Caithness-Moray Strategic Wider Works Needs Case Assessment

A report for Ofgem - REDACTED

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Executive Summary

This report provides an independent assessment of SHE Transmission's proposed transmission reinforcement at Caithness Moray (CM) under Ofgem's Strategic Wider Works (SWW) process.

To put forward a project for consideration under the SWW process, the relevant Transmission Owner (TO) must provide a "Needs Case" submission followed by a "Project Assessment" submission, in which the economic and technical case for delivery of the proposed project is described and fully justified.

DNV KEMA was appointed by Ofgem to provide an independent expert assessment of the first stage of the process, the Needs Case for the proposed Caithness - Moray transmission reinforcement project. This document provides our independent review in the form of an assessment of the TO submissions and provides recommendations to Ofgem in the relevant areas to support their evaluation. The recommendations of this report will inform Ofgem's minded-to position on the need, timing and optimal technical scope for reinforcing the transmission system in the Caithness – Moray area.

The relevant assessment areas include:

1) The consistency of SHE Transmission's proposal with fundamental guiding principles for SWW proposals.
2) Whether an appropriate range of uncertainties has been considered in testing the Needs Case as well as the scope and timing of the required reinforcement.
3) Whether SHE Transmission's has adequately evaluated its preferred proposal as well as alternative transmission solutions and / or operational measures.
4) The comprehensiveness and reasonableness of the estimated lifetime costs for each of the options set out in SHE Transmission's proposal at this stage and whether these are sufficient to allow a fair comparison of the options.
5) A review of the methodology used in the Cost Benefit Analysis (CBA) and Least Worst Regret (LWR) analysis against best practice.
6) The validity of the core input assumptions used in the supporting analysis.

Findings on the Technical Needs Case

Our review of the SHE Transmission submission assessing the feasibility of different options to reinforce the north of the SHE Transmission geographical area has confirmed that there is a strong case for reinforcement in the future given the existing network capacity and the expected increase in generation capacity in the north of Scotland. Based on our review of the technical part of SHE Transmission's submission, we agree that existing transmission capacity is limited and there is long term need for reinforcement of the transmission system in the north of Scotland.

Considering all the information provided, DNV KEMA believes that the four generation scenarios considered by SHE Transmission and their consultants capture the reasonable range of possibilities for the development of generation in the area considered. We note, however, that we have not had access to the calculations based on which SHE Transmission has determined the volumes of constrained generation. We understand that Ofgem is obtaining an alternative, independent view on constraint volumes, and have not undertaken a detailed assessment of our own.

Our key findings on the technical scope of the proposal (option 1a), which consists of a combination of onshore AC works and an offshore HVDC link, are:

1) Technical scope of the HVDC proposal (option 1a) will only meet some of the future requirement for additional network capacity.
2) Technical scope of the HVDC proposal could be improved and would meet future requirements better if combined with reinforcement of Beauly-Blackhillock corridor (option 1b).
3) Cost estimates for the HVDC link including Caithness subsea cable are at the high end of what we consider to be reasonable
4) It also includes an element of anticipatory investment to facilitate connections for additional generation capacity in the future, which is likely to offer additional benefits, but it does not capture all the risks associated with multi-terminal HVDC technology for which there is a very limited international experience.

An alternative reinforcement option investigated in the optioneering process, the AC option that rebuilds circuits from Caithness to Beauly (option 2a), can be similarly efficient from a technical perspective in delivering additional network capacity only when it is combined with the reinforcement of the Beauly-Blackhillock Corridor (BB400) from Beauly to Blackhillock (forming option 2b). However, we consider the optioneering process for the BB400 reinforcement to be too limited and lacking in detail, which prevents us from determining the full efficiency of this part of option 2b.

We believe SHE Transmission has identified all the key risks associated with the main options considered, but there is no clear link between the HVDC risk register and the potential cost impact of the risk. Other than planning risk, which is accounted for through longer delivery timescales, it is unclear how the likelihood and materiality of certain risks are taken into account, which increases uncertainty on the cost estimates and net benefits for the options considered in the Cost Benefit Analysis.

