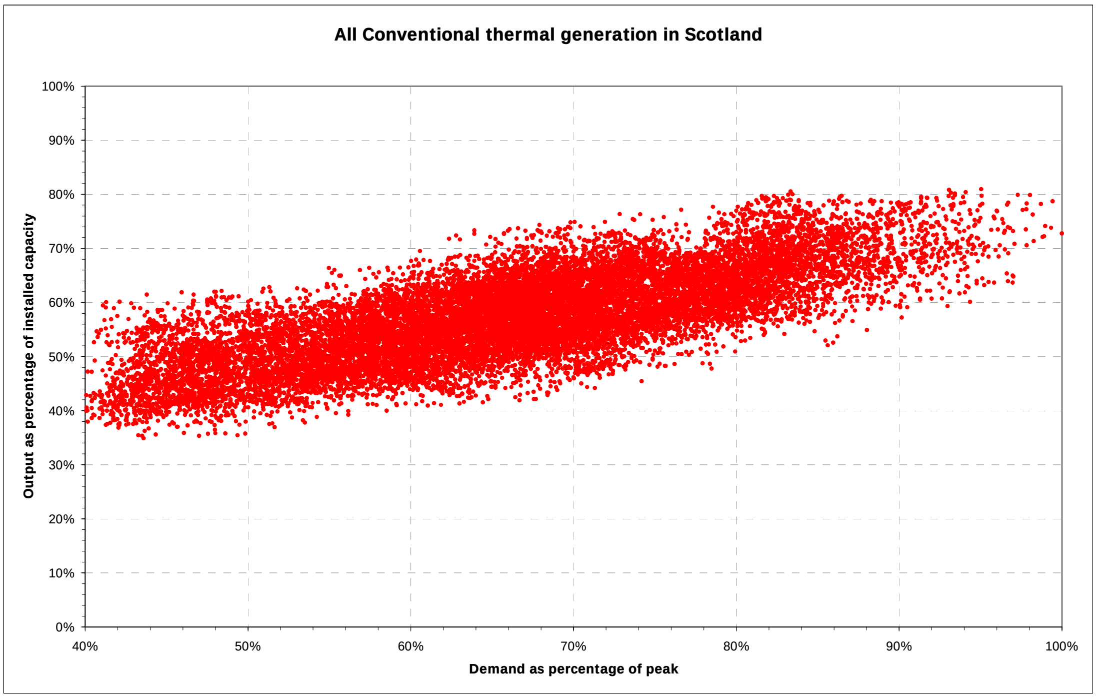
5.3.2 Wind Generation output and demand

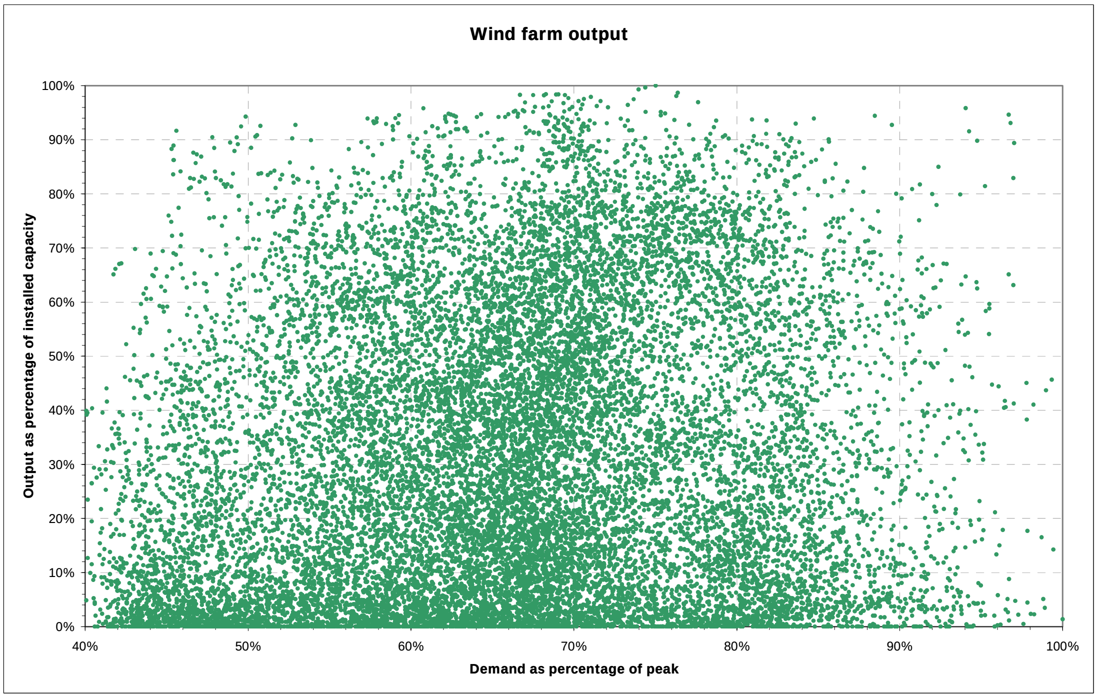
In the case of wind generation it is important that the capacity credit, or in essence the proportion of installed wind farm capacity that can reasonably be relied upon to secure demand, is established and employed, particularly in the case of deterministic assessments. It is equally important to ensure that an appropriate background generation scenario is established, particularly when looking forward a number of years with respect to network reinforcements needs.

In this respect it is informative to present a comparison between the likely power output of conventional, large thermal power stations at times of high system demand, and the equivalent of an aggregation of wind farm generators.

The figures presented overleaf are scatter diagrams of generation output plotted against system demand at the time. It can be seen from the first figure that the "dispatchable" conventional generation is closely aligned with demand. The actual power output being determined by the availability of the generation and its associated position in the generation merit order. It can be seen that generation levels at times of peak (demand > 90 percent of peak) lie in the range 60 – 80 percent of installed capacity. If required by the network, it is reasonable to assume that additional output could be dispatched to meet demand and hence an output assumption (scaling factor) of 83 percent of installed capacity of conventional generation is considered reasonable for a deterministic assessment.

Figure 8 Comparison between the correlation between demand of generation (conventional thermal and wind) and demand using half-hourly data.





In contrast, the scatter diagram for wind shows a near random variation of power output against demand, indicative of the “non-dispatchable” nature of the resource. At times of peak demand (demand > 90 percent of peak) the wind power output ranges anywhere between zero and full output, with a mean value of between about 30 and 40 percent, reasonably consistent with the wind farm load factor. Due to the lack of any evident correlation between output and network demand, the extent to which network capacity should be reserved to accommodate the scaling factor that would be applicable to wind generation by application of the security standards (83%) is highly questionable.

In order to investigate this issue further, we have looked in somewhat greater detail at the correlation between wind farm output and demand. The findings of this work are presented in graphical form in Figure 9.

Figure 9 Correlation between wind generation output (Scotland) and demand

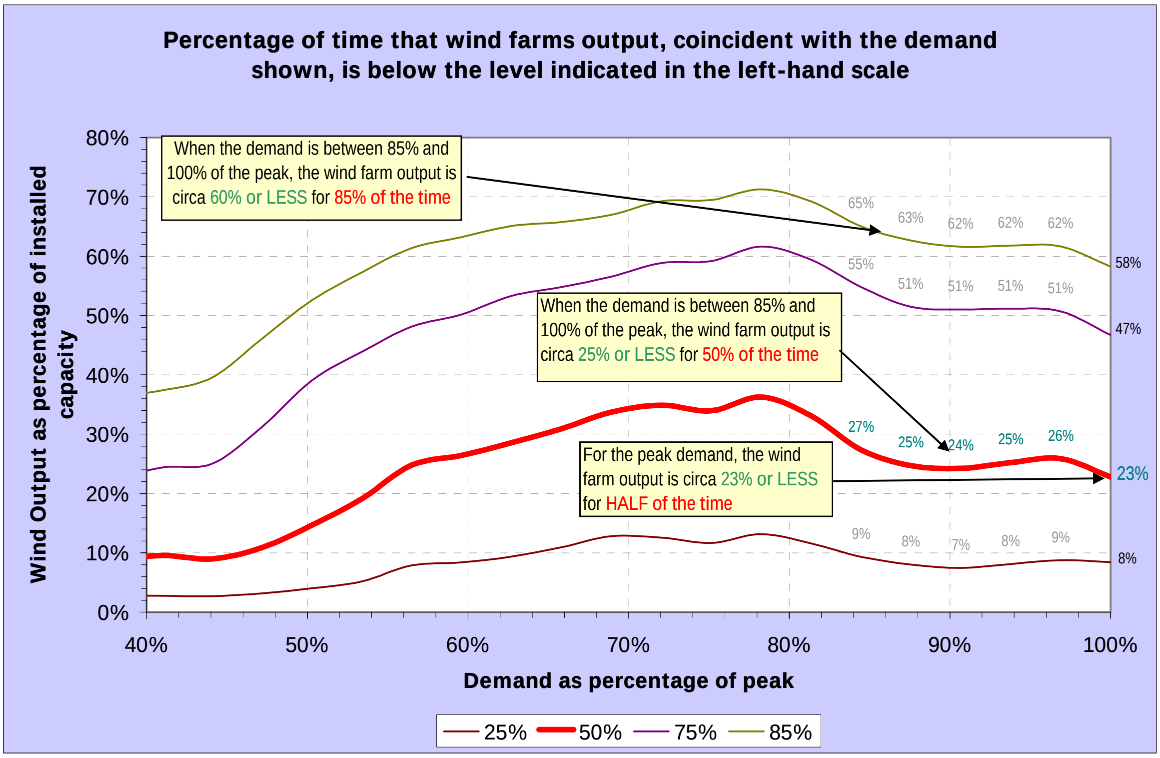


Figure 9 presents the results of a statistical analysis of the likely relationship between wind farm output and system demand. It can be seen from this graph that at times of near peak demand, the wind farm output is 60 percent[19] or less for all except 15 percent of the time. Conversely, at times of high/peak demand, the wind farm output is 25/23 percent of capacity for half of the time.

From the above it may therefore be concluded that with respect to securing demand, it is unreasonable to assume, and hence to invest in securing access to much more than about 20 percent of wind farm capacity.

In addition, when wind farm output variations are taken together with other issues, such as the non-availability of other generation, it is clear that the network may only rely upon a smaller proportion of wind generation. This aspect is addressed in greater detail below.

5.3.3 Wind Generation capacity credit

The wind generation capacity that may be considered to be available to meet system demand, and hence that capacity which needs to have a secure path to the demand groups is considerably more problematic than conventional (thermal) generation or hydro-electric generation which in most cases possesses a degree of storage capacity and hence can be reasonably dispatched to meet demand. In order to better quantify the capacity of wind generation at such times we have undertaken a Loss Of Load Expectation (LOLE) study of the GB system, based upon the NGC Generation Ranking order appended to the RETS1 report. Typical “equivalent forced outage (EFO)” and planned outage rates for the mix of generation included therein have also been used, together with a years typical half hourly wind generation output for a group of distributed wind farms and a corresponding network demand profile.

The approach adopted was to determine the LOLE corresponding to the raw demand data superimposed on the total generation availability characteristic, scaling the demand until a typical, 0.1 days per year LOLE resulted. The half-hourly wind generation output was then netted off the demand, taking full account of daily and seasonal effects to arrive at an adjusted demand profile reflecting the impact of a total of 6 GW of connected wind generation (consistent with the DTI wind generation projections) and this was then superimposed on the total generation availability characteristics, with the demand being rescaled until the same (0.1 days/year) LOLE resulted. The difference in demand scaling between the raw demand data and that adjusted to take account of wind generation indicates the capacity value of the wind generation.

The result of this analysis was that on a nominal peak system demand of 69.1 GW, with 6 GW of connected wind farm capacity the demand needed to be increased to 70.2 GW to obtain the same LOLE. In essence the capacity value of 6 GW of wind when associated with the GB grid demand of about 70 GW delivers about 1.1 GW of relevant capacity, i.e. a capacity value of 18.3 percent.

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[19] A value of 60 percent has been used by the TLs

On this basis, when determining transmission network capacity required to allow wind generation to secure demand, the scaling factor applicable to such wind generation corresponds to somewhat less than 20 percent. This finding is consistent with a significant number of references on this subject[20], including the recent work undertaken in connection with ER P2/6[21], which concludes that a maximum capacity credit of about 28 percent is appropriate for small blocks of embedded wind generation.

The quantification of the wind capacity value of about 20 percent is relevant both to the application of the deterministic planning standards, and also to the determination of generation constraint costs with particular respect to the "capacity cost" applicable to constraints associated with wind generation. These aspects are both considered in greater detail in later sections of this report.

Accordingly, when looking at the Main Interconnected Transmission System using a deterministic criteria, ideally as a first pass assessment, whilst it is appropriate, and consistent to use an 83 percent scaling factor for dispatchable generation, it is considered appropriate to assign a scaling factor of about 20 percent for wind based generation. The TLs recognize the uncertainty about the applicable figure to apply for wind generation as indicated by the change from the 83% factor used in the RETS study[22] to the 60% factor used in the assessments for the currently proposed reinforcements[23]. Our findings however show that a figure of around 20 percent may be more appropriate and indicate a significant change from the 60 percent coincidence figure adopted in the latest planning assessments by the TLs which we believe is more applicable to the determination of

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[20] Previous works on the capacity credit of wind energy, see literature survey chapter of "On the benefits of distributed generation of wind energy in Europe" PhD thesis, Dr G. Giebel, 2000. http://www.drgiebel.de/windPowerCapacityCreditLit.htm. The relevant section of this reference includes over a dozen references to earlier work on wind related capacity credit and concludes that the value falls to between about 10-15% for high penetrations.

[21] A review of the security standards applicable at distribution level, P2/5, has been recently undertaken to take into account novel sources of generation. The new standards are referred to as P2/6 and indicate a maximum average capacity contribution of wind to security of supply of about 28%.

[22] The RETS study by the TLs indicates: "The intermittent and dispersed nature of wind power presents some difficulty in determining the appropriate level of transmission system capacity. For the purposes of assessing transmission capacity at winter peak demand, it is considered that a diversity of 83% should be applied to renewable generation. This takes account of plant availability and diversity and is in accordance with the methodology specified in the Companies Planning and Security Standards."

[23] The TLs supporting analysis for the 60% figure is based upon determining the degree of correlation between the outputs of a number of wind farms when looked at as a group making use of common parts of the transmission network, refer to Appendix 5 of NGT Submission to SKM/Ofgem, dated 14 May 2004 "Technical Review of RETS2 Work

connection requirements for groups of wind farms, rather than when considering the aggregated effects of conventional generation, wind farms and demand groups.

It should be noted that this basis does not preclude the provision of additional transmission capacity to allow wind generation to be optimally used, however as required by the security standards, any additional investment should be subject to appropriate cost benefit assessment as per the requirements of the standards. The basis for such cost benefit based analysis is included in Section 5.4 below.

5.3.4 Main interconnected transmission system criteria.

As an example of the more detailed impact of this changed assumption on secured network power flows we have taken the generation assumptions appropriate to consideration of power flow requirements between Scotland and England by about 2010, and determined the impact of the above change in assumptions when applying NGC SQSS. For convenience we have based this upon the same conventional generation assumptions presented in the RETS study for that year, i.e. as follows:

Scottish generation assumptions			**Scottish demand**	
CCGT:	Peterhead	1524 MW	SP T&D	4600 MW
Coal:	Longannet:	4 x 576 MW	SHETL	1800 MW
	Cockenzie	1 x 576 MW	Moyle	450 MW[24]
Nuclear:	Hunterston B	1152 MW		
	Torness	1133 MW	E&W demand	57000 MW (required for ACS peak)
Hydro:	SSE	1000 MW		
	SP	106 MW		
Pumped Storage:	Foyers	300 MW		
	Cruachan	400 MW		
Other:	Grangemouth:	130 MW		
	Fife Power	134 MW		
Wind:		4000 MW		

[24] Not explicitly identified in the RETS study.

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The results of the associated calculations based upon the NGC SQSS are presented in Figure 10 and Figure 11.

Figure 10 NGC SQSS calculation with 60 percent wind capacity factor

Case with 60 percent wind capacity assumption

Demand	2009/10	NGC	57000	Scottish Demand		
		SP	4600	4600		
		Moyle	450	450		
		SSE	1800	1800		
		hence ACS peak	63850	6850		
					Scaling	
Generation	2009/10	SSE (Peterhead)	1524		0.83	1265
		Foyers (PS)	300		0.83	249
		SP (Coal)	2880		0.83	2390
		Cruachan	400		0.83	332
		Hydro (SSE + SP)	1000		0.8	800
		Nuclear	2285		0.83	1897
Wind TIC	**4000**	**0.6**	2400		1	2400
		Others	310		0.83	257
		Total gen	11099	11099	Scottish gen	9590
					Scottish Demand	6850
			Demand + gen (a)	17949	**Planned transfer**	**2740**
			ACS peak x 2 =	127700		
		Percentage of (a) over 2 x ACS		14%	**Plus IA (N-1)**	**4145**
	Interconnection allowance from circle diag =			2.20%		
			Hence IA in MW :	**1405**	**Plus IA/2 (N-2)**	**3443**

Figure 11 NGC SQSS calculation with 20 percent wind capacity factor

Case with 20 percent wind capacity assumption

Demand	2009/10	NGC	57000	Scottish Demand		
		SP	4600	4600		
		Moyle	450	450		
		SSE	1800	1800		
		hence ACS peak	63850	6850		
					Scaling	
Generation	2009/10	SSE (Peterhead)	1524		0.83	1265
		Foyers (PS)	300		0.83	249
		SP (Coal)	2880		0.83	2390
		Cruachan	400		0.83	332
		Hydro (SSE + SP)	1000		0.8	800
		Nuclear	2285		0.83	1897
Wind TIC	**4000**	**0.2**	800		1	800
		Others	310		0.83	257
		Total gen	9499	9499	Scottish gen	7990
					Scottish Demand	6850
			Demand + gen (a)	16349	**Planned transfer**	**1140**
			ACS peak x 2 =	127700		
		Percentage of (a) over 2 x ACS		13%	**Plus IA (N-1)**	**2481**
	Interconnection allowance from circle diag =			2.1%		
			Hence IA in MW :	**1341**	**Plus IA/2 (N-2)**	**1811**

It can be seen from these figures above that the required interconnector capacity flows change from planned, N-1 and N-2 flows of 2740 MW, 4145 MW and 3443 MW respectively obtained by the use of 60 percent capacity for wind, to flows of 1140 MW, 2481 MW and 1811 MW respectively when a 20 percent capacity credit for wind is employed. The conclusion that may also be drawn from the above, and using a similar assessment although not shown, is that based upon this conventional generation background, a further 2000 MW of wind, i.e. a total of about 6000 MW, could be connected before an N-2 secure interconnector capacity of 2200 MW is exceeded. This importance of this finding is discussed later in this document.

5.3.5 Summary of deterministic criteria

It is evident from the above that, when considering the aggregate effects of combinations of power stations of differing types and associated demand groups it is appropriate to use either the MITS deterministic criteria, correctly taking into account the capacity contribution of specific types of generation, or else to employ cost-benefit based analysis, essentially based upon generation constraint volumes and/or reductions in transmission losses coupled, when appropriate with Value of Lost Load (VoLL) or similar probabilistic security valuations.

5.4 Calculation of Constraint Volumes

5.4.1 Introduction

As concluded above, in the evaluation of the benefits driven by intermittent generation it will be necessary to quantify the volumes of constraint volumes for a level of installed wind capacity resulting from a secure operation of the network in accordance with the applicable operational standards.

The remainder of this section provides a high level overview of the process adopted to quantify the expected volumes of constraints that will result for a given level of wind installed capacity that is presented in Section 9

5.4.2 Modelling requirements

In the assessment of constraint volumes resulting from large-scale penetration of wind energy it is necessary to consider:

- The random nature of wind
- The wind turbine generator and wind farm output characteristics
- The operational standards applicable to each of the TLs
- The seasonal ratings of the network components

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- The seasonal and diurnal characteristics of wind
- The output characteristics of conventional generation in the network
- The network maintenance periods that will reduce network capability for a significant part of the year
- The changes in transmission limits of network boundaries for each network development scenario and operating condition

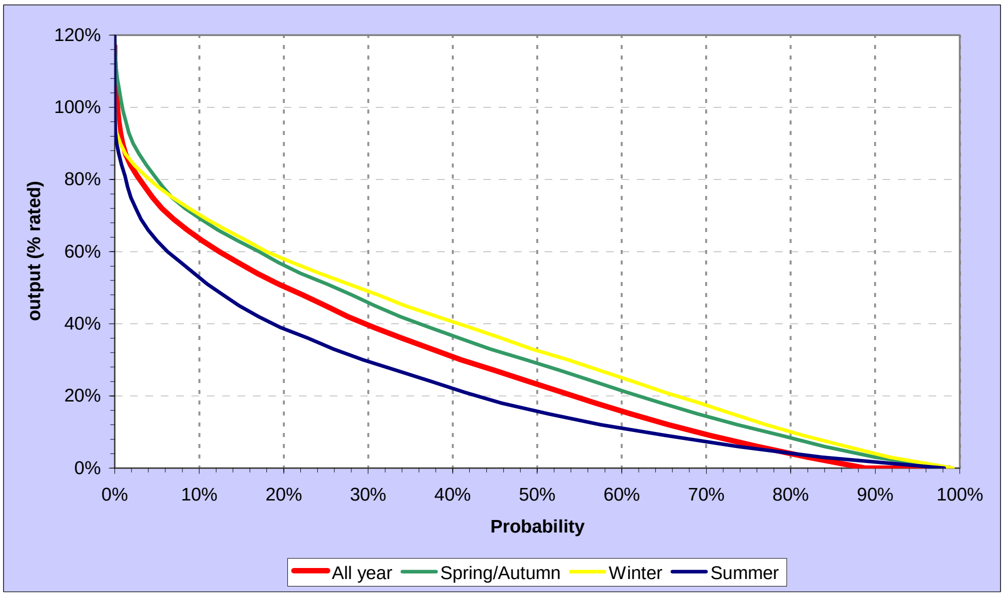
The tools employed by SKM for this review consider all of the above.

5.4.3 Data used

A. Wind Data and wind farm output

A record of wind data series applicable to Scotland has been processed through a typical wind turbine output characteristic to obtain the output from a single turbine. This output data series has been further processed through a wind farm output model that takes the statistical characteristics of the output between different wind turbines across a wind farm to arrive at a "Scottish Wind Farm output" data series. Figure 12 shows the seasonal output curves of the results obtained.

Figure 12 Seasonal wind farm output duration curves



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B. Generation and demand data series

We have used actual half-hourly generation, demand and circuit flow data comprising several recent years was provided in confidence for the purposes of this review by the two Scottish Transmission Licensees. The data has been extracted from records in their SCADA systems. Using this information we have calculated the relevant power flows across the boundaries of interest for the evaluation of constrained energy.

C. Network boundary transfer limits

The network transfer limits under each limiting boundary in the network have been modelled as advised and discussed with the TLs taking into account the results from detailed power system simulations for several operating conditions and the applicable rating of equipment for each season. Network Boundaries and limits applicable flow limits to each, before and after of the reinforcements are reviewed and are discussed in Section 7

5.4.4 Overview of the calculation process

The quantification of the expected volumes of constraints involves the following:

- Extraction of statistical distributions of wind farm output. The wind-farm output series data discussed above was processed to create 48 half-hourly statistical distributions for each season considered (Figure 13). Figure 14 shows the average half-hourly wind farm output distributions highlighting the importance of the modelling diurnal effects in Scotland as high wind farm outputs tends to coincide with high daily demand. For the purposes of this review we have grouped the Spring and Summer seasons as network equipment ratings are similar in these two seasons.

- Extraction of statistical distributions of flows (without wind) under study

- For each level of wind, power flow, season and half hourly period

    - Calculate the unconstrained power flow level (boundary flow + wind)

    - Calculate amount over applicable network boundary transfer limit (constrained volume)

    - Calculate probability of the condition above by reference to the statistical distributions of the flows and the wind calculated above.

- Collate and weight the results by season and network condition if applicable to obtain the expected volume of annual constrained energy.

Figure 13 Half-hourly seasonal distributions of wind farm output

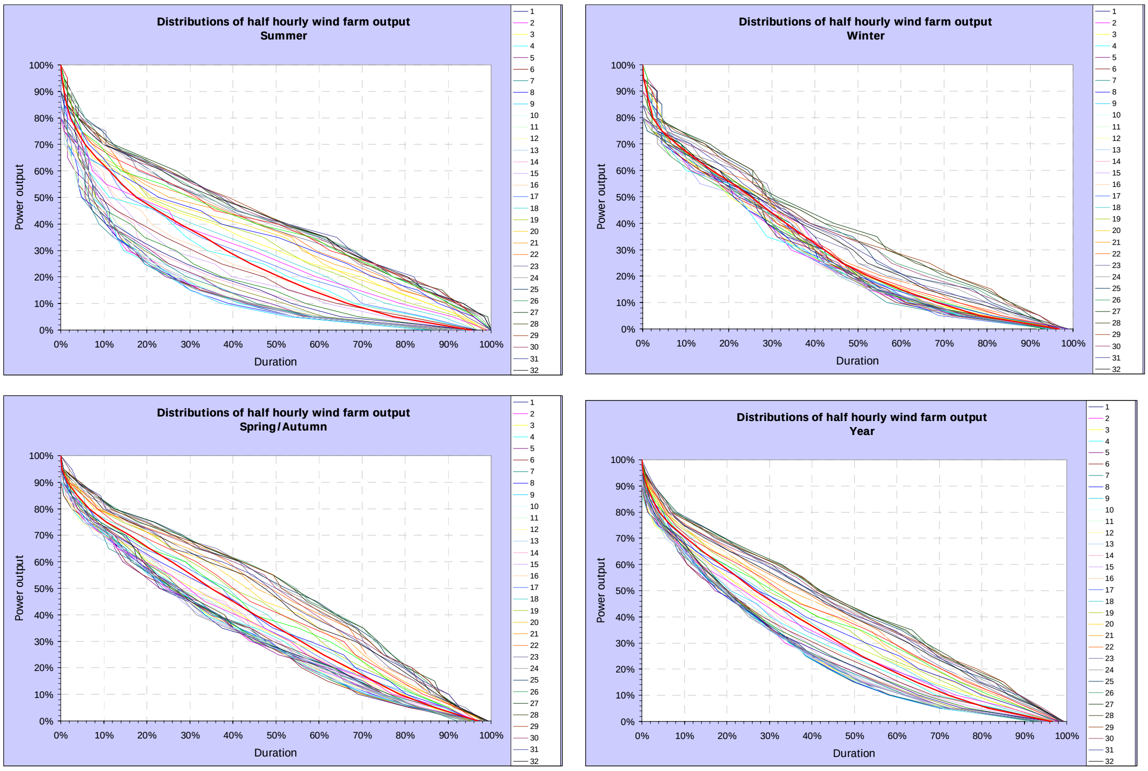
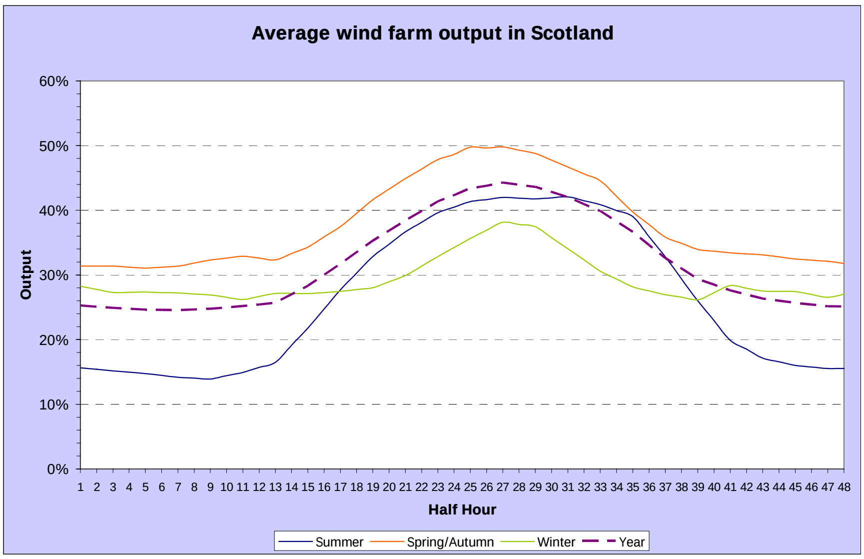


Figure 14 Half-hourly Average seasonal wind farm output (as % of maximum capacity)



5.5 Conclusions

The main conclusions from this section are:

- The methodologies in the companies' security standards do not provide guidelines for the modelling of intermittent generation sources, such as wind generation, in the assessment of transmission network capacity. It seems inappropriate to use the scaling factors applicable for conventional generation (83% of rating) to wind generation due to its different characteristics and the TLs have reflected this view in their latest planning assessment since the RETS study.
- An initial study on the correlation between wind farm output and demand indicate that, when the demand is between 85% and 100% of the peak, the wind farm outputs is below about 25% of maximum output for half of the time.
- Using a LOLE approach and using data for the complete GB system, the capacity credit factor that is applicable to wind generation for planning studies of the GB system corresponds to only about 20 percent of the total installed capacity. This observation is consistent with the reported findings from similar assessments undertaken internationally.
- The TLs have presented studies that have been undertaken including work commissioned from consultants that showed a correlation between wind farm outputs in Scotland of around 60%. The TLs have then used this correlation factor in network planning studies as a basis to determine secured network flows. However this factor is an average correlation factor between the output of wind farms and its implicit use as the "capacity credit" factor of wind generation, in the context of the companies' network planning standards e.g. when looking at the peak demand condition, is inappropriate.
- The difference between a "capacity credit" for wind generation of around 20% and the factor of 60% factor used in deterministic assessment of security will invariably result in the identification of network reinforcements either ahead of need and also in excess of actual requirements associated with a given installed wind generation capacity.
- It is this significant difference between the generation capacity available from wind on a secure basis, and that available on an average or coincident basis that point strongly for reinforcements associated with wind generation to be justified by cost-benefit based analysis. Such analysis needs to takes into account the daily and seasonal variability of wind generation, the equivalent variations in electricity demand and the inevitable, complimentary variation in conventional generation output.
- The treatment of wind generation under the planning standards is beyond our scope of work and our findings are hence based on a limited study as there are a number of other issues that need to be considered. Later in this document we have carried out some sensitivity analysis to consider other factors which may be applicable. It is recommended that the appropriate treatment of intermittent generation sources in the transmission security standards is subject to a consultation process within the industry.

6. Valuation of Constrained Generation Costs

6.1 Introduction

The penalty for not reinforcing the transmission system as the capacity of renewable generation installed in the network increases is primarily the constrained generation costs that result from the inability of the network to accommodate all the generation wanting to export into the network whilst being able to cope with the most onerous contingency under the applicable operational standards.

The penalty, in economic terms, arises from the "constrained" generation, which has to reduce its output as a result of the network operation limits, being more expensive than the generation that has to increase its output to replace it. This assumes that the "constrained" generation is the most economic to supply the required demand. This assumption is appropriate in a highly liberalised market where generation effectively "self-dispatches" such as under NETA because, in a correctly functioning electricity market, market forces will make generators and suppliers converge towards the optimum "economic" dispatch. It can only be assumed for the purposes of this review that the electricity market in GB will trend towards this goal and the Authority will continuously monitor its performance removing any distortions that divert it from this fundamental objective.

Additionally there may be an additional economic penalty if, as a result of network constraints, all or part of the generation capacity that is constrained could have been assumed to participate in securing demand. In such a case it becomes necessary to provide additional generation capacity to the other side of the constraint and the costs of this additional capacity should then also be part of the constrained generation costs above.

The economic benefit of a reinforcement driven by connection of intermittent generation sources can therefore be established by comparing the cost of the constrained generation costs against the costs of the reinforcement. A network reinforcement is justified for a level of installed capacity when the savings in constrained generation costs relieved by the reinforcement, capitalised as appropriate, equal the cost of the proposed reinforcement. The savings in constrained generation costs should therefore consider the difference in constraint costs before and after the reinforcement noting that constrained energy volumes may remain after the reinforcement.

In order to establish the costs of constrained generation energy it is then necessary to calculate the volumes of constrained generation energy for a particular level of installed renewable capacity. It is important to note that, to be consistent with the principle of the economic assessment of the costs in this review, the volumes of unconstrained generation energy should be derived from the generation dispatch that would have resulted using an economic dispatch based on actual generation costs to meet a particular level of demand. The economic dispatch however may not necessarily correspond to the resulting generation commitment and dispatch in the real market e.g. BETTA, and the impact of this issue is further investigated in Section 6.3.2.

Our review is concerned with an "economic" valuation of the constraints. The TLs have valued the constraints in RETS using prices consistent with energy balancing prices under NETA. In the following sections the assessment of appropriate values of constrained energy using "economic" and "market" valuations is undertaken which requires to be preceded by a brief review of generation prices under NETA that will provide the basis of the constrained energy price assumptions under a market scenario.

6.2 Visible generation costs under NETA

In order to validate the economic dispatch assumptions and examine applicable market prices for constraints we have reviewed half-hourly historic prices resulting in the Balancing Market under NETA from information published by Elexon. In the discussion below it should be noted that currently NETA is only applicable in England and Wales, with the forthcoming BETTA being the extension of NETA to Scotland thereby creating a unified GB wholesale electricity market. However we do consider that the generation in Scotland has been able to participate in the NETA market to some extent although the trading ability of individual generators has been limited compared to generators in the E&W system. It is considered possible that the recent historic behaviour of Scottish generators could have been broadly consistent with that resulting from their full participation in the E&W market, i.e. the position on a GB 'merit order' basis of the generators in Scotland is not changed by the introduction of BETTA (refer to Section 9.3.2). However there are uncertainties about the consistency between their future behaviour compared to its recent historic outputs after BETTA goes "live".

The market places strong incentives on generators and suppliers to balance their positions through the establishment of bilateral contracts. Any energy imbalances to the contracted positions are balanced by the System Operator by accepting bids and offers as appropriate in the Balancing Market. The two most important prices calculated in the balancing market for each half hourly period are the System Buy Price, SBP, (to increase generation and/or reduce demand) and the System Sell Price, SSP,(to reduce generation and/or increase demand). The SBP and SSP were calculated from the weighted average of the accepted offers and bids up to March 2003[25]. After this date the overall net imbalance of the system determines the main price (Buy or Sell) with the reverse price (Sell or Buy respectively) being based on prices from power exchanges.

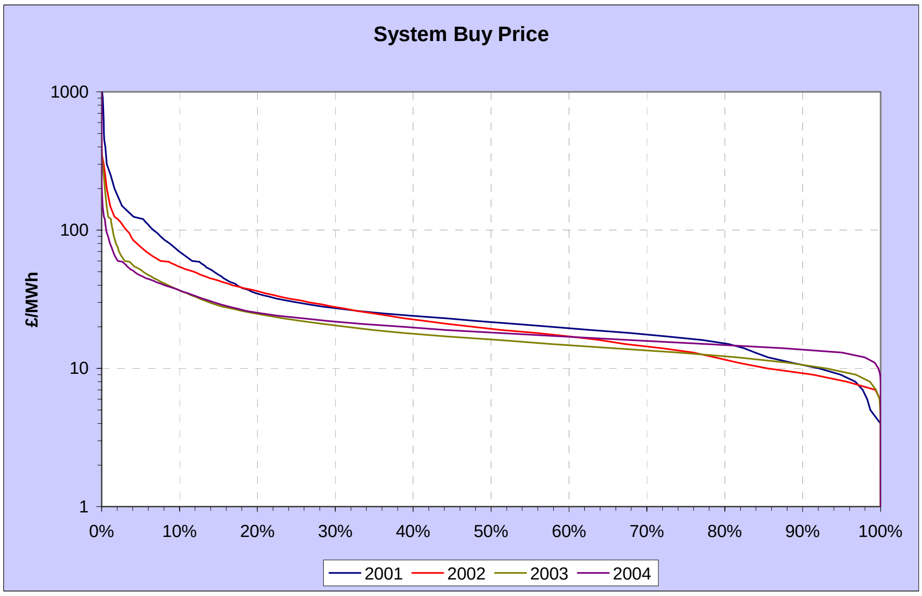
[25] Under P78 (BSC modification from March 2003 available from the Elexon website), bids and offers received in the balancing mechanism are weighted according to volumes rather than against imbalance volumes.

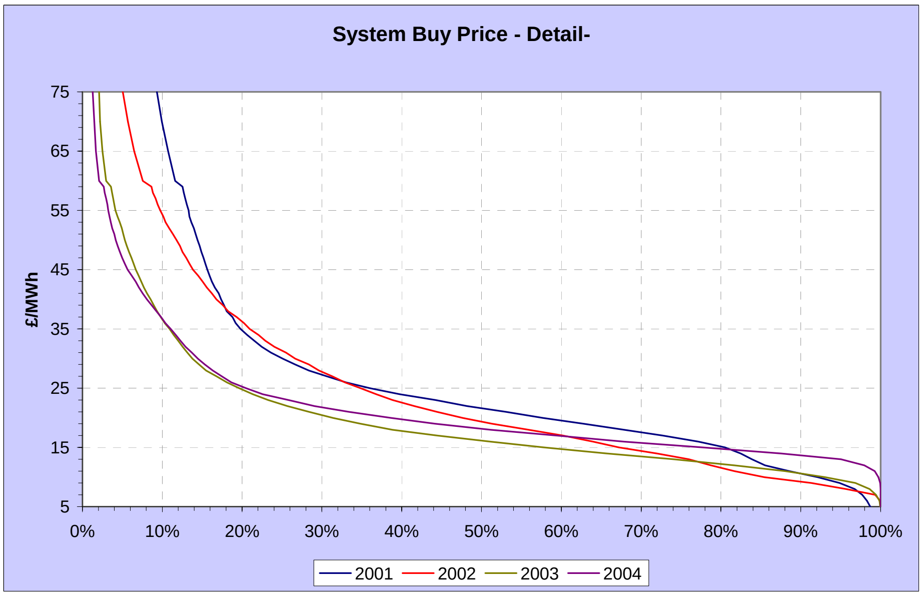
The imbalance volumes are normally a small proportion of the total generated energy. There is no direct visibility of contracted prices of the larger ‘balanced’ proportion of the supplied energy. However as generators have an obligation participate in the balancing market the resulting balancing costs can provide an indication of the underlying costs especially for operating conditions with “typical” imbalance volumes.

6.2.1 NETA Prices 2001-2004

Figure 15 and Figure 16 shows the distributions of the buy and sell prices respectively from the start of NETA to June 2004. Each point in the curve shown indicates the amount of time over the year that the price was above the indicated £/MWh value. The Buy price (Figure 15) shows extreme prices reaching hundreds of pounds per MWh (note log scale on top left chart with a chart showing a detail of the area of interest below it). It is however important to note from inspection of Figure 15 (detail) that the extreme prices occur for a small amount of time, and using the values from 2003 and 2004, values greater than £35/MWh only occurred for about 10% of the time. More than 50% of the time (median) the price was below £20/MWh over the same period.

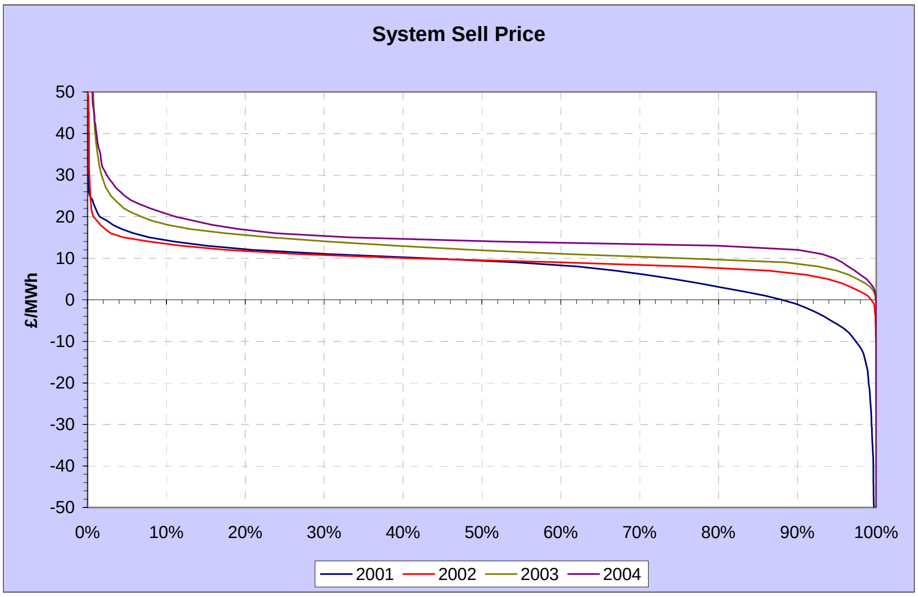
Figure 15 System Buy Prices Distributions 2001-2004 from half-hourly data

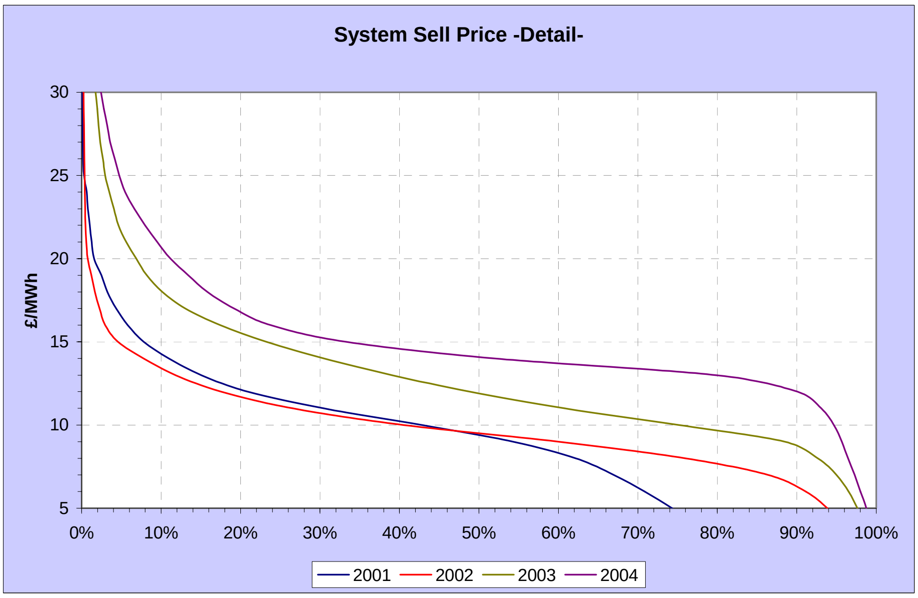




A similar analysis can be undertaken from the inspection of Figure 16 for the Sell Prices which are indicative of avoided generation fuel costs. Over the same period 01-04 the Sell price showed a much constant behaviour with prices below £15/MWh for most of the time. In 2003, the last complete year the sell price was below £12.5/MWh for more than 50% of the time (detail chart in Figure 16). Only for 10% of the time or less the Sell price went above £20/MWh.

Figure 16 System Sell Prices Distributions 2001-2004 from half-hourly data

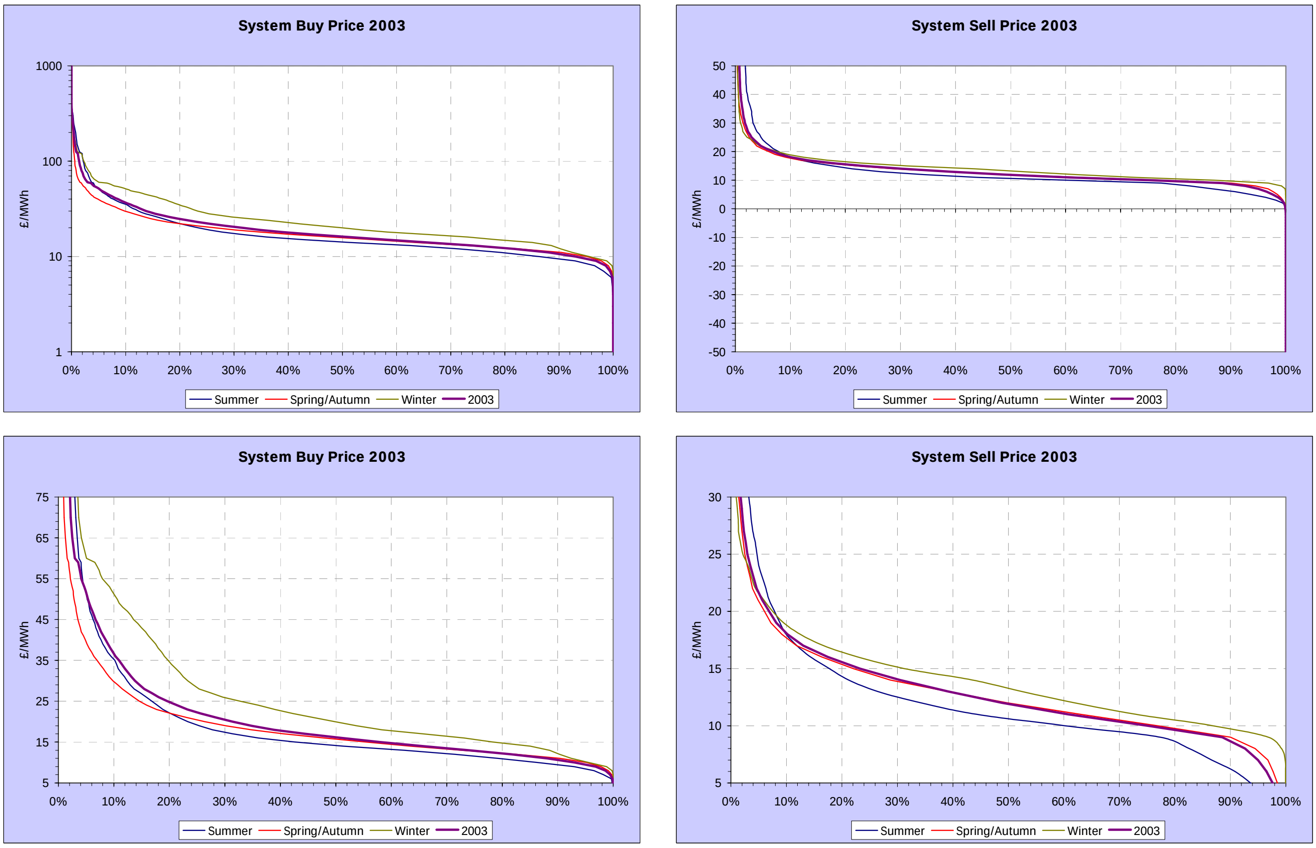




6.2.2 NETA Prices 2003

Figure 17 shows the historic buy and sell prices for 2003, the last year for which a complete record exists. As it could have been expected the record shows higher overall Buy prices during the Winter, when the demand is high and capacity is at a premium, and lowest prices during the Summer when the demand is low and there is a surplus of available capacity hence prices falling below £15/MWh for more than 60% of the time during this period. This behaviour is consistent with what could have been expected. Very high prices are also observed at certain times during the Winter period although presumably associated with relatively small imbalance volumes. The average system buy price was £23.5/MWh.

Figure 17 Seasonal System Buy and Sell Prices in 2003.



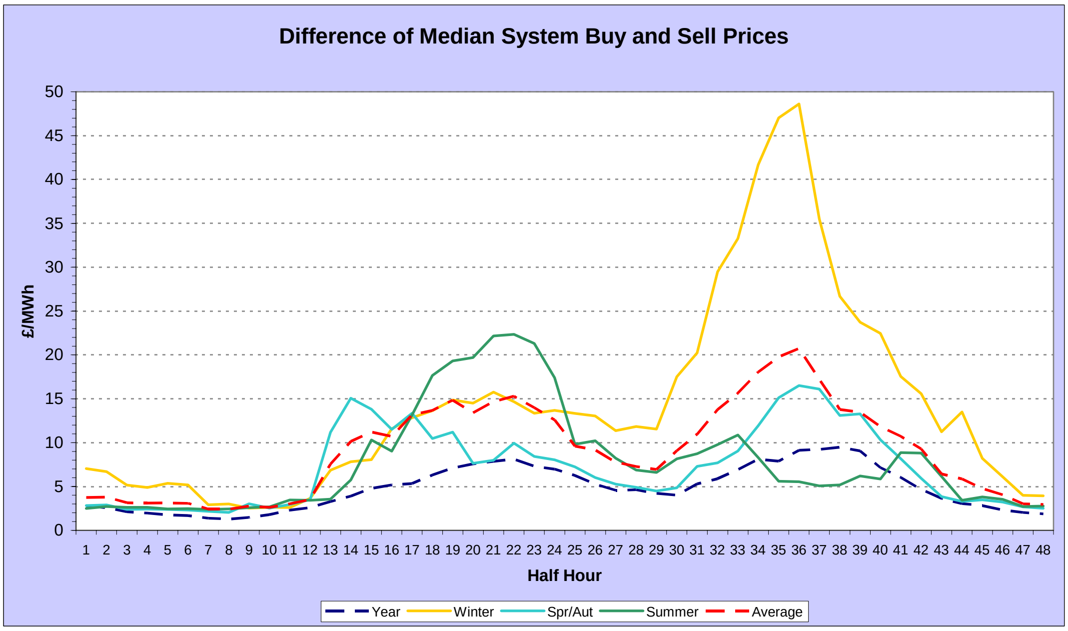
The examination of the Sell Price in 2003 indicates high prices during a small proportion of time during the summer consistent with surplus capacity that prefers to pay a premium to stay connected rather than incur the start-up costs, at least, if shut down. About 75% of the time prices are below £15/MWh. The average Sell price in 2003 was £14.4/MWh

The evolution of prices in 2003 has been further analysed to evaluate the relationship with the demand by splitting the price information in half hourly distributions for each season to take into account seasonality and time of day correlations and the added capacity value embedded into the Buy price. It can be assumed that the value of capacity in the market will be related to the difference between the Buy and Sell prices. As the information on volumes associated with each half hour period was not available the information has been ‘weighted’ using median values to avoid the “distortions” introduced by extreme price values observed in the previous figures.

Figure 17 shows the results obtained which, as it could have been expected, indicate a high capacity premium at time of winter peak, relatively modest values during the Spring/Autumn season where it can be expected that a significant amount of generation participating on the Winter peak will be available with a reduced demand, hence the lower values. Finally in the Summer somewhat higher values are observed during the day probably the result of reduced generation availability (planned maintenance) and a practically “flat” demand profile during the day.