The Needs Case submission provides reasonable evidence of a broad stakeholder engagement on the need for the reinforcement. On the other hand there is limited evidence of good stakeholder engagement regarding the selection of the reinforcement option.

Findings on the Cost Benefit Analysis

We have reviewed the Cost Benefit Analysis (CBA) analysis and conclude that the calculations and underlying assumptions are mostly reasonable, except for the following issues:

1) We note that the cost estimate for option 2a in CBA analysis erroneously includes costs for the reinforcement of the Blackhillock substation. Since this reinforcement is not required for option 2a, this error lowers the NPV of this option. However, since the error does not affect the results for option 2b, which we consider a more realistic option, it does not affect our overall conclusion.
2) We believe cost sensitivities for the HVDC reinforcement do not fully capture the risk of cost overruns.
3) The sensitivities looking at potential increases in capital expenditure, and a lower cost of energy constraints (£100/MWh), have not been taken into account in the main CBA analysis.

The results of the CBA analysis are strongly in favour of option 2b, which combines the AC reinforcement with BB400. Option 2b returns the highest net present value (NPV) in all generation scenarios under base timing and capital expenditure (capex) assumptions, as well as across all of the timing, capex and constraint cost sensitivities modelled. Option 2b is therefore also the least worst regret option considered in the CBA analysis.

Option 1b (comprising the HVDC link and the BB400) is the closest competitor to option 2b, particularly in more optimistic generation scenarios, Slow Progression (SP) and Gone Green (GG), where there is often less than 10 percent difference in NPV terms. The CBA report has put forward arguments around the potential risk of delays and associated costs for BB400 that lend support to option 1b, which is less reliant on the benefits delivered by BB400 than option 2b. Based on this argument, and citing uncertainty over future levels of generation, the CBA report argues that the option of deferring investment in BB400 provides an additional benefit in favour of option 1b.

We consider these arguments are undermined by the outcome of the CBA analysis, which shows that BB400 adds benefits under all generation scenarios. In the "central case" generation scenario, SP, assumed in the CBA report, BB400 delivers greater benefits if it is delivered earlier, and it improves the case for option 1b relative to 2b. In the more conservative generation scenarios, Ofgem and Slower Slow Progression, (SSP), should slow generation growth be a concern, the relative benefits delivered by option 2b compared to option 1b increase.

Moreover, our analysis of the effects of delays in BB400 shows that only with extreme delays might option 1b return a higher NPV than option 2b. Moreover, a lot of the opportunity costs from delays in BB400 might be avoided in option 2b by co-ordinating the delivery of BB400 and the AC reinforcement.

We have also investigated the claim in the CBA report that there are additional welfare benefits associated with the HVDC reinforcement (option 1b) relative to option 2b. The CBA report argues these arise because option 1b would provide additional transmission capacity sooner and therefore avoid constrained and frustrated renewable generation. We believe the welfare figures proposed in the CBA report are significantly overstated:

- proposed welfare benefits from constrained renewable generation have already been accounted for in the main CBA analysis; and
- much of the potentially frustrated generation is not specifically dependent on the HVDC reinforcement and the timing of other generation is highly uncertain due to legal issues regarding planning permission.

Based on the above, we consider that the HVDC reinforcement provides only a small part of the £1,124m of welfare benefits calculated in section 10.1.2 of the CBA report. Lack of further information combined with the uncertainties about the Beatrice (alternative enabling works) and Shetland (project delays) projects prevents us from making a more informed estimate. In any case, the welfare calculations should be reduced to account for the erroneous inclusion of the tax effect of the Carbon Price Floor, which is welfare neutral.

We have also noted that the analysis of frustrated generation does not take account of consumer surplus effects, as electricity costs to consumer increase from subsidising renewable generation. These effects are also relevant for the results of the main CBA analysis that compares the benefits of reinforcement options based on changes in consumer surplus

In addition to welfare benefits, the CBA report provides an overview of mainly socio-political considerations. We broadly agree with these considerations, of which the main message is that the sooner the transmission system in the Caithness Moray area is reinforced, the sooner the benefits may be realised. Also of added value is the inclusion of anticipatory investment in network capacity within the HVDC reinforcement, although the size of this benefit is uncertain.

We conclude that the overall benefits offered by options 1b and 2b are very similar. Option 2b returns a higher NPV in the “central case” as well as in all of the sensitivities explored in the CBA analysis. This strongly suggests that this option provides the most value from reinforcing the network and addressing network constraints. However, option 1b offers other benefits associated with earlier network reinforcement and the inclusion of anticipatory investment.

Overall Conclusion

We conclude that, on a standalone basis, the HVDC reinforcement option proposed by SHE Transmission is not in the best interest of existing and future consumers. However, in combination with B1 boundary reinforcement through BB400 at the earliest feasible date, the benefits provided by the HVDC option are close to those provided by the combined AC-BB400 option.

Taking account of welfare benefits and socio-political considerations of the early network reinforcement provided by the HVDC option, as well as its inclusion of investment in anticipatory network capacity, we consider that the HVDC-BB400 (option 1b) and AC-BB400 (option 2b) options might provide broadly similar benefits. We must observe that although the current proposal does not include investment in BB400, it does not preclude this investment either, and on that basis the proposed reinforcement can be part of a solution that is in the best interest of consumers.

1 Introduction

1.1 Background

During the electricity transmission price control review to set the RIIO-T1 allowances there was uncertainty around both the need for, and the cost of a number of major reinforcements to the transmission system. As a result Ofgem put in place an additional mechanism, known as Strategic Wider Works (SWW) to enable such reinforcements to be considered as expenditure adjustments during the RIIO-T1 price control period (1 April 2013 to 31 March 2021).

The purpose of the SWW arrangements is to facilitate large network developments that are needed during the RIIO-T1 period to both extend and strengthen the transmission network in order to accommodate the transport of electricity from where new generation is built to where demand is located. To put forward a project for consideration under the SWW mechanism, the relevant Transmission Owner (TO) must provide a "Needs Case" submission followed by a "Project Assessment" submission, in which the economic and technical case for delivery of the proposed project is described and fully justified.

Scottish Hydro Electric Transmission plc (SHE Transmission) has submitted an SWW application for a transmission reinforcement project between Caithness-Moray in the far north of Scotland. Ofgem has a duty to complete an assessment of the Needs Case provided by SHE Transmission.

DNV KEMA was appointed by Ofgem in May 2013 to provide an independent expert assessment of the Needs Case for the proposed Caithness - Moray transmission reinforcement project proposed by SHE Transmission. This expert review involves an assessment of the TO submissions and the provision of recommendations to Ofgem in the relevant areas to support their evaluation.

This report describes the results of our assessment of the Caithness – Moray Needs Case and provides our conclusions, with a view of informing Ofgem's view on the need, timing and optimal technical scope for reinforcing the transmission system in the Caithness – Moray area.

1.2 SWW assessment process

The Strategic Wider Works process for RIIO-T1 has been introduced to enable the onshore TOs to put forward major (in terms of cost and/or scale) wider reinforcement or development of the transmission system that were not included in the TO's baseline package of the RIIO-T1 Final Proposals.[1]

Network developments to strengthen or extend the electricity transmission system are known as wider works outputs in the context of RIIO-T1. In general, these developments are triggered by a combination of different generation connections, including those that might be expected in the future, and are required to increase the capacity or extend the network to convey electricity from where new generation is built to where demand is located, as well as comply with network security standards. In the output framework of RIIO, wider works outputs are measured in terms of increases in the electricity transfer capability across system boundaries (or within system boundaries) in accordance with the national security and planning standards for the transmission network, known as the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