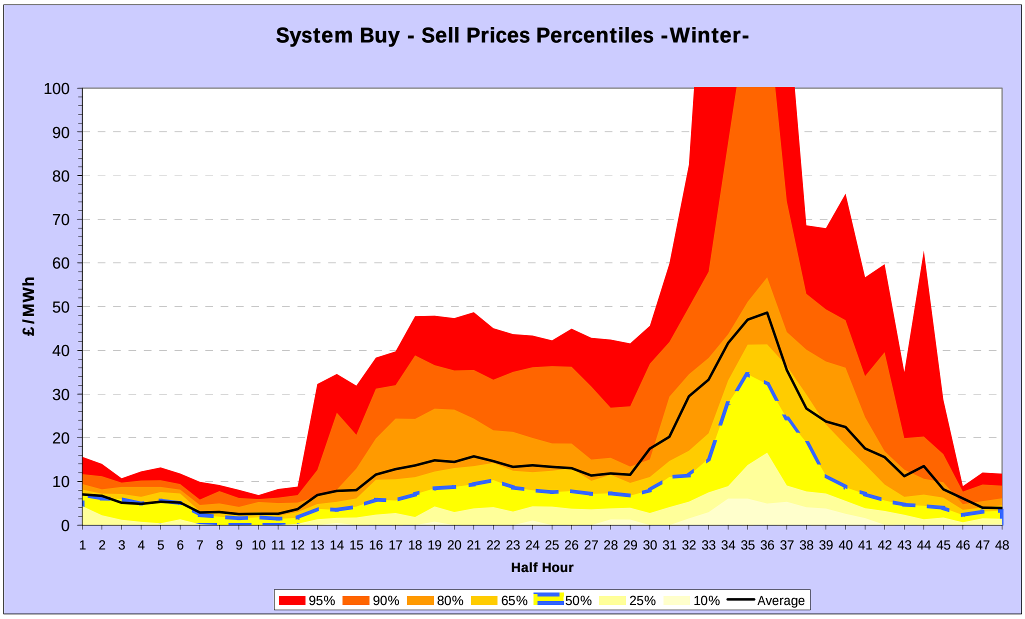
The average difference of the Buy and Sell Prices in 2003 is also shown in Figure 18. The average half-hourly “capacity premium” value was £9.2/MWh. This value compares well with the capacity payment for a conventional power station. For example, assuming values for the capital cost of conventional plant of circa £350/kW with a utilisation factor of 55%, interest rate of 12% over 25 years, the capacity cost would amount £9.25/MWh.

Figure 18 Difference of Median System Buy and Sell Prices 2003



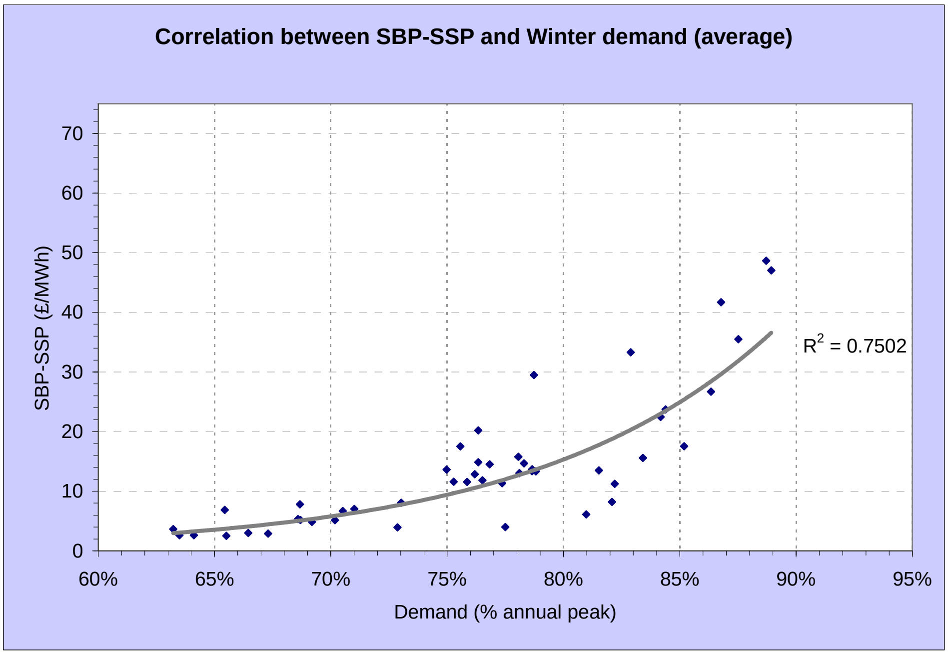
The highest “capacity premiums” are, as it could have been expected, encountered in Winter. Figure 19 shows the percentiles for the difference between buy and sell prices for Winter. Each percentile shows the amount of time within each half-hourly band that the difference between Buy and Sell Prices was below the indicated value. The results obtained reinforce the correlation with the daily demand pattern in Winter. As it could be expected, as the system runs out of generation capacity when the demand approaches the peak the capacity premium increases similarly to the case under an economic dispatch scenario where as demand increases and gets to the peak it is required to make use of lower merit order generation (i.e. more expensive). It is also important to note the marked diurnal variation in the price before the morning peak and the evening peak indicating surplus of generation capacity that is there to meet the evening peak but that probably finds more expensive or technically unfeasible to shut down. Even the 95% percentile reaches circa £7/MWh with median prices of about £2/MWh. This behaviour of the capacity is consistent with an 'economic' behaviour of the generation.

Figure 19 Winter 2003 System Buy minus Sell Prices percentiles



The review of the "capacity premiums" suggested by Figure 19 and its correlation with the demand, and implicitly with the generation on offer, has been further investigated. The Winter demand curve shown in Figure 18 has been correlated with the corresponding average Winter demand. The results obtained are presented in Figure 20 which also plots an exponential 'best-fit' trend curve which indicates a fairly high degree of correlation (75%). This result is consistent with what could have been expected, at times of high winter demand the capacity premium increases considerably as more expensive units (higher in the "underlying" merit order) are called into the system and the available margin (competing units) reduce.

Figure 20 Correlation between average SPB minus SSP and Winter demand 2003



From the brief analysis above we are satisfied that under NETA, the indications from the Buy and Sell Prices is providing signals which show a consistent performance with our expectations using an economic criteria under the various seasons and demand levels for market participants. The level of prices appearing for most of the time are likely to be reflective of underlying economic costs by virtue of the competition between generators and are, in general, considered broadly consistent with typical generation costs.

It will therefore be considered in the rest of the review that the underlying generation dispatch follows reasonably closely the optimum “economic dispatch” of the system. It can be concluded that from an energy and capacity point of view NETA would seem to be producing reasonable signalling, with typical SBPs of around £10-15/MWh and SSPs of around £20-25/MWh. However it can not be concluded that this is also the case from a constraint management point of view nor that the prices implied from the analysis above should be used as the basis for valuing constraints. These aspects are further discussed below.

6.3 Valuation of constrained generation energy

This review is primarily concerned with an economic valuation of constraints and hence an “economic” valuation of constrained generation energy however, in addition the market valuation of constrained energy will also be assessed. Under NETA the constraint energy costs are determined from bids and offers submitted by the generators and balancing actions from the system operator to achieve system balance in the most efficient manner to overcome the network

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constraint. In this context the SBP and SSP values examined above will serve as indicators of the possible constraint costs applicable under a “market scenario”. Both cases the “economic” and the “market” scenarios are considered in the following sections.

6.3.1 Economic valuation

In economic terms the constrained generation energy should be valued at the additional generation production costs incurred by the implicit generation displacement. This assumes that the initial “unconstrained” dispatch was efficient for the corresponding level of demand. Generation to one side of the constraint will be “constrained-off”, reducing its output whilst generation on the other side of the constraint will be “constrained-on”, increasing its output into the system. The difference in the cost between these two generation dispatch programmes, with and without constraints, is the “economic cost” and at times of adequate generation capacity would corresponds to the difference in marginal costs between the generation “constrained off” and the generation that is “constrained on” the system.

In the case of constraining conventional fossil-fuel generation, the economic generation costs is the difference between the heat rates of the two units. The actual value will depend on the specific units being “constrained-on” and “constrained-off” but differences in efficiencies between generation “constrained-on” and “constrained-off” will typically be quite low with values ranging from around £1/MWh (in case of ‘replacement by same technology’ e.g. old coal by old coal) to £5/MWh constrained (in case for example of CCGT being replaced by old coal) by reference to publicly available information referenced in recent reports[26].

In the case of constraining wind generation, the economic costs of constrained energy are considerably higher than the estimated difference in marginal generation costs that would be applicable for conventional fossil-fuelled generation, due to both its “zero fuel cost” and the implicit environmental costs associated with other, non-renewable generation. As indicated in Section 2.1.1 we consider the buy-out price of ROC as a proxy of its environmental added value. In addition using wind generation avoids fuel burn by conventional generation in another part of the system. Current estimates of underlying generation costs indicate an average variable cost

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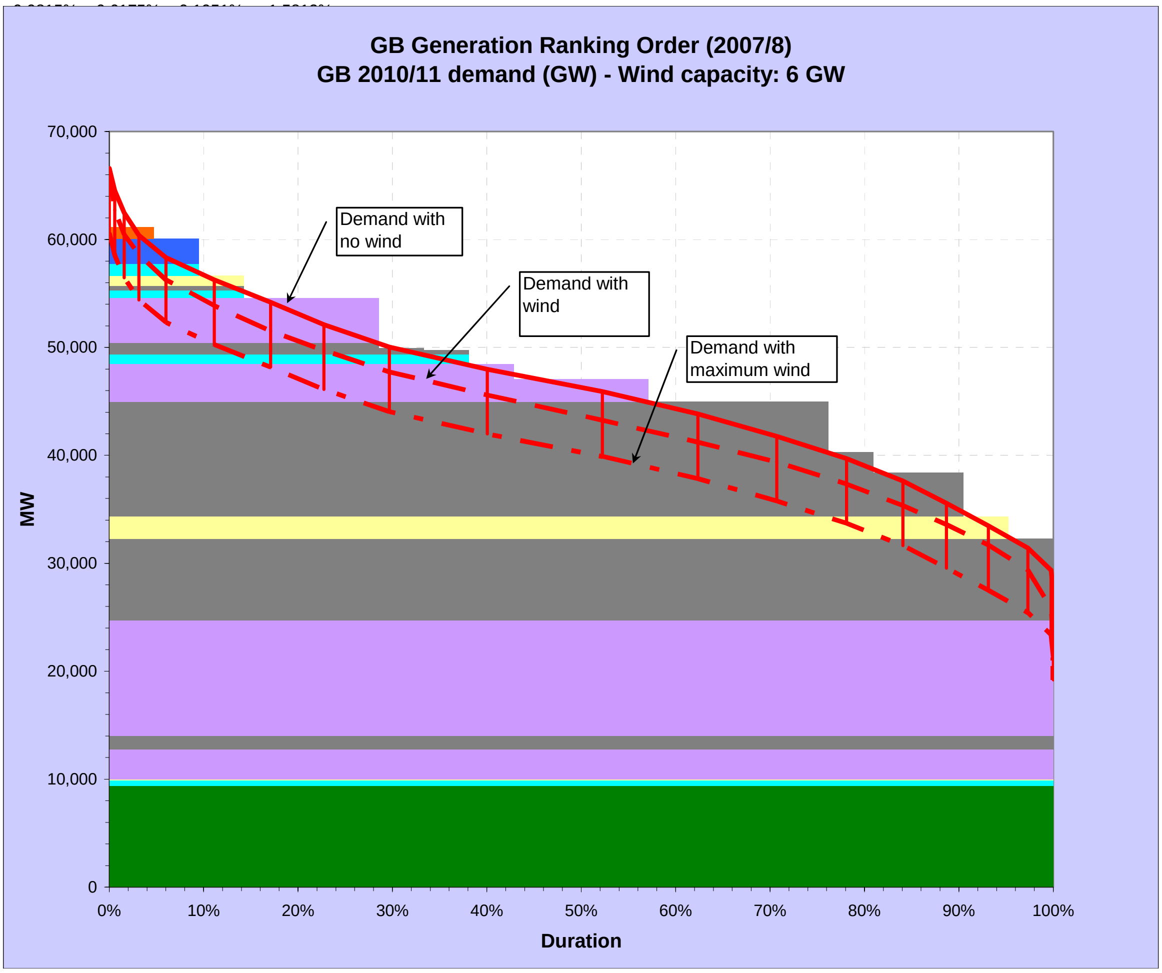
[26] “Implication of the EU ETS for the Power Sector”. A report to DTI, DEFRA and Ofgem. September 2003. Ilex Energy Consulting.
”The Non-Market Value of Generation Technologies”. Oxford Economic Research Associates. June 2003.
”The Energy Review”, Annex 6. Performance and Innovation Unit, UK Cabinet Office. February 2002.
”Costs and Benefits of East-West Interconnection between the Republic of Ireland and UK Electricity Systems”. Report to the Commission for Energy Regulation, Ireland. DKM Economic Consultants, June 2003
”Best New Entrant Price 2005”, Commission for Energy Regulation , CER/04/256, July 2003.

generation of around £15/MWh which is also consistent with the market SSP discussed in Section 6.2. The economic cost that will be applied in this study for constrained wind generation energy is hence £45/MWh (£15/MWh + £30/MWh).

6.3.2 Generation Displacement

In the case of generation constraints imposed by the combination of wind generations and transmission limitations, it should be noted that some generation reductions may be required from thermal generation located “behind the constraint” as it moves under economic or commercial pressure to create room for the renewable generation. In an economic model the extent of this would be based upon generation merit order and other operational issues. In a NETA and ROC market place this may be determined by contracts put in place with the generators supply customer and required to allow the latter to meet its renewable generation obligations. This observation can be illustrated by the graph below which presents a simplified economic stacking of GB generation based upon the use of the RETS “Generation Ranking Order” (for 2007/08) applied to an equivalent GB 2010/11 demand profile which takes into account the presence of target levels of about 6 GW of wind generation not reflected in the dominant NGC demand profiles, i.e. transmission connected wind generation in GB and also the Scottish DNO connected generation. It should be noted that this graph is not intended to indicate actual system generation dispatch or the operational role of the likes of the “EDF link”, or even the continued operation of specific plant at that time, but it is intended simply to demonstrate the generation displacement issue inevitably arising with wind generation on the system.

Figure 21 GB Generation ranking order and effect of 6 GW of additional wind capacity



For explanation, the graph presents both the underlying demand profile (solid red line) and also modified demand profiles (dashed red lines) where the seasonal distribution of wind generation has been "netted off" the system demand, both in mean terms, in essence the correctly weighted combination of demand and "netted off" wind and, in order to demonstrate the range of influence of wind generation, also the extreme "netting off" at times of high wind and hence maximum wind generation output. The key point to note from this graph is the likely effect of wind on the load factors of the mid-merit coal fired generation, including Longannet. In essence it is this generation which would normally flex in response to wind, at times of low wind operating up to the (solid red) demand line, and at times of high wind operating down to the (chain dashed red) "maximum wind" line.

If, as is likely certain of this "flexing" generation was sitting behind a constraint, Longannet say, then firstly the need to constrain the same generation against a hypothetical "no wind dispatch" would obviously be reduced, and secondly it is also clear from this chart that other generation which may be needed to make up for any constrained output from this same station would comprise very similar merit order plant on the demand side of the constraint. However, such an observation can not be made about Peterhead CCGT1 for example which, if displaced would need to be substituted by lower merit coal plant at a significantly lower thermal efficiency.

It is also reasonably clear from the above graph that there will be a sizeable market associated with following wind generation power output variations at the levels of wind penetration assumed. Whilst a large part of this variation will be expected to be managed through contracts between suppliers and both wind and conventional generators, at times of higher wind, there will be significant generation capacity which has been displaced by the wind but is nevertheless available to operate in the balancing market. It is the presence of this capacity which is expected to generate competition and hence minimise "buy prices" downstream of any constraint. In the case of generation upstream of any constraint, providing there was a reasonable amount of competition in the "sell" market place then an efficient market would be expected to deliver appropriate cost reflective "sell prices". However, if there is inadequate competition in such a market place then it is clearly inappropriate to rely solely upon market forces to deliver cost reflective prices.

6.3.3 Market valuation of constraints

Sell Prices of about £15/MWh align with the reduction of generation costs due to the reduction in fuel burn, i.e. it would seem to align to the underlying economic benefit (reduction in costs). By definition, the fact that the bid (to reduce output) is accepted, means that there is surplus of capacity in the system as another generation can secure the demand at a cheaper price whilst the generator is able to keep its contractual obligations hence bid prices will tend to largely follow the savings in fuel burn without adding a capacity premium. This is consistent with the statistical distributions of Sell Prices presented in Figure 15. The figures presented earlier show that for more than 50% of the time the Sell Price is below £15/MWh (75% in 2003) and it is reasonable to expect that the fuel costs of the contracted generators will lie below the market imbalance prices.

It has been argued that the economic cost of constrained energy for conventional generation should be higher than the difference in the marginal generation cost between the generation constrained-on and constrained-off as the players that are constrained-off will have to recover fixed costs over a smaller total revenue. Whilst it is true that there is a financial cost to the generation that is constrained-off, it is incorrect that this "financial" additional cost to the players to one side of the constraints should be included in the "economic" cost indicated above. It can be directly seen that the loss of revenue to one side of the constraint is compensated by the increased revenues to the other side of the constraint so, in economic terms, the only global additional cost is the difference in the efficiency between the units. In setting its price in the market the generator will, in simple terms, add to the variable costs per unit generated a fixed amount based on its estimate of its utilisation so that when multiplied by the expected number of units generated it will equal its fixed costs including profit. As a generator becomes constrained (reduces its utilisation) its price in the market should increase and following the same argument a generator that is constrained-on will be able to reduce its prices in the market. The generation installed capacity in the system is required to meet the peak demand. The capacity margin in the system to secure the peak demand dictates the level of generation capacity required in the system and hence it is directly related to the fixed costs that the generators as a whole will try to recover from their contracts. It can then be concluded that only if the constraints affects the capacity margin and it becomes necessary to add more capacity, that an additional cost should be added to the economic cost indicated above. Nevertheless, market forces may be such that generators tend to recover the costs of capacity across all their generation output, including when output increases because of a constraint. This issue is further considered in Section 6.4.

Buy prices averaged around £24/MWh in 2003. However average constraint costs of £40/MWh have been reported with the System Operator being exposed to high prices. The analysis shown above indicates that the addition of the forecast level of wind capacity will introduce significant pressure on existing conventional generation that will have to compensate for wind output fluctuations at reduced utilisation factors. This will result in more conventional generation capacity being available on the system for more of the time that, in a correctly functioning market, will put downward pressure on capacity prices (SBP-SSP) with the consequential effect on the applicable constraint payments.

6.4 Valuation of security of supply

There is an important additional cost that should be considered that may be factored in the offers made by generators into the balancing system and that is the capacity costs. It is considered that an additional economic cost should be added to the value of constrained energy if, as a result of the network constraints the system requires additional capacity i.e. the constrained generation capacity is required to secure the system demand at times of peak.

This element of network security is covered by NGC SQSS, in particular Chapter 3 of the SQSS which addresses the main interconnected transmission system criteria. Within this section specific guidance is given as to the determination of generation capacity to be taken into account, the resultant “planned transfer” and also the required “interconnection capacity”. In the case of power flows heavily influenced by wind, as outlined in Section 5.3, it is appropriate that a capacity value about 20% should be applicable for wind generation. In the case of hydro-electric capacity, SHETL and SPTL practice has been to assume an 80 percent factor, and in keeping with NGC SQSS a factor of 83 percent should be applied to conventional generation considered to be in merit at times of system peak demand.

Based upon the above information and the forecast system ACS peak demand, together with the demand in any identifiable demand/generation group with a demand in excess of 1500 MW, an appropriate interconnection allowance can be determined which, when applied to the planned transfer indicates the required capacity of any interconnectors, under both an N-1 and also N-2 conditions. Providing the interconnectors have the appropriate capacities, and hence do not constrain generation at such times, then at other times when generation capacity may be constrained, it will be inappropriate to assign any value to that constrained capacity.

In the event that the interconnector capacity did impose a constraints on the required power flows, then in any cost~benefit analysis related to possible reinforcement of the interconnectors, an appropriate valuation would need to be placed on the constrained capacity. This would be expected to equate to the capital costs of appropriate substitute generation capacity, possibly open-cycle gas turbine or CCGT dependent upon the likely volumes of energy associated with any capacity constraint. Typically therefore these costs could range from about £250/MW up to £350/MW depending upon size and efficiency. However, reference to Section 5.3.4 indicates that in the case of the Scotland-England interconnectors this issue would not arise until more than about 6,000 MW of wind capacity is connected.

6.5 Consideration of Losses

The establishment of annual targets for the proportion of energy that suppliers should source from renewable sources and the ROC penalty costs otherwise implies an economic value in the replacement of fossil-fuel generation by environmentally friendly renewable generation. A reduction in network losses would have the same effects and therefore we consider it justified to assign the same economic value in the reduction of losses as the economic value that has been established for the constrained renewable energy namely £45/MWh. It should be noted however that in the calculation of the benefits from loss reduction the difference should be calculated between the system losses without reinforcements (with applicable constrained flows) and the system with reinforcements (with remaining constrained flows).

This value compares well with the value of £48/MWh proposed by Ofgem[27] to incentivise loss reduction in the DPCR4. This value is higher than the value that we propose although it should be noted that in the case of the DNOs networks additional capital expenditure efficiencies (delay of network reinforcements) may be achieved through the demand reduction achieved by the reduction of losses at distribution level, hence a higher value could be expected than at transmission level.

[27] Electricity Distribution Price Control Review: Initial Proposals. Appendix – The losses incentive and quality of service. June 2004. Ofgem. www.ofgem.gov.uk

6.6 Conclusions

The quantification of benefits from network reinforcement through the valuation of savings in constrained energy and losses can be undertaken using an economic or market based valuation of constrained energy prices. Under a competitive generation scenario to both sides of a given constraint, the market prices will tend towards the economic prices that represent the underlying generation production total costs.

From the analysis undertaken of market prices the following is concluded:

- The behaviour of prices (Buy and Sell) under NETA seems to follow a logical economic pattern linked to variations in the demand.
- Large excursions are observed in the System Buy Price (SBP) and a much more stable pattern in the System Sell Price (SSP).
- The average SSP in 2003 was £14.38/MWh which is representative of average fuel savings. More than 75% of the time the SSP was below £15/MWh
- The average SBP in 2003 was £23.5/MWh which includes fuel and capacity costs. More than 60% of the time the SBP was below £15/MWh
- The average difference between the SBP and SSP which is a proxy for the capacity value was £9.2/MWh in 2003. For 50% of the time the difference between SBP and SSP was below £4/MWh
- Average constraint costs of £40/MWh however have been reported although at peak times these costs could increase significantly leaving the System Operator exposed to high constraint payments that ultimately will be transferred to the consumers tariffs.

From the economic analysis of constraint costs the following is concluded.

- The economic cost of constraining wind is around £45/MWh which includes the ROC buy-out price and fuel savings for conventional fossil fuel generation of circa £15/MWh
- The economic cost of constraining conventional fossil fuel generation is about £1/MWh for replacement by “same generation technology” and circa £5/MWh for replacement by “more efficient technology” (e.g. old coal by modern CCGT). The difference in cost corresponds to the reduction in efficiency costs. However it should be noted that the latter price difference with Peterhead of £5/MWh will be eroded as old coal gets retired. Under such future scenario the generation displacement will involves more often displacements between CCGT units and then the lower value will be applicable to constraining Peterhead.
- The costs that can be associated with the replacement of the capacity contribution of wind generation need to be determined on an individual constraint basis, based specifically upon the expected security contribution of that generation and any constraints imposed thereon by the

associated network. In the case of the Scotland-England interconnectors, analysis indicates that this will not arise until about 6000 MW of wind is connected north of the constraint.

- The economic value of losses adopted in this study is the same as constrained wind energy i.e. £45/MWh as its effects are identical. This value is consistent with recent incentive proposals by Ofgem for the DPCR4.
- Although the capacity credit of wind is small, at times the generation capacity that it will displace will be considerable as wind generators output fluctuate between high and low levels of output compensated by conventional generation. It is therefore expected that under a scenario with high levels of installed wind capacity there would be increased competition of conventional generation that would tend to reduce the historic market capacity prices indicated above.

7. Review of reinforcement proposals

7.1 Introduction

This section provides an overview of the main features and drivers for each of the proposed reinforcements under review in this study. Budget cost information for each of the projects including its phasing is provided in Section 8.

The identified network reinforcements may be broken down into the following projects, namely

- Beauly - Denny line (SHETL-SPTL)
- Scotland – England interconnector upgrades (SPTL-NGC)
- North East ring upgrade (NGC)
- Heysham area reinforcements (NGC)
- Kendoon area connection infrastructure (SPTL)
- Sloy area connection infrastructure (SHETL-SPTL), Stage 2.
- Orkney/Shetland and Western Isles connections (SHETL)
- Beauly-Keith upgrade (SHETL)[28]

Figure 22 shows the approximate geographic location of the proposed reinforcements.

[28] Initial engineering and design works only

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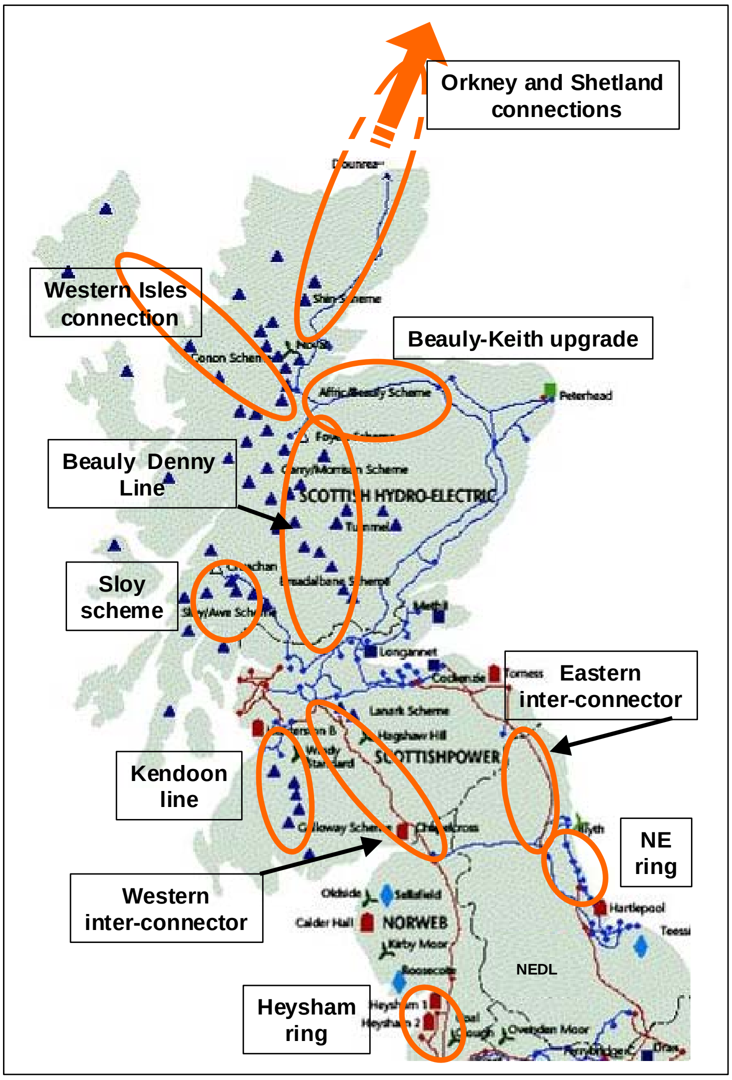
Figure 22 Location of proposed reinforcement expenditure under review



7.2 Beauly-Denny reinforcement

Over 1900 MW of quotes have been issued in the area north of Beauly with the expectation that a significant proportion of these will accept and connect. The additional generation capacity will increase the power flows through the main North-South transmissions corridors of the SSE network namely,

1. The 275 kV North South transmission corridor (Kintore/Tealing)
2. The 132 kV North- West transmission corridor (Beauly/Keith/Fort Augustus)

Two main reinforcement options have been considered which involve the reinforcement of the 275 kV network namely the reinforcement of the West and East transmission corridor. Following detailed system studies the West corridor reinforcement option resulted as the most attractive under a wide range of scenarios.

The proposed reinforcement involved building a new transmission line initially operated at 275kV but using 400kV construction between Beauly and Denny (near Bonnybridge), along a similar route to the existing 132kV tower line.

7.3 Scotland-England Interconnectors/North East ring reinforcements

Reinforcement of the Scotland –England interconnection has been proposed jointly by SPTL and NGC. However, in the work submitted by the TLs, the interconnector upgrades has been linked with the North East ring upgrade and essentially presented as a single project. Our initial review of the information submitted highlighted the fact that it was appropriate to investigate the merits of each constituent part rather than bundling such projects together. By doing so it is possible to gauge which parts, if any may be justified and which parts may be better delayed. Accordingly we have requested information from the TL in a more disaggregated form to better facilitate consideration of a staged development. It should be noted that the level of renewable generation activity necessary to justify the combined project may be considerably greater than that of one of the individual stages.

7.3.1 Scotland-England interconnector upgrade alone.

This Scotland-England interconnector upgrade project comprises reconductoring of the existing 400 kV double circuit eastern interconnector, together with associated works at the terminating substations and the establishment of a new 400 kV termination for the line at Blyth, and also the uprating of the existing 275 kV operating circuit on the western interconnector and associated substations to 400 kV operation.

The intention of reconductoring of the eastern interconnector is to increase its thermal capacity to a summer rating of about 2900 MVA per circuit. The proposed uprating of the remaining 275 kV western interconnector and associated substations to 400 kV will increase the rating of that circuit to match that of the adjacent 400 kV operating circuit, i.e. to a summer rating of 1750 MVA and will result in a double circuit 400 kV interconnection being provided on both sides of the country. Information relating to the singular benefit of this uprating, i.e when not taken in concert with other works was not initially provided by NGC. However, subsequent to our questioning on this issue and after having undertaken additional studies, recent information from NGC[29] indicates that when

[29] NGC emails of 15 July 2004 and 22 July 2004.

taken together with a Beauly-Denny upgrade, the eastern interconnector re-conductoring and the western interconnector upgrade projects will increase the Scotland –England interconnector capacity to about 2800 MW[30], from the present level of about 2200 MW, with the interconnection limit after reinforcement largely determined by stability considerations. It is on this basis that we have investigated the incremental value of these works with respect to cost-benefit analysis.

In response to SKM questions, NGC advise that with appropriate use of Static VAr Compensation (SVC) equipment, the interconnector stability limits could be increased by about 300 MW from either its present capacity of 2200 MW, i.e. to 2500 MW[31], or from the upgraded capacity of 2600 MW to about 2900 MW. Also, if only the western interconnector upgrade was undertaken in addition to Beauly-Denny, the interconnector stability limit would increase to about 2500 MVA[32]. In all cases the "firm" N-2 rating of the interconnector would be limited by thermal considerations. However, these increased stability limits would be particularly relevant if consideration was given to relaxing the operational standard to N-1 at times of low double circuit fault risk as allowed in the standards, as under such conditions increased pre and post-fault transfers could be allowed without recourse to fast generator inter-tripping to secure against the N-2 fault condition. If taken together with the likelihood of enhanced line thermal ratings at such times, due to the cooling effects of the wind[33] it is likely that such increased power flows could be tolerated without initiating any automatic generator reduction measures.

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[30] Based on stability study results which indicate 2600 MW, enhanced by additional SVC equipment to 2800 MW (not studied by NGC)

[31] Under this condition the "firm", i.e. post double circuit fault capacity would be limited to about 2200 MVA by thermal considerations. It should be noted that NGC's 2004 SYS indicates different winter/spring-autumn/summer thermal ratings for the two eastern interconnector circuits, namely 1390/1280/1110 MVA for one circuit and 1190/1100/1100 MVA for the other. Advice from NGC (telecom of 26 July 2004) indicates the capacity of the lower rated circuit is limited by the rating of EHV cable associated with two of the four interfacing, 400/275 kV, 1000 MVA transformers at Stella West. To remove this limitation it would be necessary to augment/replace such cable circuits. The associated costs would approximate to about £ 2 million. This expenditure, taken together with associated network reinforcements elsewhere, e.g. Beauly-Denny, would be expected to release up to about 200 MVA of interconnector capacity during the spring-autumn and winter periods.

[32] NGC email of 22 July 2004

[33] NGC Annual Report, 1998/1999. "…We analyse day-ahead weather forecasts from the Met Office with complex software to calculate enhanced ratings on certain critical lines, enabling them to carry as much power as possible. The software takes account of wind speed, ambient temperature and solar radiation. The

In the time available since receipt of this information on stability limits from NGC, we have not been able to complete any investigation as to the impact of adopting such an operational rule on the incremental cost-benefit associated with interconnector reinforcements although this is clearly an issue for further consideration.

7.3.2 North-East ring reinforcement

The reinforcement of the north-east ring, essentially the establishment, by uprating an existing 275 kV circuit to 400 kV to provide a stronger connection to the main 400 kV network in the Teeside area is effectively the second stage of reinforcement of the Scotland –England interconnectors. NGC have recently confirmed that this work would be undertaken following the Interconnector Upgrade and, when completed the power transfer limit between Scotland and England will increase to about 3,200 MW. The main driver for this reinforcement is voltage issues consequent to eastern interconnector outages under the winter peak condition following the proposed interconnector upgrades. A related driver in summer conditions is stated to be cross-outage conditions in the Heysham ring.

Whilst the proposed physical works, substation arrangements with respect to the necessary reconfigurations and space requirements, as well as individual costs associated with the reinforcement are reasonably well defined, the overall network security drivers are in our view very much “work in progress”. This observation is supported by the sequential developments identified above with respect to reinforcing the main Scotland-England interconnectors, with the indication that the necessary detailed staged network planning studies are yet to be undertaken. Included in such work to ensure that the most cost effective development are identified would be a more detailed investigation of alternatives such as SVCs and also quadrature boosters employed to manage the sharing between the north-east ring and the 400 kV north-west circuits. As a consequence it is our view that construction related works on the north-east ring should be delayed until such detailed studies have been completed.

7.3.3 Heysham area reinforcement

This project is stated to be driven by consideration of increased power flows from Scotland, associated with the uprating of the Scotland-England interconnector and the connection of significant renewable generation in Scotland, coupled also with the possible connection of major renewable generation in the vicinity of Heysham and essentially comprises the reconductoring of the 400 kV overhead line circuits of the “Heysham Ring” such that they can safely carry the output

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results have been impressive: we have achieved up to 21 per cent increases in ratings, which on some circuits can significantly ease power flow restrictions.”

from the Heysham nuclear power station plus local offshore wind farms in conjunction with increased power flows from Scotland under a combination of circuit outages.

In response to requests for clarification on NGC also indicate that the operation of conventional generation can have a significant influence on power flows through the ring. Although this issue may not be directly related to the connection of additional wind generation, it is indicative of the need to either reinforce, or else manage power flows on the ring at certain times.

In earlier sections of this report we have questioned the rate at which offshore wind farms may connect to the NGC network in total, and also the need or otherwise for the uprating of the Scotland-England interconnectors in the shorter term. In the case of offshore generation wishing to connect locally, there is a clear precedent for such generation to be required to underwrite any deep reinforcement expenditure that may be initiated by its connection and such an arrangement is clearly appropriate in this case.

With respect to the need to reinforce (uprate) the existing line circuits, in order to accommodate increased power flows from Scotland, subsequent to interconnector uprating, NGC have not submitted evidence that alternative means of managing such power flows have been investigated in any detail. Such means could include the introduction of quadrature-booster into the 400/275 kV ring[34] which influence power flows through the Heysham circuits. Within this ring, the 275 kV circuits between Harker and the east coast would seem to be an appropriate location for such equipment which has been successfully employed y NGC in other parts of the network. As indicated above with respect to the north-east ring, such equipment may be beneficial to both parts of the northern network. Accordingly it is our view that construction work on the Heysham ring should be delayed until its need is more clearly defined and that there is evidence that alternative solutions have been fully investigated and ruled out.

7.4 Kendoon area connection infrastructure

The purpose of the Kendoon area work, which is initially associated with the construction of a 400 kV line from Kilmarnock South to Kendoon, is to provide connection infrastructure for wind farm developments in the south-west of SPTL area, and also as precursor to the provision of a third interconnector between Scotland and England, routed through Galloway. The dilemma identified by SPTL is that there will invariably be considerable sensitivity to the construction of a new line in

[34] This ring effectively comprises the west coast 400 kV circuits running north to Harker and on into Scotland, the 275 kV circuits connecting Harker with the east coast interconnector, the north-east ring and the two 400 kV “Yorkshire lines ” together with the circuits closing the ring between Yorkshire and Lancashire networks

this area and hence there is a strong incentive to obtain consents for a project which will meet potential longer term objectives, rather than proceeding on a piecemeal basis with the risk of sterilising the area for any further development. The problem with this approach is that certain expenditure may be undertaken ahead of need, with a possible risk of essentially stranding assets should the longer term objective not be realised, or found necessary.

It is therefore important that the likely expenditure premium is determined, together with the viability of the longer term objective, by detailing and obtaining appropriate agreements with respect to overall line routing issues in particular, prior to committing capital expenditure over and above minimal requirements. Such issues will also need to go hand in hand with the actual level of wind connections realised prior to any approval being sought for any associated major expenditure. In the shorter term, i.e. over the next year or so, given the strategic importance of such a plan, it will be appropriate to undertake the necessary investigations such that more detailed proposals may be submitted at some future date.

Issues that can be considered include the possible use of 132 kV as a means of providing the necessary transmission capacity. Such a reinforcement could be based upon the use of a 400 kV line, initially operating at 132 kV, with attendant initial savings in terminal equipment costs, at both Kilmarnock South and Kendoon, whilst still allowing future development to 400 kV operation if the necessary level of wind farm connect and/or incorporation of the line into a "third" Scotland-England interconnector, if developments indicate this to be appropriate and the necessary consents are in place.

Late in the review process, and following the above, SPTL provided initial estimates of an alternative scheme using a double circuit connection from Kilmarnock South to Kendoon constructed to 400 kV specifications but operated initially at 275 kV. The scheme provides 480 MVA of non-firm capacity, vs. 720 MVA with the TLs scheme above, with a saving of £19 million. However, given the large amount of connection interest in the area, the critical issue even in this scheme, is the considerable possibility of stranded assets of the 275 kV equipment (switchgear and transformers) and its dependency on the phasing of connections that could make preferable to proceed with the more expensive TL proposed scheme. All these issues should be further examined and the convenience of proceeding with the TLs proposed scheme or otherwise demonstrated but there is a need to provide additional network capacity in this area.

7.5 Sloy area reinforcement

This project is to accommodate significant additional renewable generation on the Mull of Kintyre and comprises the establishment of a connection between the SHETL 132 kV network in the area and the existing SPTL 275 kV connection from the Cruachan pumped storage station towards Windy Hill and the main SPTL network. A total of over 100 MW of generation is currently connected, or under construction in this area, and making use of the existing relatively weak

132 kV grid in the area. A further 200 MW of wind farm quotations have also been accepted and the existing 132 kV network is considered inadequate, hence the proposed connection into the SPTL network which is seen as the most cost effective means of reinforcement.

7.6 Western Isles, Orkney and Shetland connections

SHETL have identified expenditure provisions totalling about £4.5 associated with early investigations of the feasibility of overhead line and submarine cable connections to these offshore island groups. The SHETL proposals are in response to connection enquiries and connection agreements associated with a total of over 1800 MW in the three locations. Although eventual connection costs have not been estimated, our own assessments indicates that the three submarine connections schemes would amount to about £200 million, £20 million and £175 million respectively for the estimated 50 km (Western Isles), 10 km (Orkney) and 200 km (Shetland) connections. On top of these costs would be the associated onshore transmission which would add about £200 million to the Western Isles, i.e. 400 kV transmission from Beauly with expenditure of between £ 40/75 million being associated with individual/shared 275 kV overhead line reinforcement from Beauly to the Orkney/Shetland cable connection point(s).

7.7 Beauly-Keith reinforcement

Subsequent to the Beauly-Denny works, the phasing of further reinforcements, to accommodate the growing volume of renewable generation in the north of Scotland has led SHETL to propose a 400kV single circuit ring built on the Beauly to Denny line, uprating one of the existing 275 kV circuits from Kincardine, via Tealing, Kintore and through to Keith, all suitable for 400 kV operation, with the final link from Keith to Beauly being a rebuild of the existing 275 kV line from Beauly to Keith/Blackhillock to make it suitable for 400 kV operation. It is proposed that one circuit of this line will operate initially at 400 kV and the other circuit will operate at 275 kV.

The need for major expenditure on the Beauly-Keith reinforcement is some time in the future, it will most likely be initiated by the connection of a major wind farm project in one of the islands. As a consequence we are of the view that there is little justification for any early expenditure on this project.

7.8 Construction programme and outages

The following table summarises the expected required circuit outages during construction for the main reinforcements discussed in this section using information provided by the TLs. It should be noted that the construction outage programme is in all cases preliminary and subject to change following detailed design.

Table 14 Preliminary construction outage programme (weeks)

Area	2005	2006	2007	2008	2009
Beauly-Denny		30	4	20	
Interconnectors	30	30	28		
North East England			26	28	14
North West England				30	30

The indicated outages will be scheduled during the Spring/Summer/Autumn seasons. The outages considered average about 30 weeks per year between 2005 and 2009 represent a significant proportion of time during the ‘maintenance’ season under which the network capacity will be depleted and hence the system will be subject to higher constraint costs that at a time when the network ratings reduce and will be exacerbated for larger installed wind capacity and high levels of wind output. An assessment of the costs during construction derived from these constraints costs is provided in the cost-benefit analysis presented in Section 9.

8. Transmission reinforcement expenditure proposals

8.1 Introduction

Further to the publication of the May 04 consultation paper by Ofgem referred to earlier in this document, the TLs provided updated forecasts of the expenditure proposals associated with the connection of wind generation in Scotland for the purposes of this work. The following table shows the latest expenditure forecasts and phasing indicated by the TLs to accommodate more than 2,900 MW of additional renewable capacity in Scotland and 700 MW in North West England which total just over £804 million.

Table 15 TLs expenditure forecasts (£ '000s)

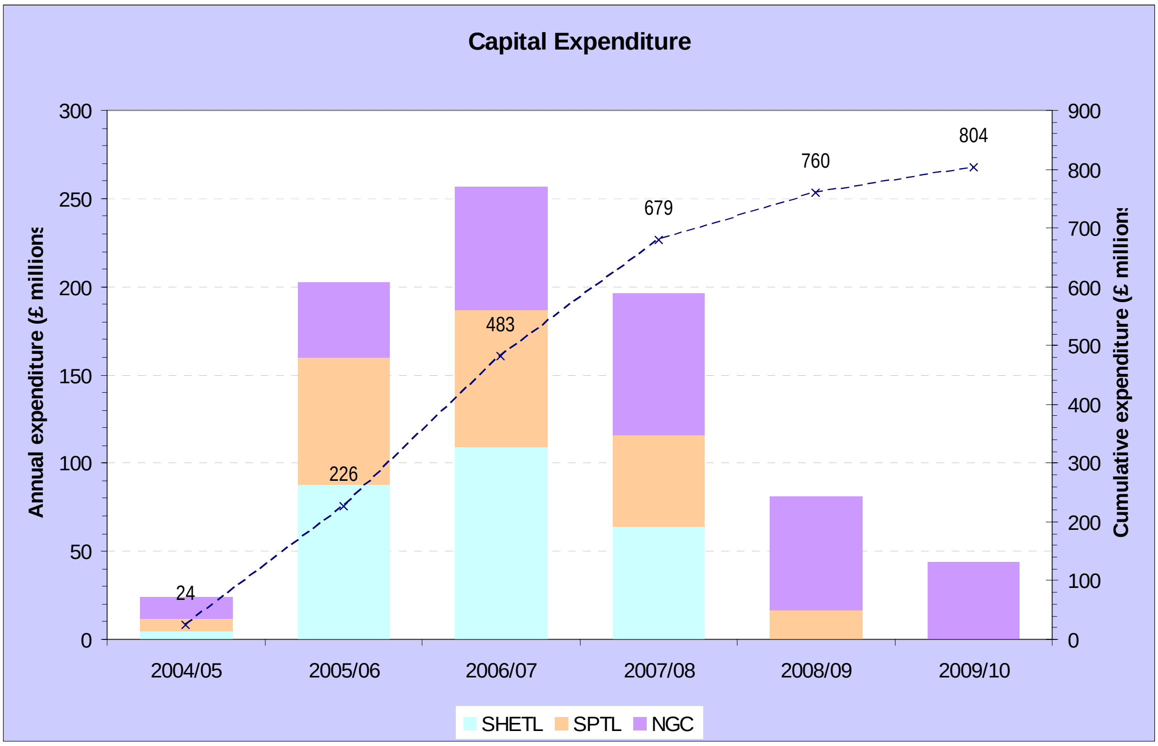
	Summary by reinforcement	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	Total
1	Beauly-Denny related	7,435	100,722	127,957	82,933	12,882	0	331,928
2	England/Scotland Interconnectors	14,510	42,461	42,087	23,022	23,451	6,356	151,887
3	North East Ring	0	8,894	31,595	46,304	28,052	24,809	139,654
4	Heysham area reinforcements	0	6,516	13,032	16,290	16,290	13,032	65,158
5	Kendoon area connection infrastructure	1,104	31,652	31,161	26,131	0	0	90,049
6	Sloy area reinforcements	100	11,342	9,521	0	0	0	20,963
7	Beauly to islands (Shetland/Orkney/W. Isles)	597	1,055	1,085	1,400	0	0	4,137
8	Beauly / Keith reinforcement	0	97	0	185	0	0	282
	Total	23.7	202.7	256.4	196.3	80.7	44.2	**804,058**

Two main projects constitute the majority of the investments namely the Beauly-Denny 400/275 kV overhead line in SHETL/SPTL area totalling about £332 million and increasing the capacity of the Scotland to England and Wales interconnectors and also the associated North East ring reinforcements, totalling about £291 million. These two reinforcements represent almost 80% of the total proposed reinforcement expenditures.

Also it should be noted that SHETL also indicated initial expenditure for anticipatory works on some reinforcements, e.g. Beauly-Keith reinforcements in Table 15, and also budgetary figures for expenditure covering the period up to 2011. The overall total over the extended period on which expenditure forecasts have been undertaken totals in this case over 1 billion pounds (£1,044 million) although this excludes any other expenditure by the other two TL's (SPTL and NGC). The main reason for this is to justify earlier initial engineering and design work expenditure required to address customer connection applications.

The following figure shows the expenditure shown in Table 15 broken down by company:

Figure 23 Proposed investments broken down by company



The cumulated totals broken down by transmission company are as follows

- SHETL: £266 million
- SPTL: £225 million
- NGC: £313 million

It should be noted that in the majority of cases the indicated reinforcement estimates have been undertaken using budgetary figures based on recent costs based on past projects and have been made prior to undertaken detailed design and engineering works (PSE[35]). PSE works allows establishing a detailed scope and budgeting of the tasks required to undertake the identified reinforcements hence removing uncertainties on final project costs. PSE works comprise items such as:

[35] These works are referred to by some of the TLs as Pre-Sanction Engineering works and we have adopted this terminology in the report.

- Condition assessment of tower and foundations
- Environmental and geotechnical surveys
- Detailed design of the schemes
- Desktop studies using field data
- Site surveys
- Wayleaving
- Seabed, shore surveys
- Access schedules

The particular group of activities required for each PSE varies from project to project depending on its nature. Additionally the companies have identified a number of factors which may cause variations from the indicated investment figures. Amongst the most important are:

- Consenting. Some of the proposed projects involve the construction of new lines and substations which will require a number of consents and permits. Recent experience , e.g. second Yorkshire line, indicates that it is quite lengthy at best to obtain consents for new transmission lines. Most of the proposed reinforcements make use of existing transmission routings which are expected to facilitate obtaining the necessary permits. The preparation and work involved during the public consultation process carries by its own nature a certain degree of uncertainty

- Undergrounding and routing requirements. Permitting some sections of the lines may not be possible unless the lines are undergrounded and/or substations footprints and land requirements reduced by use of the more expensive Gas Insulated Switchgear (GIS) technology compared to conventional switchgear technology.

- Variation of raw materials costs. The budget costs are subject to fluctuations based on changes in prices in raw materials especially metal. The TLs have indicated a significant appreciation of steel prices due to a sustained significant demand from China in recent years.

- Access. Some of the proposed reinforcements will require works in remote areas which may present difficult access by road or are not suitable for access of heavy equipment at all demanding the use of helicopters or special arrangements. Contingency provisions have been made for these based on previous experience, however again some further variations may results from the consents process.

- On-costs. The proposed reinforcements may represent a significant increase in the capital expenditure activities of some of the TLs, e.g. SHETL. The TLs have included a level of on-costs as a percentage of the prime capital costs. These factors reflect the direct labour costs associated with the increased activity and also a portion of corporate overheads allocated to the capital expenditure activities which are capitalised. The on-costs factors vary between companies as they depend on the internal structure and level of external contractor participation. As the level of activity increases these factors should reduce over historical levels.

Also it should be noted that SHETL also indicated initial expenditure for PSE works on some reinforcements, e.g. Beauly-Keith reinforcements in Table 15, and also budgetary figures for the follow-on expenditure covering the period up to 2011.

The following sections provide further high-level details of the proposed reinforcements categorised by main company undertaking the bulk of the reinforcements. It should be noted that due to confidentiality issues, detailed cost information supplied by the companies for our review including aspects such as costs break down, applicable on-costs, phasing etc. of the proposed expenditure has not been reproduced below.

8.2 Scottish Hydro-Electric Transmission Ltd

SHETL were requested to provide details on the costs of the proposed RETS reinforcements. The dominant reinforcement in the SHETL forecast, and of the overall RETS reinforcements, is the Beauly-Denny 400/275 kV line. SHETL provided a detailed account of costs of the Beauly-Denny reinforcement based on the results of a tendering process using costs from the preferred contractor for the overhead line whereas the substation costs associated with the line are based on outturns from previous projects undertaken by SHETL and budget estimates from manufacturers

Overall we are satisfied about the reasonability of the indicated costs, by virtue of the open tender process in the case of the overhead line, although we note that the contract is still under negotiation and significant provisions may have been included in the absence of regulatory sanction, detailed design, uncertainties in the scope and volatility in the steel prices. Considering the uncertainties in the scope we do not consider the indicated costs and provisions made as unreasonable at this stage. However, in case of regulatory sanction of the indicated budget costs, these aspects would have to be considered in a future analysis of outturns in the context of a transmission price control, especially on the merits of possible claimed efficiencies.

Budget costs estimates were also produced for Stage 2 of the South West reinforcements which also involve activity by SPTL. Stage 1 has already been approved for construction, has been granted planning consents and work will commence later this year (2004).

The above was complemented with information about initial design costs included for the interconnection reinforcements with the islands (Shetland, Western Isles and Orkney) to Beauly following developer connection applications in the islands.

We consider that the level of costs indicated for the initial design costs are reasonable and include prudent provisions for the anticipated scope of works at this stage. We note however that some of these costs seem to be undertaken well in advance of the project initiation, e.g. expenditure stream of the Beauly-Dounreay project which seems to be inconsistent with the phasing indicated in the case of the Beauly-Keith project of identical amount. In our view the initial design works should only be undertaken if the associated transmission reinforcement is considered justified.