The SWW arrangements are a part of the RIIO-T1 framework for all TOs. Details of the SWW arrangements applicable to SHE Transmission, are set out "Guidance on Strategic Wider Works Arrangements"[2] published by Ofgem in October 2013. Figure 1 below provides an overview of the stages in the overall SWW process:

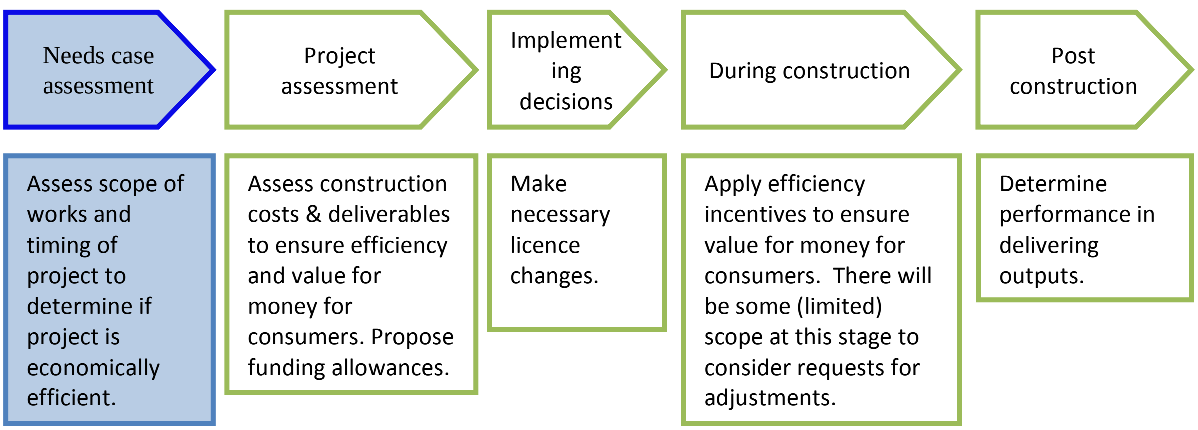

Figure 1: SWW process

[1] RIIO-T1: Final Proposals for SP Transmission Ltd and Scottish Hydro Electric Transmission plc [April 2012]
http://www.ofgem.gov.uk/Networks/Trans/PriceControls/RIIO-T1/ConRes/Documents1/SPTSHETLFPsupport.pdf

RIIO-T1: Final Proposals for National Grid Electricity Transmission and National Gas Grid [December 2012]
http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=342&refer=Networks/Trans/PriceControls/RIIO-T1/ConRes

[2] Available at:
http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=190&refer=Networks/Trans/PriceControls/RIIO-T1/ConRes

The assessment leading to a decision on cost recovery involves two stages:

1. Needs Case assessment following receipt of the TOs proposal submission; and
2. Project Assessment following receipt of the technical case submission.

The SWW arrangements are designed to ensure value for money for consumers and timely funding of the construction costs and additional operating expenses associated with large projects that are needed to meet wider network capability requirements.

1.3 Needs Case assessment objectives

The key objectives of the Needs Case assessment are to determine whether:

- there is a demonstrable need and robust case for investment given a credible range of uncertainties, including the potential development of the future generation capacity;
- the technical scope of the proposal is appropriate and represents an economical response to the need relative to the alternative options and the status quo;
- the timing of the investment is appropriate given that there is a satisfactory case for need and that scope of investment is appropriate; and
- the proposed reinforcement is in the interests of existing and future consumers.

In assessing the costs and benefits of the proposed Caithness-Moray project, and the case for incorporating anticipatory investment within the design, it is also relevant to take into account the potential future utilisation of that anticipatory investment, and the costs and lead times for any additional transmission works associated with such options.