We also note the diverse on-cost factors applied by SHETL to the various projects, which depend on issues such as the proportions of external and internal work components, project management requirements additional personnel involvement etc and although the range of values is not unreasonable, we would consider it appropriate to review these factors in the context of a price control review where a comprehensive review of capex/opex, capitalisation policies etc would be applicable which are outside the scope of this review.

8.3 SP Transmission Ltd

SPTL provided details of their proposed expenditure forecast for RETS including the applied level of on-costs based on historic levels.

SPTL provided detailed breakdown of costs broken down by main asset category and asset type although they were preliminary and subject to detailed engineering. These costs were based on recent projects undertaken by SPTL and manufacturer's budget costs. They also include provisions for items such as the appreciation of the steel price. Overall we are satisfied that the budget costs indicated by SPTL are reasonable at this stage and the provisions included are consistent with prudent assumptions about the expected scope of works at this stage.

SPTL also gave an indication of the overall levels of pre-sanction engineering works. The indicated cost estimate assumes a two stage design and build process and reflects estimated costs to the point of placing construction contracts.

In our view the provision for public inquiries should not be part of the PSE works since this cost would only be incurred if the project gets sanctioned. We would also question the nature of the significant amount labelled as miscellaneous. We also note considerable internal engineering and delivery charges for which limited evidence could be provided as the internal accounting practices do not easily lend themselves to separate this information as it was the case for the other two TLs . It can be concluded that the initial engineering and design provisions seem very conservative, with the resulting budgetary figures being above the values submitted for similar concepts by the other two TLs.

8.4 National Grid Company

NGC were requested to provide details about the proposed expenditure forecast for the identified reinforcements required for RETS and provided details of the forecast expenditure stream broken down in 13 main sub-projects.

The expenditure forecast was based on budget costs for the estimated scope from recent contracts for equivalent activities undertaken by NGC and is therefore subject to variations following detailed PSE work. NGC also indicated the level of on-costs included based on historic levels.

Overall we consider satisfactory that the budget estimates included in the expenditure streams are based on past experience on similar projects and are generally in line with our expectation of current costs trends. However we would take issue with the indicated scope of works and the timing of the reinforcement requirements (in particular the high level of expenditure in 2004/05), under certain scenarios, as discussed in Section 7.

The expenditure forecasts include a provision for PSE works in 2004/05. Detailed PSE works cost estimates have been provided by NGC indicating the share between external and internal costs. The estimated duration of the PSE works activities is between 4 and 6 months. The balance of the expenditure indicated for 2004/05 corresponds to initial payments associated with contracts for the reinforcement works basically to secure materials and contractor resources. It also should be noted that the expenditure forecast for the PSE costs themselves are subject to some variation for example in the case that engineering design support is required to support consent applications. The total forecast amounts includes also a total provision for land purchases

Supporting evidence was requested from NGC that the forecast levels of expenditure for the PSE works were based on recent experience for similar works. We are satisfied that the forecast is consistent with outturns for similar tasks recently undertaken by NGC in other projects and that includes reasonable provisions for work, and hence expenditures, that may be ultimately be required for the purposes of PSE noting that it is also possible for PSE works outturn expenditure to be higher, as well as lower, than forecast.

We are of the opinion however that, in order to separate PSE works from the actual reinforcement costs to facilitate staged regulatory sanctions, it would be preferable to group the indicated land purchase costs indicated in with the costs of its associated reinforcement. This would ensure that land purchases will only proceed if the reinforcements, obtain regulatory sanction. This latter process would be based on updated expenditure forecasts informed by the results of the PSE works. Following regulatory sanction, monitoring the outturn of the identified PSE work expenditure can be undertaken as part of the regulatory activities of next Transmission Price Control. The evaluation of the merits of any difference between outturns and the sanctioned regulatory amount would be subject to similar analysis to any other historic expenditure undertaken by the TLs in order whether it should be considered as an efficiency or otherwise.

8.5 Conclusions on reinforcement expenditure proposals

The latest TL's expenditure forecasts are summarised in Table 15 on a project by project basis. These costs reflect budget costs based upon the companies present knowledge of the scope of the projects, based in part upon specific tender information (Beauly – Denny overhead line works) or on outturn costs on recent relevant contract works. These costs include reasonable levels of contingencies with the intention that the level of contingency will be refined by undertaking initial engineering and design works, budget provisions for which are identified.

SKM is satisfied that the forecast levels of expenditure are broadly reasonable for the proposed works and are reflective of present market status with respect to the highest cost items, namely overhead line works. We do have some issues with respect to the staging of certain parts of the works, in particular SHETL's indicated early PSE spend on the proposed connections to Orkney and Shetland and the Beauly-Keith reinforcement, the provisions made by SPTL for initial engineering and design works which seem high compared to the other two TLs, and also NGC's early non-PSE spend on the Eastern Interconnector circuits.

It is our expectation that all expenditure, regardless of nature or project will be subject to the normal Transmission Price Control Review as to its need and the efficiency of its delivery. The convenience or otherwise of sanctioning the initial design and engineering work expenditure is subject to the suitability of the associated reinforcement scheme. The cost benefit analysis of the proposed reinforcements is undertaken in Section 9.

9. Cost benefit analysis

9.1 Introduction

This section evaluates and quantifies the benefits provided by the proposed reinforcement schemes including savings in constrained energy, losses, network betterment etc. using the conclusions and considerations from previous sections to identify the levels of additional wind capacity that would justify the proposed network reinforcements.

9.2 Beauly-Denny reinforcement

9.2.1 Scenarios and assumptions

In order to quantify the benefits of the Beauly-Denny proposed reinforcement an assessment has been undertaken of the constrained energy volumes prior and after the reinforcements as well as the impact of the reduction of losses. The approach used follows the methodology indicated in Section 5.4 using half hourly generation and demand records supplied from SHETL covering the period from 1997 to 2001.

In the case of the Beauly-Denny line the only alternative to overcome post contingency operational violations is to constraint wind generation north of Beauly or to make use of pumped storage mainly at Foyers. The only thermal generation in the SHETL area is Peterhead which is south of the identified constraint and hence the sensitivity on the constraint of the Peterhead output is negligible. It can be expected that the volumes of constrained energy calculated would correspond to wind generation. For the purposes of this study constrained wind generation energy attracts an economic value of £45/MWh as discussed in Section 6.3.1.

9.2.2 Constrained energy volumes

The following table lists the results from the weighting of the volumes of constrained wind and losses obtained for the various operationally secured scenarios (N-1, N-2, N'-1) considered under the corresponding seasonal transmission limits (Summer, Spring/Autumn, Winter).

Table 16 Constrained energy volumes and losses analysis for the Beauly-Denny reinforcement

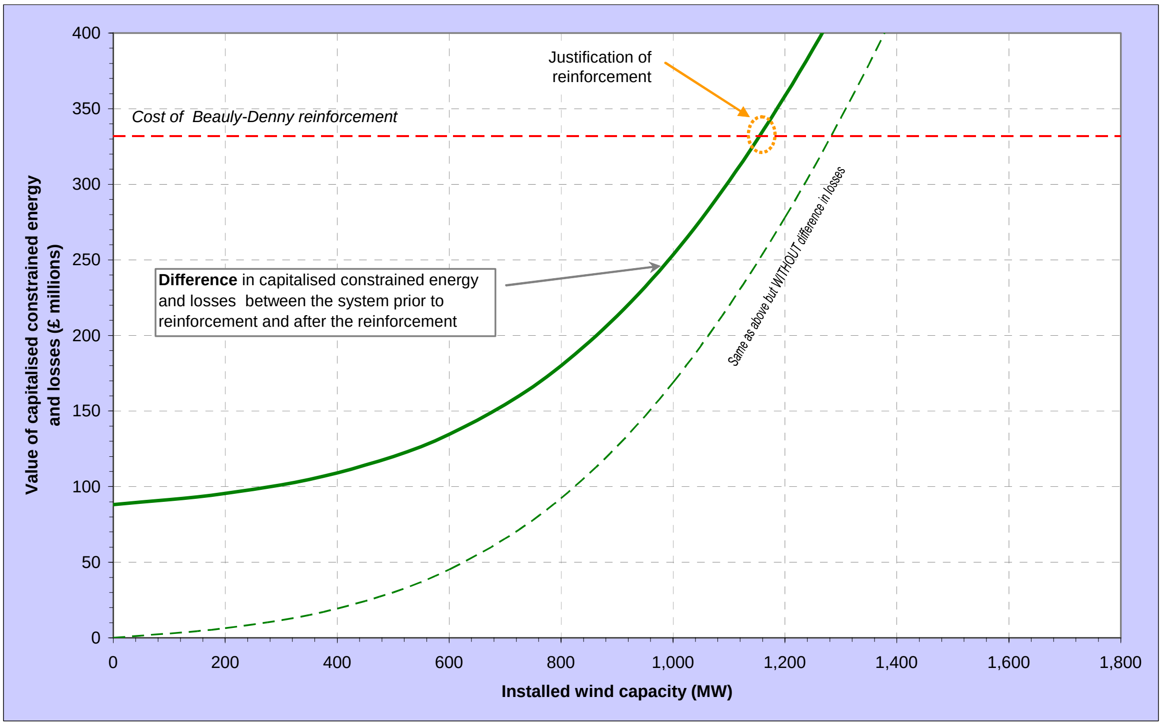
	Constrained Energy (GWh)			Losses (GWh)		
Installed Wind capacity (MW)	Existing network	Network with QBs at Ft Augustus (under construction)	Network with Beauly-Denny 400/275 kV Overhead line	Existing network	Network with QBs at Ft Augustus (under construction)	Network with Beauly-Denny 400/275 kV Overhead line
0	0	0	0	251	254	120
200	41	10	0	253	258	122
400	135	31	1	250	261	125
600	312	73	4	243	263	127
800	581	153	13	232	263	129
1,000	923	287	30	223	260	132
1,200	1,315	483	59	216	256	134
1,400	1,742	737	103	215	252	135
1,600	2,193	1,040	162	219	250	137
1,800	2,662	1,382	238	229	250	139
2,000	3,142	1,755	335	245	256	141
2,250	3,757	2,255	496	272	268	143
2,500	4,382	2,784	703	308	288	147
2,750	5,015	3,335	959	350	315	151
3,000	5,655	3,904	1,259	400	349	157

In order to estimate the constrained energy volumes under construction the results obtained for N-2 and N'-D in the calculation of the results presented in Table 16 have been weighted by the duration of the expected outages as indicated in Table 14, the expected implementation program for the reinforcement and the expected phasing of the wind connections capacities indicated in Section 4.

9.2.3 Justification of the proposed reinforcement

The capitalised benefits of the reduction of constrained energy costs and losses are shown in Figure 24 compared to the total cost of the Beauly-Denny reinforcement. The capitalisation of energy costs has been calculated assuming an interest rate of 6.25% and a 40 years depreciation life consistent with the assumptions used in the last transmission price control. The results shown indicate that the proposed reinforcement is justified when the installed wind capacity in the area north of Beauly reaches around 1,200 MW.

Figure 24 Justification of the Beauly-Denny reinforcement



These results do not consider the possible mitigation of constraints that can be made by making use of the pumped storage facility at Foyers (2 x 150 MW). Additional data was requested from SHETL to establish the storage capacity and constraints in the operation of Foyers in order to investigate its value in the management of constraints to wind generation. Based upon this information and our associated modelling of a full year operation against equivalent wind generation variability, it was found that up to about 1,400 MW of wind could be managed to 700 MW equivalent, with minimal wind spill (8 percent plus an associated 2 percent of increased pumping loss). This analysis included modelling of the high levels of run-off into the upper reservoir and also maintained the required 6 hour of "black start" energy storage provided by the station. However, in economic terms it will be cheaper to reduce thermal generation than to operate pumped storage plant due to the lower efficiency of the pump-generation cycle.

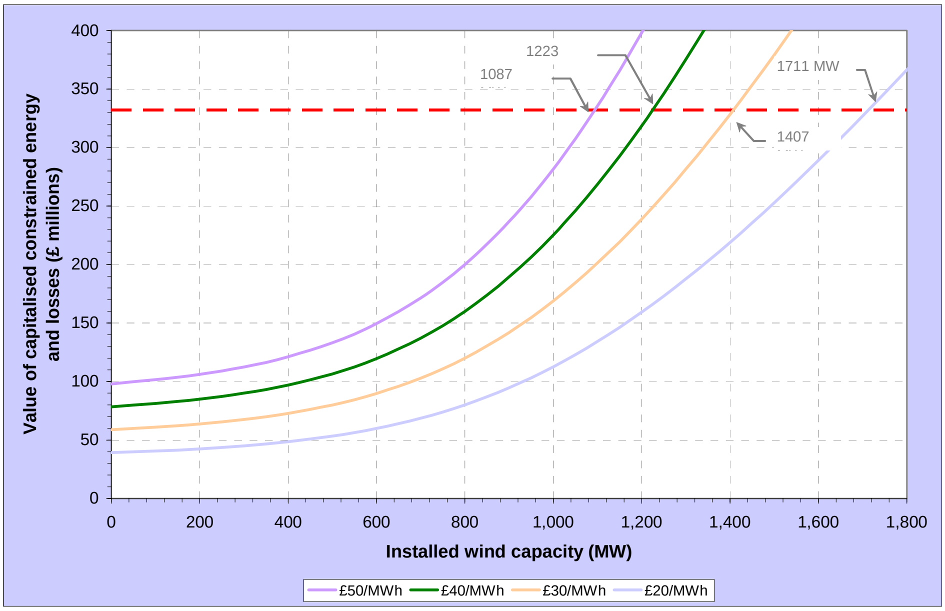
The indicated phasing of installed capacity north of Beauly discussed in Section 4.3 shows that around 2007/8 there could be enough capacity wind capacity connected to the network to justify the reinforcement on the basis of avoided economic constraint costs and losses. Assuming a challenging four year construction programme for the proposed scope of works associated with the Beauly-Denny line, it can be concluded that this project should be sanctioned in 2004.

9.2.4 Sensitivity analysis

Additional analysis has been undertaken to study the sensitivity of the results to the assumptions on constrained energy costs indicated above. Figure 25 shows the change in the installed wind capacity required to justify the construction of the Beauly-Denny line for a range of values of constrained energy from £20/MWh to £50/MWh with a corresponding installed wind capacity that ranges from about 1,700 MW to 1,100 MW respectively.

However it is considered very unlikely that the costs of constraining wind generation will be below £45/MWh as the only generation behind the constraint is hydro and pumped storage which have the same economic value as the renewable wind generation. Under a BETTA market scenario it is probable that the levels of renewable generation in GB will be below the yearly targets and hence the costs of constraining wind generation will tend to be higher than the £45/MWh economic value of the constrained energy.

Figure 25 Sensitivity analysis to the price of constrained energy



9.2.5 Constrained energy volumes during construction

Based on the expected outage pattern indicated in Table 14 we have calculated the additional value of the constraints volumes that will be created during construction by factoring a corresponding proportion of time under which the network will have to be secure for the loss of a circuit when one is under planned outage during the Summer and Spring/Autumn seasons. As the network has to be secure against an effectively N-2 (N'-1) event which results in more onerous transmission limits the volume of constraints increase and hence the costs.

The results obtained from the difference of the constraint costs with and without the line construction indicate total constraint costs during construction of around £17.4 million. These costs increase to £26.9 million is the construction programme is delayed by one year. These costs are relatively modest due to the timed phasing of the wind and the underlying maintenance outages under ‘normal’ conditions during the maintenance seasons (Spring to Autumn).

9.2.6 Summary of findings

Based on the quantification of the savings in constrained energy and losses our studies indicate that the proposed Beauly-Denny reinforcement is justified for a wind installed capacity of about 1,200 MW. Based on the expected phasing of wind generation connections and the expected construction programme it is concluded that this project should be sanctioned in 2004.

9.3 Scotland-E&W interconnectors and NE ring

9.3.1 Scenarios and assumptions

As discussed in Section 4, in order to analyse the benefit of the reinforcements associated with the increase in transfer capacity between Scotland and England and Wales it is necessary to consider:

- The underlying interconnector flows without additional wind capacity
- The possibility of reducing thermal generation to alleviate constraints
- The possibility of making use of pumped storage schemes (Foyers and Cruachan) to alleviate constraints

9.3.2 Interconnector flows

The evaluation of the constraint energy volumes resulting from the addition of wind generation in Scotland is undertaken by statistically combining a typical interconnector flow with the output from the wind farms for varying levels of installed wind capacity. It is therefore necessary to arrive at a typical interconnector flow. The following figure shows the distribution of the interconnector flows in 2001/02 and 2002/03 that was obtained using half hourly settlement data supplied by SPTL and SHETL.

Figure 26 Scotland-E&W Actual Interconnector Flows 01/02 and 02/03

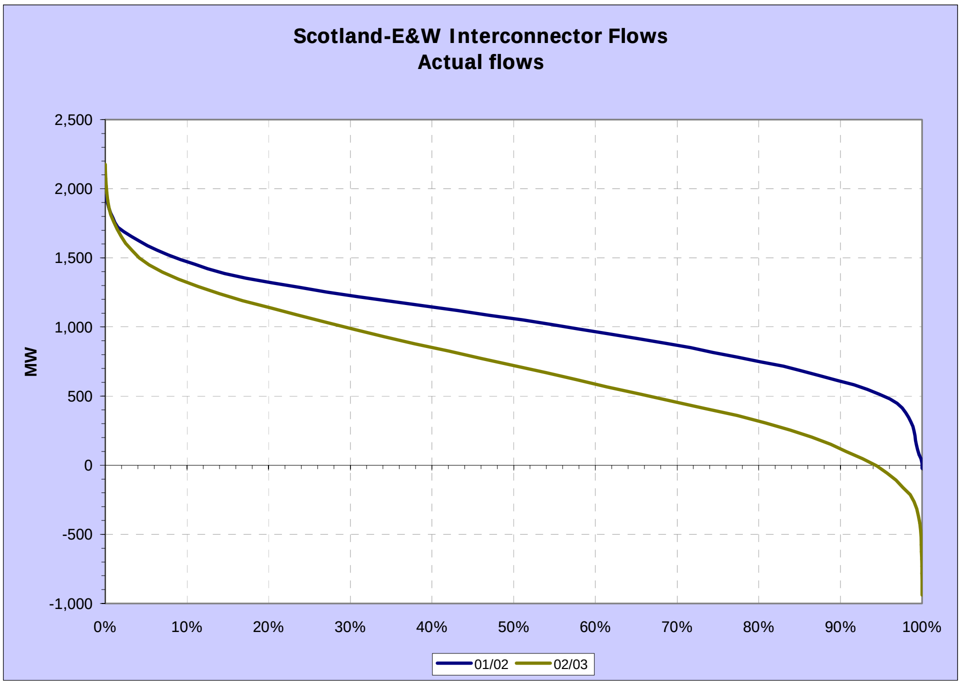


Figure 26 shows that the interconnector operated well below its maximum declared capability indicated in Section 7.3 for most of the year, with particularly low levels during 02/03 where for about 50% of the time the flows were below 750 MW. However this does not take into account the effect of generation outages and network outages which affected the transfer capability of the interconnector and hence the resulting power flows. The two main reasons for the reduced interconnector transfers in the two years shown above are:

- The outage of Torness and Hunterston nuclear power stations
- Reduced importing capability of the network in Northern England associated with planned outages mainly related with the construction of the second Yorkshire line in 2002/03.

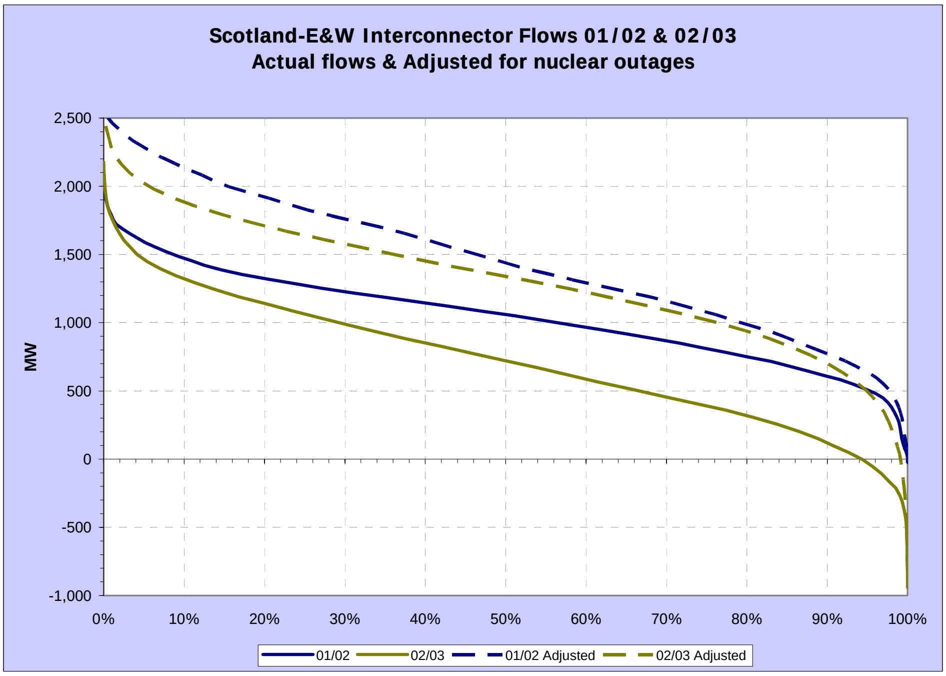
Prior to calculate the volumes of constrained energy by increased wind generation capacity following the approach outlined in Section 5.4 it is necessary to arrive at “normal” interconnector flows removing some of the anomalies identified above which otherwise might lead to an optimistic assessment of the remaining capacity of the interconnector.

9.3.3 Adjustment of historic interconnector flows

In order to represent a typical year, the output of the Torness and Hunterston nuclear power stations was adjusted to remove the effect of the forced outages whilst maintaining the characteristic periods of reduced export during refuelling (not shown due to data confidentiality issues). The utilisation of the main generation plant in Scotland during 2001/02 and 2002/03 (not shown due to data confidentiality issues) indicate very similar utilisation for Longannet and increased utilisation of Peterhead and Cockenzie that tends to compensate the reduced output from the nuclear station in 02/03.

Figure 27 shows the actual flows indicated in Figure 26 and the resulting flows with the adjustments to the nuclear output indicated above. The results show a considerably higher utilisation of the interconnector on a typical year. The results indicate flows above the interconnector capability (circa 2.2 GW) but no further modifications to the flows have been undertaken as the constraint analysis is based on the difference on the constraints before and after the reinforcement and hence it is not significant for the purposes of the analysis undertaken in this section.

Figure 27 Actual and adjusted interconnector flows



It can be observed from inspection of Figure 27 that during a significant proportion of time there is capacity in the interconnector that could be used by existing generation plant to further export in the E&W system. Notwithstanding any market distortion issues, the use of this plant should be closely related to the economic ranking order of the plants in Scotland relative to other units in England and Wales. These aspects were discussed in Section 5.

For the purposes of this analysis the behaviour of the Scottish Generation during the last winter period was investigated in order to establish whether further modifications on the base power flows shown in Figure 27 were required. Figure 28 shows the declared interconnector capability and use during Winter 2003 were the interconnector was restored to its full capability and generation plant (nuclear) were available. The resulting interconnector flows were well below the interconnector capability.

Figure 28 Interconnector capability and flows. Winter 2003

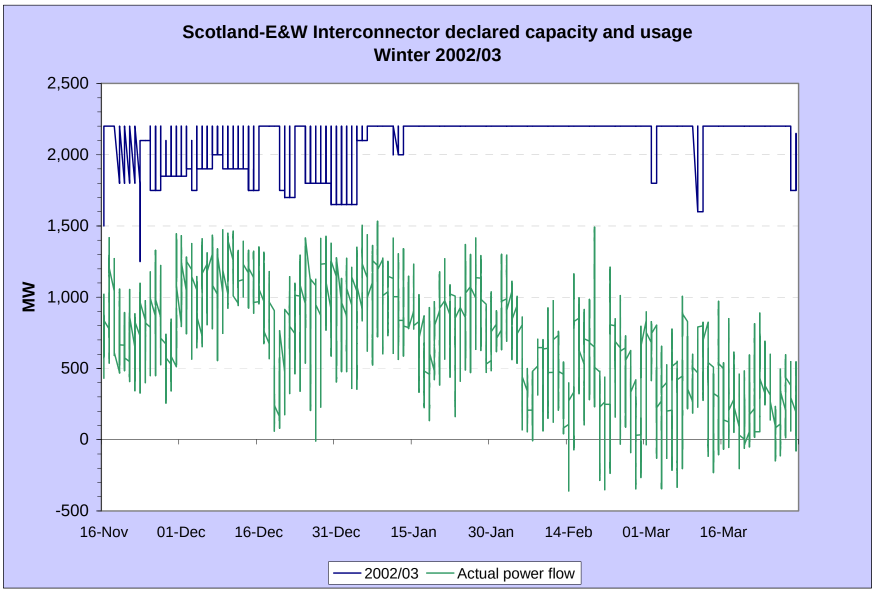
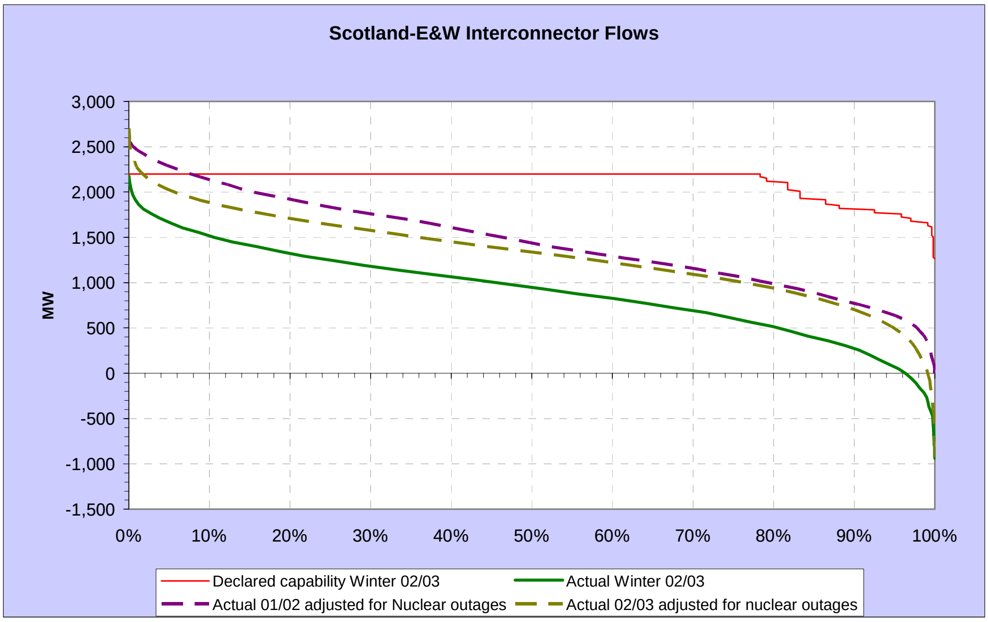


Figure 29, Figure 29 presents the adjusted flows with the distribution of the Winter 2003 flows together with the corresponding declared interconnector capability. It can be observed that the declared interconnector capability was for most of the time (80%) close to its maximum and that the flows were below 50% of the maximum capability for about 50% of the time. The actual flows adjusted for the nuclear outages, also shown in Figure 29, are consistently above the observed flows in Winter 2003. It can be concluded that using the adjusted flows in the evaluation of constraints energy volumes with increased wind generation capacity would tend to produce higher volumes of constraints in the cost-benefit analysis assuming that the behaviour of the Scottish generation in the future is broadly consistent with the recent past.

Figure 29 Comparison of adjusted flows and Winter flows 2003 vs declared interconnector capability



9.3.4 Constrained energy volumes

The calculation of constraint volumes presented below is based on the analysis of base cases for the interconnector flows which have been discussed in Section 9.3.2 making use of:

- Actual interconnector flows
- Adjustments to the flows to consider 'atypical' generation availability
- The seasonal ratings of the interconnector transfers under N-1, N-2 and N'-1/D as discussed in Section 7.3

In order to estimate the constrained energy volumes that would result with increased levels of wind generation the actual interconnector flows for 01/02 has been used corrected for the nuclear outages, as presented in Section 9.3.2.

The volumes of constrained energy have been calculated by statistically combining a historic typical interconnector power flow with a level of installed wind capacity. In this approach it is implicitly assumed that the historic flows will be maintained into the future. However it is likely that for most of the fossil-fuel generation in Scotland this will not be the case as the increased renewable generation can be expected to displace a proportion of conventional generation in Scotland as indicated in Section 5.4. The analysis based on continuation of historic flows may therefore indicate somewhat optimistic, i.e. lower values of installed wind capacity to justify the reinforcement.

Similarly by using the historical interconnector power flows it is implicitly assumed all the existing units will operate in the same manner in the future and therefore does not account for possible station closures into the future. It is possible however that a reinforcement that is justified by the value of constrained energy at a certain level of installed wind capacity will be justified at a much higher level if a power station contributing to the constraint were to close. This indicates that there would be a risk of stranding assets if the higher level of installed wind capacity required to justify the reinforcement when a power station closes would not materialise. This risk being particularly important if the difference between the two levels of capacity is high. In order to investigate this effect it is necessary to undertake the analysis considering the most likely generation closures to compare the results and hence evaluate the risk.

The following table shows the levels of constrained energy resulting from operation under various interconnector transfer capability limits and operating conditions including N-2, N' secure against double circuit outage and N-2 post interconnector reinforcement.

Table 17 Constrained energy volumes (GWh) associated with additional wind capacity in Scotland using 01/02 interconnector flows adjusted for nuclear outages

	Max. Transfer Limits (MW)	N-2	N-2 post reinf.	N'-1/D
	Summer	2,000	3,200	1,000
	Spring / Autumn	2,200	3,200	1,130
	Winter	2,200	3,300	1,130
	Wind Capacity (MW)	Constrained energy (GWh)	Constrained energy (GWh)	Constrained energy (GWh)
1	0	0	0	0
2	200	87	0	467
3	400	204	0	958
4	600	357	0	1,496
5	800	548	0	2,053
6	1,000	774	3	2,630
7	1,200	1,039	11	3,207
8	1,400	1,343	30	3,790
9	1,600	1,690	65	4,396
10	1,800	2,076	124	4,988
11	2,000	2,497	207	5,587
12	2,200	2,942	321	6,175
13	2,400	3,413	468	6,793
14	2,600	3,897	650	7,389
15	2,800	4,403	868	8,000
16	3,000	4,914	1,123	8,603
17	3,250	5,574	1,488	9,363
18	3,500	6,246	1,901	10,119
19	3,750	6,921	2,348	10,881
20	4,000	7,605	2,835	11,636
21	4,250	8,299	3,343	12,398
22	4,500	9,004	3,881	13,161
23	4,750	9,710	4,433	13,938
24	5,000	10,418	5,004	14,679
25	5,250	11,133	5,592	15,447
26	5,500	11,852	6,185	16,209
27	5,750	12,579	6,795	16,960
28	6,000	13,298	7,417	17,731

The indicated constrained energy volumes in Table 17 are depicted graphically in the following figures. Figure 30 and Figure 31 show the expected duration curves of the interconnector flows that would result from increasing levels of installed wind capacity for the following cases respectively: Historic interconnector flows adjusted for the nuclear outages and the historic interconnector flows adjusted for nuclear outages minus Longannet and Cockenzie (scenario corresponding to a potential closure/significant change in the generation dispatch of existing conventional generation). The two limits indicated for the flows correspond to the existing limit on the interconnector flows and the applicable limit following the reinforcement of the network.

The level of constrained energy is the area above the indicated limit (albeit only a single limit is shown for simplicity). The figures also demonstrate that the constraints are not fully removed by the reinforcement and that the remaining constraints are significant, especially with higher levels of installed wind capacity, and should be considered in the evaluation of the benefits of the reinforcement.

Figure 30 Illustration of the effect of increasing levels of wind generation (2 GW-6 GW) on the volumes of constraints. Historic interconnector Flows adjusted for Nuclear outages

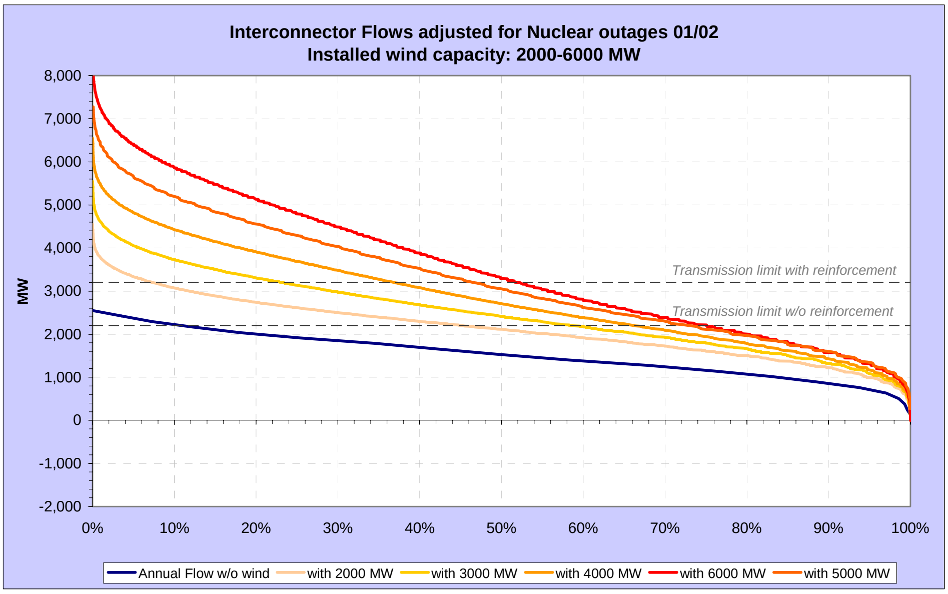
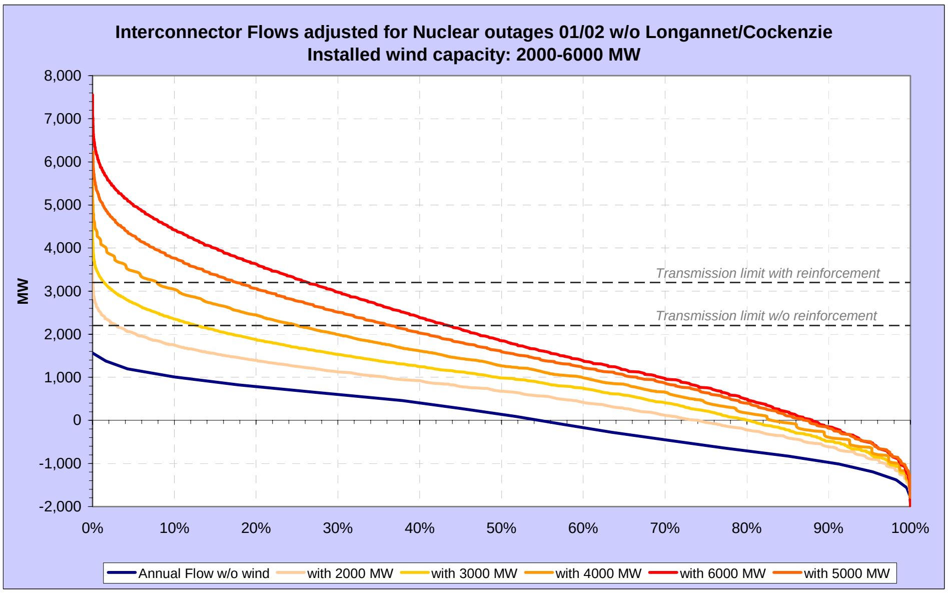


Figure 31 Illustration of the effect of increasing levels of wind generation (2 GW-6 GW) on the volumes of constraints. Flows as above without Longannet/Cockenzie.



9.3.5 Justification of the proposed reinforcements

The benefit of the proposed reinforcement under an N-2 operation criteria is the difference in between the cost of reinforcement and the capitalised cost of the difference in the constraint costs. The volumes indicated above have been capitalised using an interest rate of 6.25%, consistent with the assumptions in the last transmission price control and a depreciation period of 40 years to calculate the capital expenditure that can be justified by avoiding the annual constraint payments implied by the constrained energy volumes indicated above.

The total reinforcement costs have been discounted at the same interest rate as above taking into account the proposed phasing of expenditure which in the case of the combined interconnector and North East ring expands over a period of about 5 years. The cost of the proposed reinforcement has also been "credited" by the savings in losses resulting from the levels of constrained flows before and after the reinforcement (also discounted at the same rate). Finally the reinforcement costs has been credited by the proportion of the costs that can be associated with early asset replacement discounted using the same interest rate

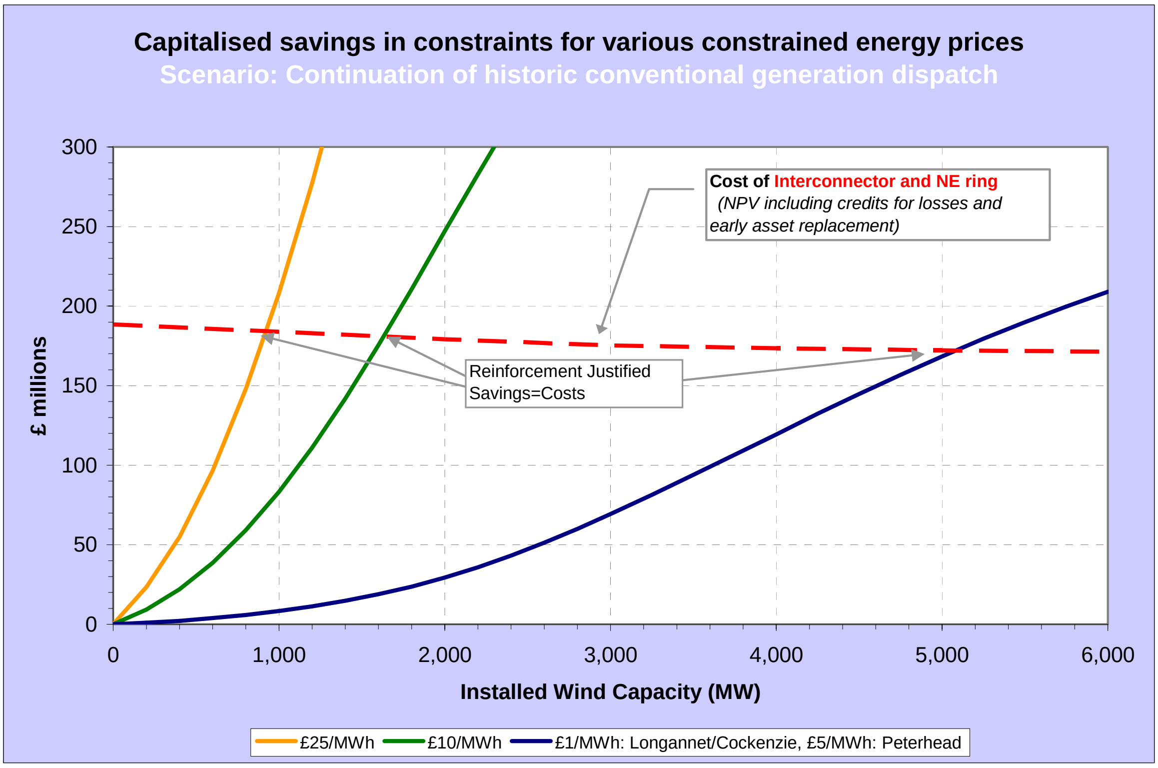
Figure 32 shows the capitalised cost of the constrained savings assuming three different costs for the constrained energy namely:

- £25/MWh in case of assuming the same value as that indicated in the RETS study, which is also the preferred reference cost used by the TLs in their economic assessments. The results (yellow line in Figure 32) indicate that the full reinforcement of the interconnector capacity including the NE ring is justified with circa 900 MW of installed wind capacity

- £10/MWh in case of assuming the same value as the average difference between the SBP and SSP under NETA in 2003. The results (green line in Figure 32) indicate that the full reinforcement of the interconnector including the NE ring is justified with circa 1,700 MW of installed wind capacity.

- £1/MWh for the proportion of constrained energy associated with Longannet and Cockenzie (efficiency difference with the unit that increases its output in the E&W system), and £5/MWh for the proportion of constrained energy associated with Peterhead. This value is associated with the 'typical' difference in efficiency between a CCGT and an old coal power station. The results (blue line in Figure 32) indicate that the full reinforcement can be justified with a level of wind reaching 5000 MW.

Figure 32 Cost-benefit of the full reinforcement associated with the Scotland-E&W interconnector (including NE ring) with all existing generation



The risk to significant changes to historic generation operation is illustrated by reference to Figure 33 which is the same cost-benefit case as that presented in Figure 32[36] but showing the effects of the closure of Longannet and Cockenzie. The comparison of the break even points between Figure 32 and Figure 33 highlights the risk that, due to possible significant changes of the historic operation of existing generation in the future (including closure decisions), the proposed reinforcement could become stranded assets in the system. For the £1/MWh-£5/MWh curve the level of capacity that would justify the reinforcement is above 6,000 MW.

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[36] Note that in this case the £1/MWh: Longannet/Cockenzie and £5/MWh Peterhead shown in the legend only the latter is applicable.

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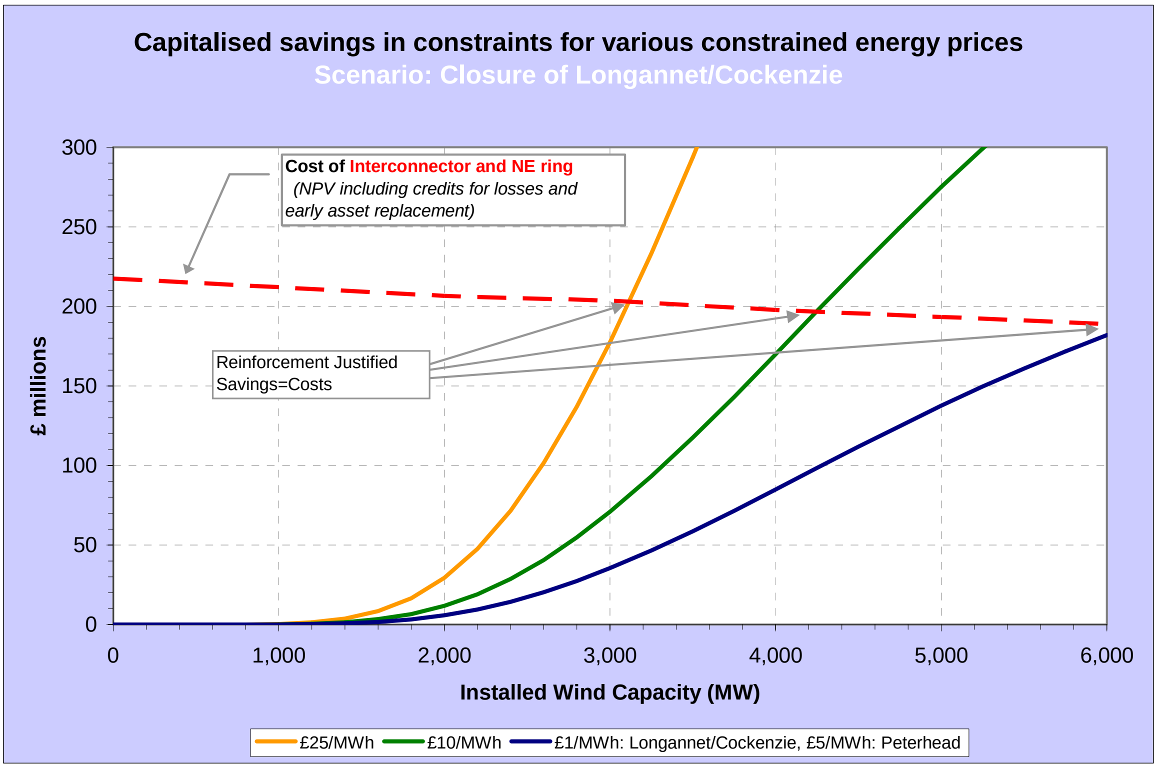
Figure 33 Cost benefit analysis of Figure 32 assuming closure of Longannet and Cockenzie



The results presented in Figure 32 and Figure 33 indicate a wide range of variation depending on the value used for the constrained energy and the base scenario used. It can be concluded that, using an economic value of the constrained energy volumes, the reinforcement of the Interconnector and the NE ring is only justified when the level of installed capacity reaches around 5000 MW. In the case of closure of Longannet and Cockenzie the capacity required to justify the reinforcement would rise to about 6,000 MW although it should be noted that in this case it may be necessary to undertake some, as yet unidentified reinforcements, to allow the import of capacity into Scotland to secure its demand.

The value of the reduction of losses has been estimated at around £32 million using the full economic value of reduction in losses of £45/MWh and taking into account the increased flows that would result but does not significantly change the above finding. In addition it should be noted that this analysis does not consider the economic benefit from the possible optimisation of the operation of pumped storage Foyers and Cruachan. Our studies indicate that the use of the pumped storage can manage wind equivalent to a reduction in its installed capacity of around 600 MW. However, in economic terms and, due to inefficiency in the pump/generation cycle, it will normally be cheaper to constrain fossil-fuel generation in Scotland.

9.3.6 Staging

The cost-benefit analysis above were based on the combined reinforcement of the Interconnectors and the NE ring as these both reinforcements have been indicated by NGC as required in order to allow the connection of more than 2,000 MW of additional wind capacity in Scotland. Although not specifically studied by NGC we have considered the case of staging the reinforcements related to the interconector into the reinforcement of the interconnectors (West and East) followed by the reinforcement of the North East ring.

Figure 34 shows the cost benefit associated with only the reinforcement of the interconnector. The capital cost requirements are reduced accordingly but also the transmission limits post-reinforcement are lower, circa 2.6 GW vs. 3.2 GW with the full reinforcement. The results obtained indicate that the initial interconnector reinforcement is justified with about 3,700 MW of installed wind capacity although in case that Longannet and Cockenzie were to close then the level of installed capacity would increase to about 5,000 MW (Figure 35).

In the case of using a constrained energy price of about £10/MWh the levels of installed wind capacity that justify the reinforcement are 1,000 MW and 3,700 MW for the respective scenarios presented above. The results indicate much better benefit to cost ratios than those indicated in Figure 32 and Figure 33 for the reinforcement of the Interconnectors and the NE ring and would indicate sufficient benefits to justify the reinforcement considering that the expected level of installed wind capacity in Scotland is circa 4 GW by 2010. (Section 4)

Figure 34 Cost benefit of staging the reinforcement. Stage 1: Interconnector reinforcement. Scenario: Continuation of historic conventional dispatch

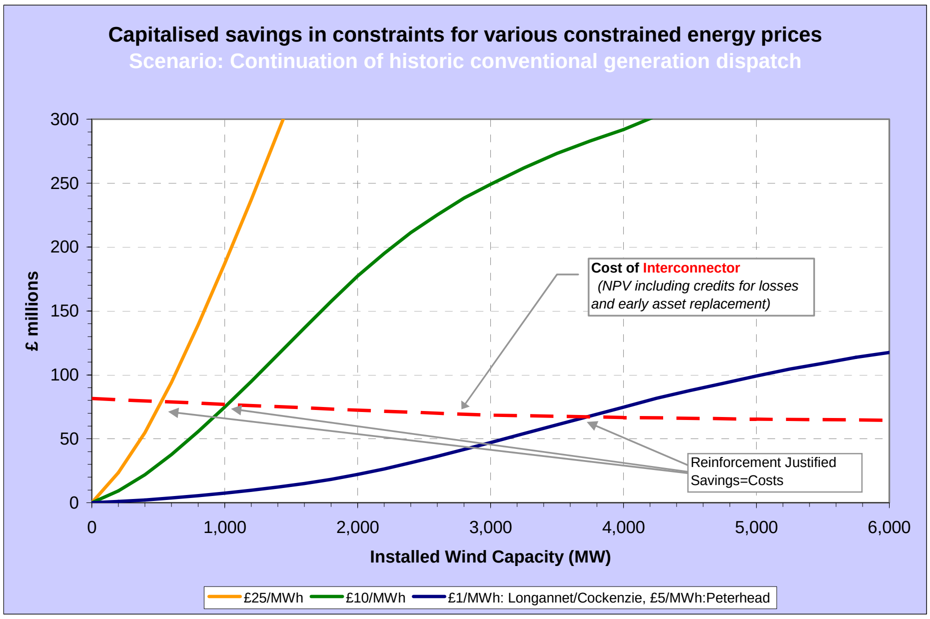
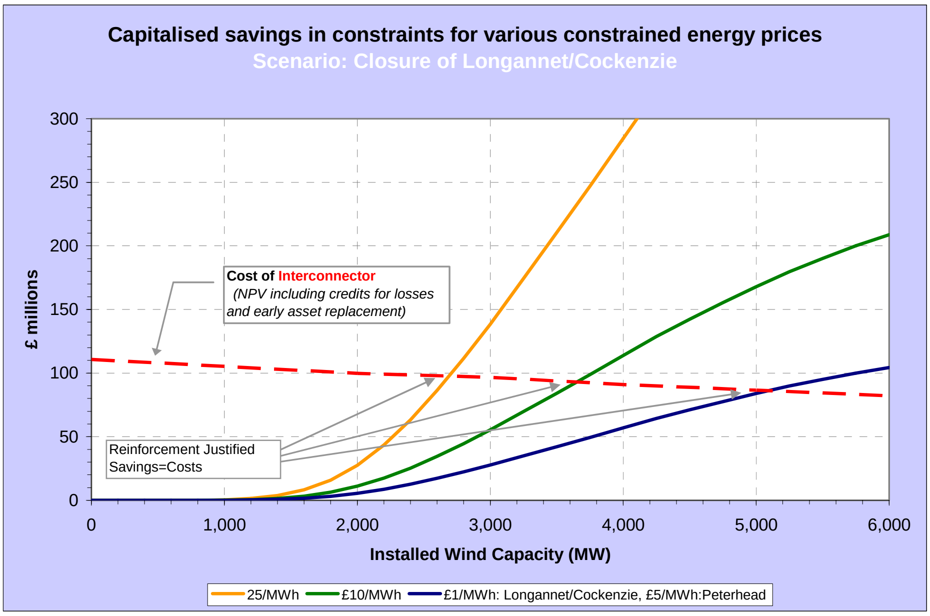


Figure 35 Cost benefit of staging the reinforcement. Stage 1: Interconnector reinforcement. Scenario: Closure of Longannet/Cockenzie



Following the reinforcement of the interconnector, the NE ring reinforcement is justified when the total level of installed generation capacity reaches over 6,000 MW with a much larger volume of installed generation and significantly over 6,000 MW in case of closure of Longannet and Cockenzie (Figure 36 and Figure 37). These figures much lower benefit ratios in the case of the NE Ring compared to the main Interconnectors.