1.4 Assessment process

DNV KEMA were appointed in May 2013 to support Ofgem in its assessment of SHE Transmission's Needs Case submission and supporting evidence on its proposed Caithness Moray reinforcement project. With Ofgem, DNV KEMA has engaged extensively with SHE Transmission and its consultants, to seek further information on a number of issues and relevant considerations involved with this complex and large scale transmission project proposal. The assessment and analysis in our report cover the original Needs Case submission presented by SHE Transmission, additional clarification sought and provided by SHE Transmission and its consultants at a number of bi-lateral meetings, and responses to a significant number of supplementary questions raised by DNV KEMA and Ofgem.

1.5 Assessment approach

Under the principles of the RIIO framework, the depth of Ofgem's and DNV KEMA's supporting review of the above assessment areas is undertaken proportionately to the quality of the Needs Case submission and the level of justification provided by SHE Transmission with reference to relevant supporting evidence.

In assessing the reinforcement proposal put forward by SHE Transmission we have considered the following aspects:

1) The consistency of SHE Transmission's proposal with fundamental guiding principles for SWW proposals.
2) Whether an appropriate range of uncertainties has been considered in testing the Needs Case as well as the scope and timing of the required reinforcement.
3) Whether SHE Transmission has adequately evaluated its preferred proposal as well as alternative transmission solutions and / or operational measures.
4) The comprehensiveness and reasonableness of the estimated lifetime costs for each of the options set out in SHE Transmission's proposal at this stage and whether these are sufficient to allow a fair comparison of the options.
5) A review of the methodology used in the Cost Benefit Analysis (CBA) and Least Worst Regret (LWR) analysis against best practice.
6) The validity of the core input assumptions used in the supporting analysis.

1.6 Report structure

The remainder of this report is structured as follows:

- Section 2 gives an overview of SHE Transmission's proposals;
- Section 3 provides our assessment of the technical needs case underpinning SHE Transmission's proposal;
- Section 4 provides our assessment of the Cost Benefit Analysis; and
- Section 5 summarises our findings.

2 Overview of the SHE Transmission proposals

Under the terms of its licence, SHE Transmission is required to provide an efficient, economic and co-ordinated transmission system in the north of Scotland. The transmission infrastructure needs to be capable of maintaining a minimum level of security of supply and of transporting electricity from and to customers. This chapter provides an overview of the current SHE Transmission network together with a description of the proposed works.

2.1 Existing SHE Transmission network

The existing SHE Transmission network in Caithness was predominantly developed in the 1950's and serves around 160 MW of local demand. The transmission system in the area to the north of Beauly is limited in terms of available capacity and requires significant reinforcement to accommodate the volume of renewable generation seeking connection in the area.

Recently completed works (late 2013) to reinforce the transmission system north of Beauly, referred to as Beauly-Dounreay Phase 1, included the following works:

- Installation of a second circuit on the existing 275kV overhead line between Beauly and Dounreay;
- Upgrade of the Dounreay substation; and
- Installation of Quadrature Boosters at Beauly on the 132kV overhead lines between Beauly and Shin.

The current network to the north of Beauly is shown in figure 2 below.