Figure 36 Cost benefit of staging the reinforcement. Stage 2: Northeast ring reinforcement. Scenario: Continuation of historic conventional dispatch

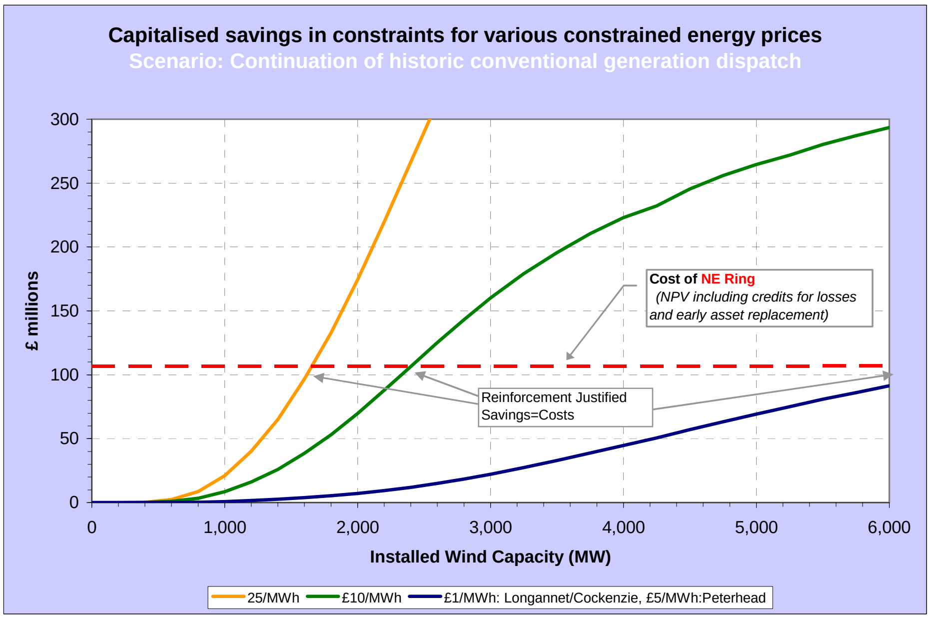
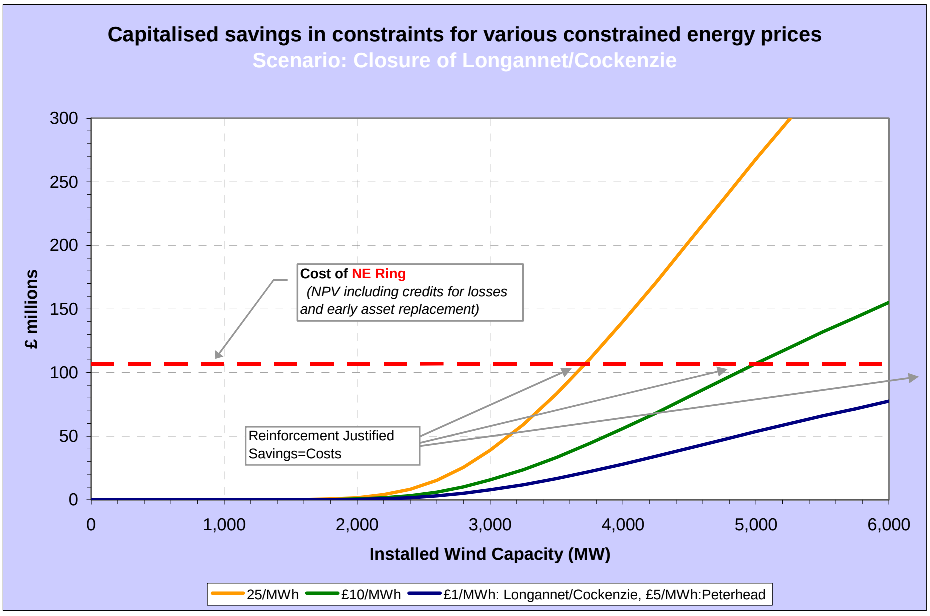


Figure 37 Cost benefit of staging the reinforcement. Stage 2: Northeast ring reinforcement. Scenario: Closure of Longannet/Cockenzie



It can be concluded that the reinforcement of the interconnector is unlikely to be justified on a cost-benefit basis until the level of wind generation capacity in Scotland reaches levels around 6,000 MW. In economic terms it will always be cheaper to constraint fossil fuel generation in Scotland rather than to reinforce the interconnector. The indicated levels of installed wind capacity required to justify the reinforcement are well into the future, current connection activity analysis discussed in Section 4 indicating a horizon beyond 2011.

Following this reinforcement constraints are not fully removed as indicated in Table 17. If it is assumed that the next reinforcement will involve a new double circuit at an estimated cost of £300 million and that most of the indicated constraints will be removed by this reinforcement then the trigger of this reinforcement would occur when the level of wind generation capacity reaches circa 6,000 MW.

9.3.7 Constrained energy volumes during construction

During construction of the proposed interconnector reinforcements, the interconnector capability will be further constrained as it will effectively require taking one circuit out of service for the majority of the outage season, Spring to Autumn, (Table 14). This will increase the volume of constrained energy and hence the cost of the interconnector reinforcement.

The volumes of constrained energy associated with the outage of the interconnector have been evaluated in a similar manner as described above taking into account that the interconnector capability during the outage season will be reduced to just over 1000 MW. The phasing of the works (and hence the required outages) has been assumed consistent with the indicated construction period in Section 7.8. A constrained energy cost of £1/MWh has been assumed consistent with the assumptions about displacement of old coal units discussed earlier in this document. The expected wind capacity generation profile indicated in Section 4.7 has been used in the calculation of the constrained energy volumes.

The results obtained indicate increasing construction costs that would range from £5.2 million per year in 2005 to £6.1 million per year in 2010. For the duration of the interconnector construction programme it will add between £25 and £30 million. There is no substantial advantage by doing this work ahead of time to avoid the construction costs as the penalty increase year-on –year is relatively modest. Alternatively there are no substantial penalties caused by delays in the anticipated programme of works.

9.3.8 Summary of findings

The proposed combined reinforcement of the Scotland-E&W interconnectors and the North East Ring has been investigated. Increasing levels of wind has been statistically superimposed on the interconnector flows adjusted for nuclear outages. Two scenarios have been considered in the determination of the benefits of the proposed determined as determined by the reduction in constrained energy and losses. These scenarios are the continuation of underlying dispatch levels of conventional generation in Scotland and the same scenario but with the closure of Longannet and Cockenzie this latter scenario indicating the increase in the required level of installed wind capacity to justify the reinforcement following a possible future closing of these two old power stations.

Table 18 summarises the results obtained from the studies for three possible staging alternatives namely the combined reinforcement of the Interconnectors and the NE Ring

Table 18 Scotland-E&W Interconnectors and NE Ring. Summary of results

	Constrained Energy Cost (£/MWh)	Adjusted Historic Flows	Adjusted Historic flows minus Longannet and Cockenzie	Would the reinforcement be justified on the basis of expected wind generation capacity by 2010?
Interconnectors and NE Ring	£25/MWh	900 MW	3,100 MW	Yes
	£10/MWh	1,700 MW	4,300 MW	Yes (Risk)
	£1/MWh-£5/MWh	5,000 MW	6,100 MW	No
Interconnectors Only	£25/MWh	600 MW	2,600 MW	Yes
	£10/MWh	1,000 MW	3,600 MW	Yes
	£1/MWh-£5/MWh	3,700 MW	5,000 MW	Yes (High risk)
NE Ring Only (after Interconnectors)	£25/MWh	1,600 MW	3,700 MW	Yes
	£10/MWh	2,400 MW	5,000 MW	No
	£1/MWh-£5/MWh	>6,000 MW	>>6,000 MW	No

9.4 Heysham reinforcements

NGC have identified a need to increase the capacity of the Heysham ring in response to a combination of increased Scotland –England interconnector flows and also the connection of offshore wind farms into the two 400 kV substations on the adjacent coast. NGC also indicate that the operation of conventional generation can have a significant influence on power flows through the ring and effectively “backs off” power flows down the west coast 400 kV circuits, issues which are not directly related to the connection of additional wind generation but rather changes in overall generation dispatch.

In earlier sections of this report we have questioned the rate at which offshore wind farms may connect to the NGC network in total, and also the need or otherwise for the uprating of the Scotland-England interconnectors in the shorter term. In the case of offshore generation wishing to connect locally, there is a clear precedent for such generation to be required to underwrite any deep reinforcement expenditure that may be initiated by its connection and such an arrangement is clearly appropriate in this case.

We are also of the view that some element of management of power flows through the Heysham ring will be needed irrespective of renewable generation connections, both in England and Scotland. It is not clear from the information that has been provided that there are not more cost effective means available to manage such power flows, either by "constraining on" local conventional generation or by the introduction of quadrature-booster into the circuits which influence power flows in the ring. This latter type of equipment has been successfully employed y NGC in other parts of the network and may also have significant benefits with respect to avoiding, or reducing the extent to which NGC may need to constrain generation in the area, either on or off the system.

Accordingly it is our view that expenditure on the Heysham ring should be delayed until its need is more clearly defined and that there is evidence that alternative solutions have been fully investigated and ruled out.

9.5 Kendoon area infrastructure

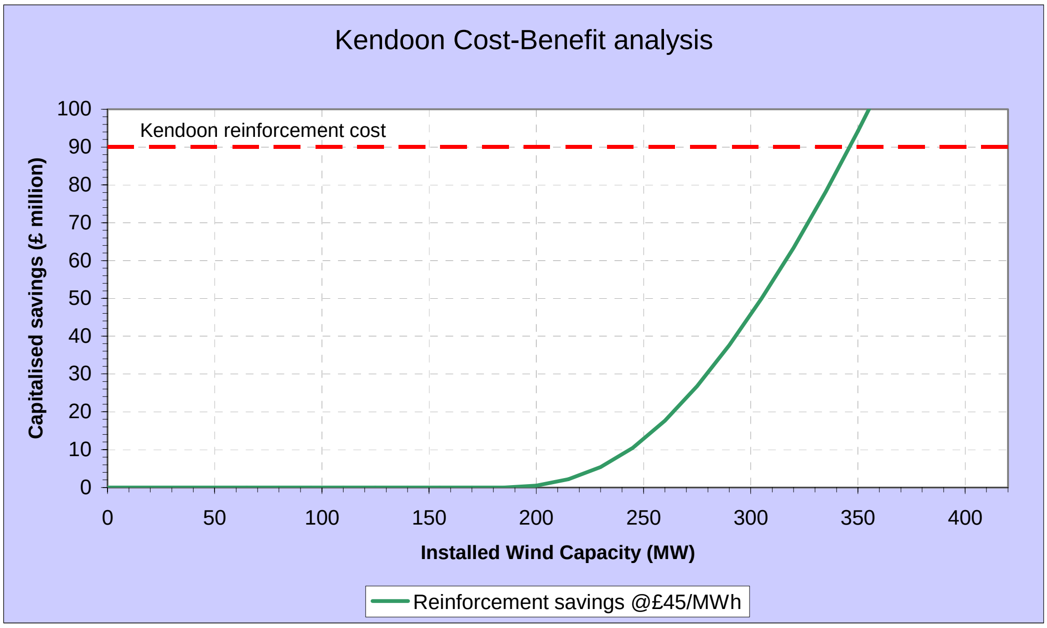
The total capital cost of this reinforcement is £90 million. A similar cost-benefit analysis has been undertaken to determine the break-even point of wind generation capacity that would justify initiating this reinforcement.

As indicated in Section 7 part of the need for reinforcements in the area is driven by load-related as it will serve to secure the Kilmarnock group demand which is forecast to exceed 300 MW by 2007/08 and there would be a need to reinforce the Kilmarnock group to secure 200 MW under second circuit outage in order to meet their license standards. (Currently the indicated second outage capacity at Kilmarnock is about 120 MW). Additionally the scope proposed reinforcement takes into account the outlined future development of a third interconnector line between Scotland and England and hence provides more capacity (and hence expenditure requirements) than otherwise would have been required by use for example of 132 kV circuits. This minimum "fit for purpose" network reinforcement has not been presented by SPTL.

Cost-benefit analysis has been undertaken to determine the capacity of wind generation that would justify the reinforcement on the basis of savings in constraint costs in a similar manner as undertaken for the reinforcements discussed above. The applicable value of constrained energy used in this case is £45/MWh as there is no alternative to remove constraints other than to constraint wind generation. There is hydro capacity in the area with limited storage that economically is similar in value to wind.

The results from the analysis are shown in Figure 38 which shows that the capitalised savings in constrained energy equal the cost of the reinforcement for Kendoon when the installed wind capacity is about 350 MW. Currently there are 36 MW connected and a further 166 MW under construction totalling 202 MW. A further 26 MW have accepted a connection quote. This would indicate that a further 120 MW would be required to justify the reinforcement noting that SPTL currently reports 165 MW under quote (69 MW issued and 96 MW under process)

Figure 38 Cost-benefit analysis of the Kendoon area reinforcement



It is therefore considered that the proposed reinforcement is very close to achieve enough wind generation capacity to be justified. However, there seems to be a significantly cheaper alternative network reinforcement to allow the unconstrained connection of the forecast levels of wind generation capacity, namely by using 132 kV, rather than 400 kV circuits. This coupled with considerable uncertainties about the need, and significant consents issues associated with a third interconnector in the foreseeable future, leads us to recommend against the sanction of this project as presented at this stage.

9.6 Sloy area reinforcements

The Sloy area reinforcement has been evaluated calculating the savings in constrained energy that would result from Stage 2 of the proposed reinforcement in the Sloy with a total capital cost of £21 million between SHETL and SPTL. Our evaluation has been based on the studies undertaken by SHETL on the need for the reinforcement, already discussed in Section 7.5, for the identification of network limits, as well as other relevant generation and demand information.

The result from the analysis indicates that, with the expected level of wind generation capacity of circa 300 MW and taking into account the demand and the hydro generation in the area, the value of the capitalised savings in constrained renewable generation would justify circa £43 million of capital expenditure. This valuation is based on a constrained energy cost of £45/MWh as the generation that would have to be constrained (wind or hydro) is of equal economic value as discussed in Section 6.

It is therefore considered that the Stage 2 of the Sloy area reinforcement is justified on the basis of the savings in capitalised constrained generation energy and our recommendation is to proceed with the sanction of this project.

9.7 Preliminary design and engineering work for the "island" interconnections

The island interconnection projects comprises large amounts of wind generation capacity connected in the Shetland, Orkney and Isle of Lewis and are characterised by the need of expensive network reinforcements that could be considered as dedicated generation assets in a spur configuration from the "main" transmission system of SHETL. Whilst the Beauly~Denny line may be considered to be somewhat similar to a spur, it sits alongside significant existing transmission infrastructure and would reinforce a part of the network relatively heavily utilised by existing hydro-generation. Accordingly relatively detailed analysis has been undertaken to determine the level of wind generation needed to justify its introduction.

In the case of a number of the network reinforcements proposed to interconnect the "islands" they are essentially dedicated spurs to proposed new wind farm locations. In the absence of these "spurs" any proposed wind farm, if developed would not be able to export any significant levels of power to the main network. The calculation required to justify such reinforcements may be linked directly to the capital cost of the proposed reinforcement, coupled with some assumptions with respect to any connecting wind generation. As outlined below.

$$\text{Wind capacity (MW)} = \frac{\text{Capital cost of reinforcement}}{\text{NPV factor}^{37} \times \text{Value of wind generation}^{38} \times \text{Annual energy production}^{39}\ \text{(MWh)}}$$

Based on the above, a £100 million pound reinforcement for example would be justified if more than 43 MW of wind farm capacity with an annual load factor of 40% wished to connect. In the consideration of each of the proposed "islands" projects load factor of 40% has been used following advice by SHETL that higher load factors can be expected. We have not obtained an estimate from SHETL of the capital costs of the reinforcements required for the interconnection of these developments. Based on information available in-house an estimated of the costs involved has been made for the interconnection of the Shetland.

Considering each of the proposed "spur" connections in turn.

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[37] NPV factor based upon 6.25 percent return over 40 years, i.e 14.7

[38] Taken to be £45/MWh in this example

[39] Annual production = Capacity (MW) x load factor x 8760

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Western Isles connection

Generation capacity of 1150 MW, therefore justified investment to remove a complete constraint would be £2,975 million

Orkney connection

Generation capacity of 160 MW, therefore justified investment to remove a complete constraint would be £414 million

Shetland connection

Generation capacity of 560 MW, therefore justified investment to remove a complete constraint would be £1,449 million

The figures above indicate that if the proposed schemes are built they would justify any of the required reinforcements to interconnect. The calculations above however do not include the capital cost of the wind generator and assume capital repayment terms similar to the TLs (6.25% and 40 years life). However in this case the transmission assets are clearly for the only purpose of the connection of wind generation which is unlikely to have a "life" of more than twenty years. This also is consistent with the expiry date of the ROCs, the expected typical life of current wind turbines and the dependency of these projects on the construction of the Beauly-Denny line.

In order to further investigate the likelihood of these projects estimates have been made of the cost of the interconnection assets and the total capital costs, including the costs of the Wind Turbine Generators (WTG, typically £600/kW for onshore), has been compared with the annual revenue assuming an energy price of £45/MWh and a utilisation factor of 45%. The ratios used for the capex include an interest rate of 15% and 20 years return for the generation assets. Table 19 shows the results obtained which are representative of an outline "business case" of the Islands Projects. It should be noted that the outline costs shown do not include provisions for items such as TUOS charges from Beauly or O&M costs.

Table 19 Outline "Business case" of the Islands Projects

Island	Capacity (MW)	Submarine Cable Distance (km)	Land Distance (km)	Costs Cable Infr. (£ million)	Costs OHL Infr. (£ million)	Total Capex including WTG (£ million)	Capital Annual Charge (£ million)	Annual Revenue @ £45/MWh (£ million)
Western Isles	1150	60	100	207	150	**900**	**144**	**204**
Orkney	160	30	150	19	40	**166**	**27**	**28**
Shetland	560	170	150	175	40	**546**	**87**	**99**
Orkney& Shetland	720	200	150	194	74	**706**	**113**	**128**

The results shown in Table 19 show small differences between the annual revenue and annual capital service charges in the case of the Orkney and Shetland projects. In the case of the Western

Isles however the results indicate a large positive difference between costs and revenues. It can be concluded that the Orkney and Shetland projects would not seem to be particularly attractive given the risks involved and the large amount of capital involved. From the outline numbers above it would seem as the most attractive project financially is the Western Isles although it is the most capital intensive and also has some considerable risks in the form of a completely new overhead line crossing the Highlands.

Considering the above we conclude that it would not be in the customers' interests to fund the expenditure associated with the detailed design, engineering and surveying for these capital intensive developer projects running the risk that these projects would not be continued. We understand that SHETL has a requirement to provide a binding connection offer and hence that these works may be required for this purpose. However we consider that in these cases funding should be provided from the developing party which should also serve to demonstrate commitment to the project given the amounts of capital that would be involved. A mechanism could be established to discount appropriately these initial costs if the project proceeds. Alternatively an exception may be made and the TL and Ofgem may agree to provide a conditional connection offer with indicative costs prior to any further expenditure commitment.

9.8 SHETL North East Reinforcements

SHETL has also indicated the intention to include PSE works to eventually proceed with the reinforcement of the circuits from Beauly to Keith. This reinforcement is not expected to start before 2008. However this reinforcement is expected to be required only after the main Beauly to Denny reinforcement has been commissioned and then it will be possible to manage constraints on wind generation by reducing the output of Peterhead. This implies that significant amounts of additional wind generation capacity north of Beauly to justify this reinforcement. The need for this reinforcement will be pushed well beyond the indicated prospective start date of 2010 and hence it is our view that the proposed PSE works are not required at this stage and may be considered in the context of the next transmission price control where there will also be a clearer view of the current wind generation forecast and the state of the "islands" wind generation projects as well as the consent and construction timetable of the Beauly-Denny line.

10. Conclusions and recommendations

This section summarises the main conclusions and recommendations of this report.

10.1 On the review of the TLs RETS report

- The positive benefit to costs ratios indicated for each of the three stages considered (2 GW, 4 GW and 6 GW in Scotland respectively) become negative for Stage 2 (which assumes that Stage 1 has been implemented) if the incremental costs and benefits provided by each stage are considered.
- High benefit to cost ratios associated with certain reinforcements may mask low or even negative benefit to cost ratios for proposed reinforcements in other areas if all the costs and benefits are lumped
- It is therefore necessary to consider in the evaluation of the benefits provided by the reinforcements through the difference in constrained energy before and after each proposed reinforcement taking into account that some reinforcements may involve works in more than one of the TLs areas.
- Critical aspects in the evaluation of the benefits from reinforcement are:
  - The assumption on the conventional generation dispatch
  - The assumption on the contribution of wind generation to the peak (treatment of wind generation under the planning standards)
  - The evaluation of constraint volumes
  - The assumptions in the valuation of constrained energy and capacity.

10.2 On the connection forecasts

- On balance we are satisfied that a forecast of about 4,000 MW of installed wind generation by 2010/11 within Scotland is reasonable based on the evidence provided by the TLs of the total capacity under construction, with connection contracts and signed agreements. The 4GW level is also considered as a plausible scenario for 2010 against the background of overall GB connection activity and with meeting government targets. As a consequence we are of the view that it can be used as a basis for assessing the associated shorter term network reinforcement requirement discussed later in this report.
- In the case of connections to the NGC transmission network, essentially offshore wind farm connections at Heysham, we are of the view that there is significant uncertainty on the likely outturn volumes and timing.

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10.3 Planning standards and its application to wind generation

- The methodologies in the companies' security standards do not provide guidelines for the modelling of intermittent generation sources, such as wind generation, in the assessment of transmission network capacity. It seems inappropriate to use the scaling factors applicable for conventional generation (83% of rating) to wind generation due to its different characteristics and the TLs have reflected this view in their latest planning assessment since the RETS study.
- A initial study on the correlation between wind farm output and demand indicate that, when the demand is between 85% and 100% of the peak, the wind farm outputs is below about 25% of maximum output for half of the time.
- Using a LOLE approach and using data for the complete GB system, the capacity credit factor that is applicable to wind generation for planning studies of the GB system corresponds to only about 20 percent of the total installed capacity. This observation is consistent with the reported findings from similar assessments undertaken internationally.
- The TLs have presented studies that have been undertaken including work commissioned from consultants that showed a correlation between wind farm outputs in Scotland of around 60%. The TLs have then used this correlation factor in network planning studies as a basis to determine secured network flows. However this factor is an average correlation factor between the output of wind farms and its implicit use as the "capacity credit" factor of wind generation, in the context of the companies' network planning standards e.g. when looking at the peak demand condition, is inappropriate.
- The difference between a "capacity credit" for wind generation of around 20% and the factor of 60% factor used in deterministic assessment of security will invariably result in the identification of network reinforcements either ahead of need and also in excess of actual requirements associated with a given installed wind generation capacity.
- It is this significant difference between the generation capacity available from wind on a secure basis, and that available on an average or coincident basis that point strongly for reinforcements associated with wind generation to be justified by cost-benefit based analysis. Such analysis needs to takes into account the daily and seasonal variability of wind generation, the equivalent variations in electricity demand and the inevitable, complimentary variation in conventional generation output.
- The treatment of wind generation under the planning standards is beyond our scope of work and our findings are hence based on a limited study as there are a number of other issues that need to be considered. Later in this document we have carried out some sensitivity analysis to consider other factors which may be applicable. It is recommended that the appropriate treatment of intermittent generation sources in the transmission security standards is subject to a consultation process within the industry.

10.4 Valuation of constrained energy

The penalty for not reinforcing the transmission system as the capacity of renewable generation installed in the network increases is primarily the constrained generation costs that result from the inability of the network to accommodate all the generation wanting to export into the network whilst being able to cope with the most onerous contingency under the applicable operational standards.

The penalty, in economic terms, arises from the "constrained" generation, which has to reduce its output as a result of the network operation limits, being more expensive than the generation that has to increase its output to replace it. Additionally there may be an additional economic penalty if, as a result of network constraints, all or part of the generation capacity that is constrained could have been assumed to participate in securing demand. In such a case it becomes necessary to provide additional generation capacity to the other side of the constraint and the costs of this additional capacity should then also be part of the constrained generation costs above.

The quantification of benefits from network reinforcement through the valuation of savings in constrained energy and losses can be undertaken using an economic or market based valuation of constrained energy prices. Under a competitive generation scenario to both sides of a given constraint, the market prices will tend towards the economic prices that represent the underlying generation production total costs.

From the analysis undertaken of market prices the following is concluded:

- The behaviour of prices (Buy and Sell) under NETA seem to follow a logical economic pattern linked to variations in the demand.
- Large excursions are observed in the System Buy Price (SBP) and a much more stable pattern in the System Sell Price (SSP).
- The average SSP in 2003 was £14.38/MWh which is representative of average fuel savings. More than 75% of the time the SSP was below £15/MWh
- The average SBP in 2003 was £23.5/MWh which includes fuel and capacity costs. More than 60% of the time the SBP was below £15/MWh
- The average difference between the SBP and SSP which is a proxy for the capacity value was £9.2/MWh in 2003. For 50% of the time the difference between SBP and SSP was below £4/MWh
- Average constraint costs of £40/MWh however have been reported although at peak times these costs could increase significantly leaving the System Operator exposed to high constraint payments that ultimately will be transferred to the consumers tariffs.

From the economic analysis of constraint costs the following is concluded.

- The economic cost of constraining wind is around £45/MWh which includes the ROC buy-out price and fuel savings for conventional fossil fuel generation of circa £15/MWh
- The economic cost of constraining conventional fossil fuel generation is about £1/MWh for replacement by “same generation technology” and circa £5/MWh for replacement by “more efficient technology” (e.g. old coal by modern CCGT). The difference in cost corresponds to the reduction in efficiency costs. However it should be noted that the latter price difference with Peterhead of £5/MWh will be eroded as old coal gets retired. Under such future scenario the generation displacement will involves more often displacements between CCGT units and then the lower value will be applicable to constraining Peterhead.
- The costs that can be associated with the replacement of the capacity contribution of wind generation need to be determined on an individual constraint basis, based specifically upon the expected security contribution of that generation an any constraints imposed thereon by the associated network.
- The costs that can be associated with the replacement of the capacity contribution of wind generation need to be determined on an individual constraint basis, based specifically upon the expected security contribution of that generation and any constraints imposed thereon by the associated network. In the case of the Scotland-England interconnectors, analysis indicates that this will not arise until about 6000 MW of wind is connected north of the constraint.
- The economic value of losses adopted in this study is the same as constrained wind energy i.e. £45/MWh as its effects are identical. This value is consistent with recent incentive proposals by Ofgem for the DPCR4.
- Although the capacity credit of wind is small the generation capacity that it will displace will be considerable as wind generators output fluctuate between high and low levels of output compensated by conventional generation. It is therefore expected that under a scenario with high levels of installed capacity there would be increased competition of conventional generation that would tend to reduce the historic market capacity prices indicated above.

10.5 Summary of proposed reinforcements

10.5.1 Beauly – Denny line

This project is required to reinforce connections into the north of Scotland and will be justified on avoided constraint costs and transmission loss savings providing about 1200 MW of generation connects in its serviced area. Constraint costs associated with this reinforcement are high as only renewable generation, namely hydro-electric and wind farm generation exists behind the existing transmission constraint. At the present time a total of over 800 MW of wind farms are either connected, under construction or have accepted quotation in this area. In addition over 1900 MW of quotes have been issued with the expectation that a significant proportion of these will accept and connect once adequate connection capacity is committed. On this basis it is recommended that project funding is approved.

10.5.2 Scotland-England Interconnectors/North East ring reinforcements

Reinforcement of the Scotland –England interconnection has been proposed jointly by SPTL and NGC. However, in the work submitted by the TLs, the interconnector upgrades has been linked with the North East ring upgrade and essentially presented as a single project. Our initial review of the information submitted highlighted the fact that it was appropriate to investigate the merits of each constituent part rather than bundling such projects together. By doing so it is possible to gauge which parts, if any may be justified and which parts may be better delayed. Accordingly we have requested information from the TL in a more disaggregated form to better facilitate consideration of a staged development. It should be noted that the level of renewable generation activity necessary to justify the combined project may be considerably greater than that of one of the individual stages.

10.5.3 Scotland-England interconnector upgrade alone.

This Scotland-England interconnector upgrade project comprises reconductoring of the existing 400 kV double circuit eastern interconnector, together with associated works at the terminating substations and the establishment of a new 400 kV termination for the line at Blyth, and also the uprating of the existing 275 kV operating circuit on the western interconnector and associated substations to 400 kV operation.

The intention of reconductoring of the eastern interconnector is to increase its thermal capacity to a summer rating of about 2900 MVA per circuit. The proposed uprating of the remaining 275 kV western interconnector and associated substations to 400 kV will increase the rating of that circuit to match that of the adjacent 400 kV operating circuit, i.e. to a summer rating of 1750 MVA and will result in a double circuit 400 kV interconnection being provided on both sides of the country. Information relating to the singular benefit of this uprating, i.e when not taken in concert with other works was not initially provided by NGC. However, subsequent to our questioning on this issue and after having undertaken additional studies, recent information from NGC indicates that when taken together with a Beauly-Denny upgrade, the eastern interconnector re-conductoring and the western interconnector upgrade projects will increase the Scotland –England interconnector capacity to about 2800 MW, from the present level of about 2200 MW, with the interconnection limit after reinforcement is largely determined by stability considerations. It is on this basis that we have investigated the incremental value of these works with respect to cost-benefit analysis. Subsequent to the above, information has been obtained from NGC which indicates that some further more detailed consideration of the stages associated with the interconnector reinforcements may be appropriate and this is clearly an issue for further consideration.

10.5.4 North-East ring reinforcement

The reinforcement of the north-east ring, essentially the establishment, by uprating an existing 275 kV circuit to 400 kV to provide a stronger connection to the main 400 kV network in the

Teeside area is effectively the second stage of reinforcement of the Scotland –England interconnectors. NGC have recently confirmed that this work would be undertaken following the Interconnector Upgrade and, when completed the power transfer limit between Scotland and England will increase to about 3,200 MW. The main drivers for this reinforcement is voltage issues consequent to eastern interconnector outages under the winter peak condition following the proposed interconnector upgrades. A related driver in summer conditions is stated to be cross-outage conditions in the Heysham ring.

Whilst the proposed physical works, substation arrangements with respect to the necessary reconfigurations and space requirements, as well as individual costs associated with the reinforcement are reasonably well defined, the overall network security drivers are in our view very much “work in progress”. This observation is supported by the sequential developments identified above with respect to reinforcing the main Scotland-England interconnectors, with the indication that the necessary detailed staged network planning studies are yet to be undertaken. Included in such work to ensure that the most cost effective development are identified would be a more detailed investigation of alternatives such as SVCs and also quadrature boosters employed to manage the sharing between the north-east ring and the 400 kV north-west circuits. As a consequence it is our view that construction related works on the north-east ring should be delayed until such detailed studies have been completed.

10.5.5 Heysham area reinforcement

This project is stated to be driven by consideration of increased power flows from Scotland, associated with the uprating of the Scotland-England interconnector and the connection of significant renewable generation in Scotland, coupled also with the possible connection of major renewable generation in the vicinity of Heysham and essentially comprises the reconductoring of the 400 kV overhead line circuits of the “Heysham Ring” such that they can safely carry the output from the Heysham nuclear power station plus local offshore wind farms in conjunction with increased power flows from Scotland under a combination of circuit outages.

With respect to the need to reinforce the existing line circuits in order to accommodate increased power flows from Scotland, subsequent to interconnector uprating, we are concerned that alternative means of managing such power flows appear not to have been fully investigated. As indicated above with respect to the north-east ring, such equipment may be beneficial to both parts of the northern network. Accordingly it is our view that construction work on the Heysham ring should be delayed until its need is more clearly defined and that there is evidence that alternative solutions have been fully investigated and ruled out.

In the case of offshore generation wishing to connect locally, there is a clear precedent for such generation to be required to underwrite any deep reinforcement expenditure that may be initiated by its connection and such an arrangement is clearly appropriate in this case.

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10.5.6 Kendoon area connection infrastructure

The purpose of the Kendoon area work, which is initially associated with the construction of a 400 kV line from Kilmarnock South to Kendoon, is to provide connection infrastructure for wind farm developments in the south-west of SPTL area, and also as precursor to the provision of a third interconnector between Scotland and England, routed through Galloway. The dilemma identified by SPTL is that there will invariably be considerable sensitivity to the construction of a new line in this area and hence there is a strong incentive to obtain consents for a project which will meet potential longer term objectives, rather than proceeding on a piecemeal basis with the risk of sterilising the area for any further development. The problem with this approach is that certain expenditure may be undertaken ahead of need, with a possible risk of essentially stranding assets should a third interconnector not be found necessary.

Late in the review process, and following the above, SPTL provided initial estimates of an alternative scheme using a double circuit connection from Kilmarnock South to Kendoon constructed to 400 kV specifications but operated initially at 275 kV. The scheme provides 480 MVA of non-firm capacity, vs. 720 MVA with the TLs scheme above, with a saving of £19 million. However, given the large amount of connection interest in the area, the critical issue even in this scheme, is the considerable possibility of stranded assets of the 275 kV equipment (switchgear and transformers) and its dependency on the phasing of connections that could make preferable to proceed with the more expensive TL proposed scheme. All these issues should be further examined and the convenience of proceeding with the TLs proposed scheme or otherwise demonstrated but there is a need to provide additional network capacity in this area.

10.5.7 Sloy area reinforcement

This project is to accommodate significant additional renewable generation on the Mull of Kintyre and comprises the establishment of a connection between the SHETL 132 kV network in the area and the existing SPTL 275 kV connection from the Cruachan pumped storage station towards Windy Hill and the main SPTL network. A total of over 100 MW of generation is currently connected, or under construction in this area, and making use of the existing relatively weak 132 kV grid in the area. A further 200 MW of wind farm quotations have also been accepted and the existing 132 kV network is considered inadequate, hence the proposed connection into the SPTL network which is seen as the most cost effective means of reinforcement.

10.5.8 Western Isles, Orkney and Shetland connections

SHETL have identified expenditure provisions totalling about £4.5 associated with early investigations of the feasibility of overhead line and submarine cable connections to these offshore island groups. The SHETL proposals are in response to connection enquiries and connection agreements associated with a total of over 1800 MW in the three locations. Although eventual connection costs have not been estimated, our own assessments indicates that the three submarine connections schemes would amount to about £200 million, £20 million and £175 million respectively for the estimated 50 km (Western Isles), 10 km (Orkney) and 200 km (Shetland) connections. On top of these costs would be the associated onshore transmission which would add about £200 million to the Western Isles, i.e. a new 400 kV transmission line route from Beauly across the highlands to the Hebridean Sea and also expenditure of between £ 40/75 million being associated with individual/shared 275 kV overhead line reinforcement from Beauly to the Orkney/Shetland cable connection point(s) near to Dounreay. In the light of the high capital costs associated with essentially dedicated generation connection assets and higher risks associated with obtaining consents for such, we do not consider it appropriate for the TL to incur any expenditure which is not underwritten by the developer.

10.5.9 Beauly-Keith reinforcement

Subsequent to the Beauly-Denny works, the phasing of further reinforcements, to accommodate the growing volume of renewable generation in the north of Scotland has led SHETL to propose a 400kV single circuit ring built on the Beauly to Denny line, uprating one of the existing 275 kV circuits from Kincardine, via Tealing, Kintore and through to Keith, all suitable for 400 kV operation, with the final link from Keith to Beauly being a rebuild of the existing 275 kV line from Beauly to Keith/Blackhillock to make it suitable for 400 kV operation. It is proposed that one circuit of this line will operate initially at 400 kV and the other circuit will operate at 275 kV.

The need for major expenditure on the Beauly-Keith reinforcement is some time in the future, it will most likely be initiated by the connection of a major wind farm project in one of the islands. As a consequence we are of the view that there is little justification for any early expenditure on this project.

10.6 Reinforcement expenditure forecasts

- The latest TL's expenditure forecasts are summarised in Section 8 on a project by project basis. These costs reflect budget costs based upon their present knowledge of the projects, based in part upon specific tender information (Beauly – Denny overhead line works) or on outturn costs on recent relevant contract works. These costs include reasonable levels of contingencies with the intention that the level of contingency will be refined by undertaking initial engineering and design works, budget provisions for which are identified.
- SKM is satisfied that the forecast levels of expenditure are broadly reasonable for the proposed works and are reflective of present market status with respect to the highest cost items, namely overhead line works. We do have some issues with respect to the staging of certain parts of the works, in particular SHETL's indicated early PSE spend on the proposed connections to Orkney and Shetland and the Beauly-Keith reinforcement (SHETL Projects 4, 5, 6, and 7), the provisions made by SPTL for initial engineering and design works which seem high compared

to the other two TLs, and also NGC's early non-PSE spend (£12 million) on the Eastern Interconnector circuits.

- It is our expectation that all expenditure, regardless of nature or project will be subject to the normal Transmission Price Control Review as to its need and the efficiency of its delivery. The convenience or otherwise of sanctioning the initial design and engineering work expenditure is subject to the suitability of the associated reinforcement scheme. The cost benefit analysis of the proposed reinforcements is undertaken in Section 9.

10.7 Summary of recommendations

The following table summarises our recommendations for the proposed reinforcements.

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	Reinforcement	Estimate costs of complete works (£'000s)	Costs seeking regulatory sanction (£'000s)	Wind installed capacity that justifies project (MW)	Stranded Assets Risks	Views
1	Beauly-Denny	331,928	331,928	1,200 MW	Low	Justified on the basis of savings in constraints costs and losses
2	England/Scotland Interconnectors upgrade.	151,887	151,887	3700 MW to 5,000 MW (Note:4000 MW of wind expected by 2010)	Sensitive to constraint costs, project staging and operation of conventional stations in Scotland	Further assessment required before the project could be deemed justifed, at this stage, proceed with initial design and engineering works £3.3 million (£2.8 m NGC, £1.5 m SPTL). Easier to be justified on a cost-benefit basis if staged (West uprating followed by East reconductoring). Also should follow 1 above (Beauly-Denny)
3	North East Ring upgrade.	139,654	139,654	6,200 MW to 6,800 MW (Note: 4,000 MW of wind expected by 2010)	Sensitive to assumptions on the operation of conventional stations in Scotland	Unlikely to be justified at this stage, proceed only with initial design and engineering works and should follow 2 above (Beauly-Denny plus E/S interconnector).
4	Heysham area reinforcements	65,158	65,158	As for 2 & 3 above plus also 500 MW local wind farms (offshore)	High, also lower cost alternatives should be investigated	Lower cost alternative should be investigated. Should follow 2 above (Beauly-Denny plus E/S interconnector)
5	Kendoon area connection infrastructure	90,049	90,049	350 MW (228 MW accepted/construction)	Medium, also lower cost/risk alternative should be investigated	Lower cost alternative should be investigated but in any case reinforcement circuits required. Justified Initial design and engineering works £2.3m
6	Sloy area reinforcements	45,963	20,963 (Stage 2)	150 MW (currently 300 MW under construction/contract)	Low	Justified on the basis of accepted connection offers and associated constrained generation costs
7	Beauly to islands (Shetland/Orkney/ W.Isles)	625,000 (SKM estimate)	4,137 [Initial engineering]	Not applicable. Specific connection driven assets with costs recoverable from customer	N/A	Initial design and feasibility work should be underwritten by developer. Outline "business case" indicates in favour of Western Isles and against Orkney/Shetland
8	Beauly / Keith reinforcement	158,449	282 [Initial engineering]	Circa 5000 MW north of Beauly	N/A	Well ahead of need, recommended to review at a later date
	TOTAL	1,608,090	804,058			

Appendix A: List of sources used

The following documents were used in the elaboration of this report. It should be noted that some of these documents are provided in confidence to Ofgem for the purposes of this project.

Document register

Number	Description	Reference	Source	Date recv'd	Form	Location	Notes
1	Narrative on points raised during first meeting with TLs		NGC	27/04/2004	e-mail		Word Document
2	RETS 2004 Renewable generation Position: April 2004		SHETL	28/04/2004	Hard Copy	NCL	Area Map indicating renewable connections and interest
3	Data exchange with SP and NGC: Renewable generation activity		SHETL	28/04/2004	Hard Copy	NCL	Table 1 page
4	Snapshot of current renewable generation activity		SHETL	28/04/2004	Hard Copy	NCL	Table 1 page double sided
5	Narrative on RETS system design strategy and need case		SPTL	29/04/2004	Hard Copy	NCL	Comb bound copy
6	Renewable Energy Transmission Study		SPTL	29/04/2004	Hard Copy	NCL	Original RETS report undertaken jointly by the three TLs
7	Transmission Design Memorandum 13/10.001 Issue 2		SPTL	29/04/2004	Hard Copy	NCL	Planning standards
8	Transmission Design Memorandum 13/10.003 Issue 1		SPTL	29/04/2004	Hard Copy	NCL	Voltage control and reactive compensation criteria
9	Technical Approval Paper. RETS Stage 1, Phase 1	NI 437	SPTL	29/04/2004	Hard Copy	NCL	
10	Technical Approval Paper. RETS Stage 1, Phase 2	NI 369	SPTL	29/04/2004	Hard Copy	NCL	
11	Technical Approval Paper. RETS Stage 2, Advanced works	SDC 329	SPTL	29/04/2004	Hard Copy	NCL	
12	Transmission Seven Year Statement 2003-2009	Apr-03	SPTL	29/04/2004	Hard Copy	NCL	2 copies
13	ASSESS Description Paper	CIGRE	NGC	30/04/2004	Soft copy	NCL	Sent by e-mail
14	ASSESS Description Paper		NGC	01/05/2004	Soft copy	NCL	Sent by e-mail
15	Letter to Andrew Walker on RETS		NGC	06/05/2004	Hard/Soft	NCL	Handed out and sent by e-mail by Suart Boyle
16	RETS 2 Study Programme	RETS2	NGC	10/05/2004	Soft copy	NCL	Handed out and sent by e-mail by Suart Boyle
17	Generation Ranking orders		NGC	10/05/2004	Soft copy	NCL	Sent by e-mail by Stuart Boyle
18	NGC Powerpoint Presentations to SKM on RETS		NGC	10/05/2004	Soft copy	NCL	Sent by e-mail by Stuart Boyle

19	Ofgem May Consultation Paper		Ofgem	07/05/2004	Soft copy	Web	Ofgem website
20	Distribution Long Term Development Statement 2003-2007	Nov-03	SPTL	13/05/2004	Hard copy	NCL	
21	Colin Bayfiled's IEE Lecture: Wind Power from Scotland to England	24/03/2004	SPTL	13/05/2004	Hard copy	NCL	Powerpoint presentation
22	Core generation levels to secure Interconnector transfers (Table)		SPTL	13/05/2004	Hard copy	NCL	One page copy of a report
23	Current renewable activity in the SPTL area (Table)		SPTL	13/05/2004	Hard copy	NCL	
24	An assessment of the Potential renewable energy resource in Scotland		SPTL	13/05/2004	Hard copy	NCL	Joint Scottish Executive study
25	Generators Connection Agreement Template Pre Jan 2004		SPTL	13/05/2004	Hard copy	NCL	
26	Generators Connection Agreement Template Post Jan 2004		SPTL	13/05/2004	Hard copy	NCL	
27	Easterhouse s/s layout SLD		SPTL	13/05/2004	Hard copy	NCL	
28	Clyde's Mill s/s layout SLD		SPTL	13/05/2004	Hard copy	NCL	
29	SHET Seven Year Statement 2003-2009		SHETL	14/05/2004	Hard copy	NCL	
30	PB Power report on optimum transmission reinforcement		SHETL	14/05/2004	Hard Copy	NCL	
31	Initial assesment of North South Transmission Reinforcement (report)		SHETL	14/05/2004	Hard Copy	NCL	Report by Richard Sherry 4/05/99
32	Technical Review of RETS 2		NGC	14/05/2004	E-mail		Zipped file from S Boyle
33	Renewable Energy Transmission Study Business Case		SHETL	13/05/2004	Hard Copy	NCL	Draft Report
34	Figure for Transmission Limits of PBP Report		SHETL	13/05/2004	Hard Copy	NCL	PSSE Power Flows
35	Beauly Denny Single Line Diagram Draft May 2004		SHETL	13/05/2004	Hard Copy	NCL	One page
36	Overview of the Transmission reinforcements required for wind in Scotland		NGC	06/05/2004	Hard Copy	NCL	Hard and Soft Copy
37	Strathclyde University study on Wind Farm Load factors		SHETL	18/05/2005	Soft copy	NCL	Word Document, sent by e-mail by Brian Punton
38	NGC Advanced engineering works		NGC	20/05/2004	Soft copy	NCL	Word document sent via e-mail by Stuart Boyle
39	RETS Infrastructure North East -Stage 1, Single line diagram		NGC	21/05/2004	Hard Copy	NCL	A0 SLD
40	RETS Heysham Ring 400 kV Single Line Diagram		NGC	21/05/2004	Hard Copy	NCL	
41	ZZA & 4ZY Double Tee RETS, Single line diagram		NGC	21/05/2004	Hard Copy	NCL	
42	4ZY and YG Junction arrangements		NGC	21/05/2004	Hard Copy	NCL	
43	Breakdown of advance Enginnering expenditure for RETS		NGC	21/05/2004	H/S Copy	NCL	
44	Preliminary consents and property costs required for RETS		NGC	21/05/2004	H/S Copy	NCL	
45	Presentations during second meeting		NGC	21/05/2004	Soft copy	NCL	pdf file of Powerpoint presentations

46	400/275 System Overhead Line system data		NGC	01/06/2004	Hard Copy	NCL	Single line diagram North and South (2 Docs)
47	Diagram of the North East Ring		NGC	02/06/2004	Soft Copy	NCL	Pdf sent by e-mail
48	Offshore windfarms at May 2004		NGC	01/06/2004	Soft Copy	NCL	Excel sheet sent via e-mail
49	Response to actions from second meeting		NGC	01/06/2004	Soft Copy	NCL	Pdf sent by e-mail
50	Note on the procurement process for the Beauly Denny line		SHETL	02/06/2004	Soft Copy	NCL	Sent via e-mail by B Punton
51	Schedule of prices for undergrounding sections at 275kV and 400 kV		SHETL	03/06/2004	Soft Copy	NCL	Sent via e-mail by B Punton
52	Schedule of costs for the PES for the Islands connections		SHETL	04/06/2004	Soft Copy	NCL	Sent via e-mail by B Punton
53	Link document between North-South report and RETS report		SHETL	05/06/2004	Soft Copy	NCL	Sent via e-mail by B Punton
54	SCADA data for 2001/02		SPTL	03/06/2004	Soft Copy	NCL	Sent via e-mail by D MacMenemy (Excel sheets 25)
55	Interconnector limits for 2002/03		SPTL	04/06/2004	Soft Copy	NCL	Sent via e-mail by D MacMenemy (Excel sheets 25)
56	Response to queries from SKM		SPTL	05/06/2004	Soft Copy	NCL	Word file sent via e-mail by David Adams
57	Grid Control instruction B1		SPTL	05/06/2004	Soft Copy	NCL	Word file sent via e-mail by David Adams
58	Interconnector limits for 2001/02		SPTL	08/06/2004	Soft Copy	NCL	Worksheet sent via e-mail by D McMenemy
59	Cruachan characteristics		SPTL	10/06/2004	Soft Copy	NCL	e-mail response by David Adams
60	PDDs of the RETS Schemes		NGC	11/06/2004	Soft Copy	NCL	Sent via e-mail by Stuart Boyle
61	Southwest Diagrams, justification and power flows		SHETL	11/06/2004	Soft Copy	NCL	Sent via e-mail by B Punton
62	Series data for Peterhead and demand		SHETL	11/06/2004	Soft Copy	NCL	Sent via e-mail by B Punton
63	Power flows of system studies showing limits		SPTL	14/06/2004	Hard Copy	NCL	Sent via post by D Adam
64	Breakdown of RETS costs		SHETL	14/06/2004	Soft Copy	NCL	Sent via e-mail from M Barlow
65	Breakdown of Beauly-Denny line costs		SHETL	16/06/2004	Soft Copy	NCL	Sent via e-mail from M Barlow (Word)
66	Confirmation of on-costs values adopted		SHETL	18/06/2004	Soft Copy	NCL	E-mail message from M Barlow
67	Response to some of the outstanding queries (Heysham ring)		NGC	18/06/2004	Soft Copy	NCL	E-mail message from S Boyle
68	Power flows (63) showing the effect of the Beauly-Denny line		SHETL	21/06/2004	Hard Copy	NCL	Hard copy from D Adam received by post
69	Engineering costs used		NGC	21/06/2004	Soft copy	NCL	E-mail message from S Boyle
70	Further clarifications about on-costs		SHETL	21/06/2004	Soft Copy	NCL	Word document sent via e-mail by M Barlow
71	Reconciliation of costs from the Ofgem CP to updated f'cast		SHETL	17/06/2004	Soft Copy	NCL	Word document sent via e-mail by B Punton
72	Updates to actions 3,4,7 (21/05/04) & cost brakdown in TPC format		NGC	18/06/2004	Soft copy	NCL	E-mail message sent by S Boyle

73	Renewable generation activity data (as sent to Ofgem)		SPTL	18/06/2004	Soft Copy	NCL	E-mail message sent by D Adam
74	Need for NE ring, comparison with rective compensation		NGC	23/06/2004	Soft Copy	NCL	E-mail message sent bt S Boyle
75	Estimates of construction outages for Beauly-Denny Line		SHETL	25/06/2004	Soft Copy	NCL	E-mail message sent by B Punton
76	Use of triple over twin conductor (East coast Inte.)		NGC	30/06/2004	Soft copy	NCL	E-mail message sent bt S Boyle
77	Load Flow Diagrams showing effect of Beauly-Denny reinf.		SPTL	30/06/2004	Hard Copy	NCL	PSS/E Plots
78	N-1/N-D transfer limits and construction outages		SPTL	30/06/2004	Soft Copy	NCL	E-mail message sent by D Adam
79	Economic reinforcement benefits under NETA/BETTA		NGC	02/07/2004	Soft Copy	NCL	Paper by L Dale sent by S Boyle
80	Further claridications following meeting		SPTL	02/07/2004	Soft Copy	NCL	E-mail message sent by D Adam
81	Use of Intertripping to increase interconnector capability		NGC	02/07/2004	Soft copy	NCL	E-mail message by A Hiorns
82	Supplemental clarifications on the use of intertripping		NGC	05/07/2004	Soft Copy	NCL	E-mail message by S Boyle
83	Summary of windfarms in Northern England		NGC	08/07/2004	Soft Copy	NCL	E-mail message by S Boyle
84	Summary of windfarms in Southern England		NGC	09/07/2004	Soft Copy	NCL	E-mail message by S Boyle
85	Estimated expenditure RETS S1 PSE		SPTL	09/07/2004	Soft Copy	NCL	E-mail message sent by D Adam
86	Interim reinforcement stability studies		NGC	15/07/2004	Soft Copy	NCL	E-mail message by S Boyle
87	Further clarifications of the interim reinforcement stability studies (SVCs)		NGC	16/07/2004	Soft Copy	NCL	E-mail message by S Boyle
88	Stability studies with the Beauly-Denny reinforcement		NGC	22/07/2004	Soft Copy	NCL	E-mail message by S Boyle
89	Response to further queries (16/07/04)		NGC	22/07/2004	Soft Copy	NCL	E-mail message by S Boyle