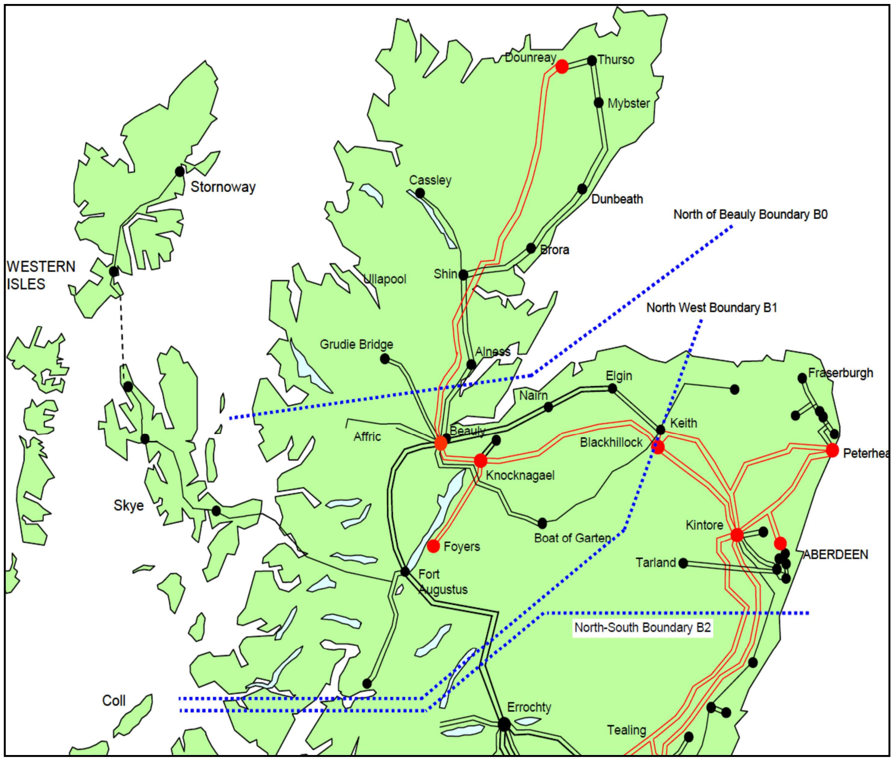

Figure 2 - Existing SHE Transmission network with transmission boundaries[3]

The transmission system in the area north of Beauly (boundary B0) consists of the following two steel tower routes:

1. The first (red route) is a 275kV double circuit overhead line that was commissioned under the Beauly-Dounreay Phase 1 works (previously only strung with one circuit)
2. The second tower line is a 132kV double circuit overhead line which connects all the east coast grid supply points (GSPs) from Brora, Dunbeath, Mybster, Thurso and Dounreay.

As a result of the recently completed reinforcement, the transmission capability in the north of Beauly, Boundary B0 capacity has increased from 150MW to 245MW. SHE Transmission has indicated that this increased capacity is not adequate to accommodate the anticipated increase in renewable generation and further reinforcement is required.

The transmission system in the north west B1 boundary comprises a 275kV double circuit overhead line between Beauly, Foyers and Blackhillock. In addition there are three 132kV double circuit tower lines to the south and east of Beauly.

National Grid's Electricity Ten Year Statement has estimated that the current transmission capability in the north west Boundary B1 is around 500 MW. Two key reinforcements to the

[3] Source: SHE Transmission Needs Case Report, December 2013.

B1 boundary currently under construction are the Beauly–Blackhillock–Kintore project and the Beauly–Denny project which are forecast for completion in 2014 and 2016 respectively. The completion of these reinforcements will increase the B1 boundary capability from around 500 MW to around 2000 MW.

2.2 Description of the SHE Transmission proposals

In 2013, SHE Transmission presented submissions to Ofgem on the Needs Case for the Caithness - Moray transmission reinforcement project. SHE Transmission is proposing the project to reinforce the transmission system to support the significant growth in renewable generation in the far north of Scotland. The proposed reinforcement includes a combination of onshore AC works and offshore HVDC link works and comprises the following elements:

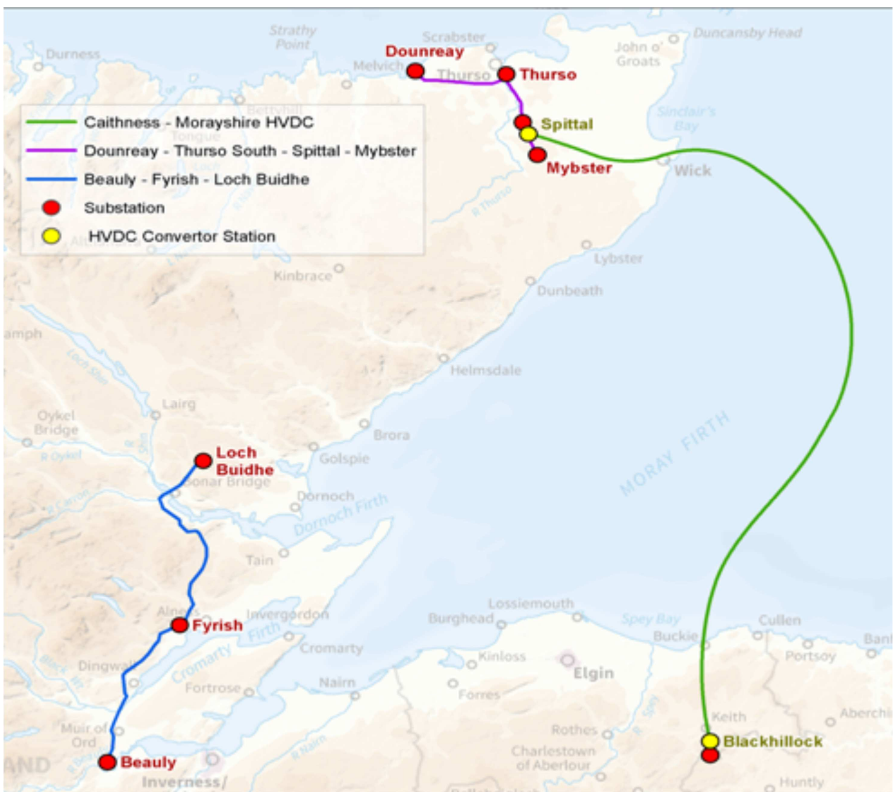

Figure 3. - **Geographic location of project elements**

- Establish a 275/132kV substation at Spittal, a new site approximately 4km north of Mybster;
- Redevelop the Blackhillock substation and establish a new 400kV busbar at the site;
- Install an 800/1200MW HVDC Link between Spittal and Blackhillock;

- Establish a new 275kV/132kV substation at Loch Buidhe, at the crossing of the Beauly to Dounreay 275kV and Shin to Brora/Mybster 132kV overhead lines;
- Construct a 275/132kV substation at Fyrish near the existing Alness 132kV Tee point and move the existing Alness GSP onto the new substation;
- Replace the existing conductors on the 275kV circuit between Beauly and the proposed new substation at Loch Buidhe (part of original BUW circuit) to match or exceed the conductor rating on the new circuit installed under Beauly-Dounreay Phase 1 works (c. 62km);
- Rebuild the existing Dounreay – Thurso – Spittal 132kV circuits at 275kV (c. 32km) and establish a new 275/132kV substation at Thurso South close to the existing Thurso GSP; and
- Build a new 132kV double circuit overhead line between the proposed new substation at Spittal to Mybster (c. 4km) and create a new 132/33kV arrangement to accommodate the high volume of wind generation around Mybster.

Figure 4 represents a schematic diagram of the proposed SHE Transmission reinforcement:

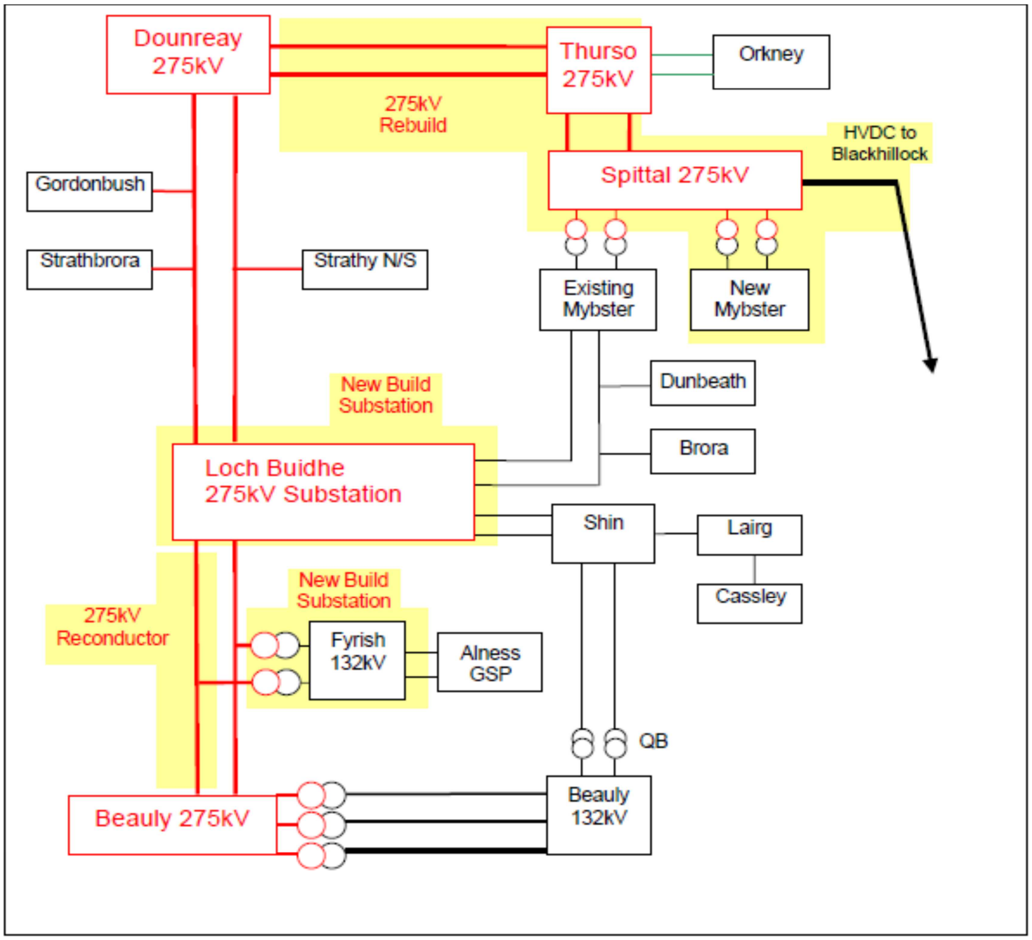

Figure 4 - Electrical diagram of the proposed reinforcement

The proposed reinforcement will increase the actual boundary B0 capability from 245MW to 1040MW.

SHE Transmission's proposed project incorporates an additional 400MW of anticipatory transmission capacity from Caithness to Blackhillock, i.e. beyond that required to accommodate expected onshore generation in Caithness. SHE Transmission identifies this as its preferred solution because it will allow forthcoming renewable generation in the Scottish islands to connect without requiring a second separate reinforcement.

3 Assessment of technical elements of SHE Transmission's proposal

We concur with SHE Transmission's assessment that existing transmission capacity is limited and there is long term need for reinforcement of the transmission system in North Scotland. We conclude that the technical scope of the SHE Transmission proposal is appropriate in that it offers a mostly efficient solution to meet the requirement for additional network capacity. The following summarises our key comments on specific aspects of the technical proposal:

Deterministic planning criteria of the Security and Quality of Supply Standard -. The approach taken by SHE Transmission is consistent with the SQSS planning criteria and it represents adequate technical assessment of the existing capacity of the transmission network.

Generation background - Considering all the information provided DNV KEMA believes that the five scenarios capture the reasonable range of the possibilities for the development of generation in the area considered.

Connected capacity - planning consent has yet to be obtained for the majority of the generation capacity identified and it is unclear when the reinforcement trigger will be reached or indeed exceeded. In addition, there is no clear information regarding the minimum transmission capacity required for expected generation levels.

Technology assessment - It is our opinion that SHE Transmission has carried out a satisfactory analysis of the range of available technologies to address the reinforcement requirement and used this analysis to identify the most appropriate technical solution in the submitted Needs Case.

Optioneering – Detailed methodology with a comprehensive list of key criteria coupled with selection of weighting factors was considered for the option scoring for reinforcement of the B0 boundary. We find this approach to be reasonable and it represents good practice in optioneering process. At the same time we find that the optioneering process for the reinforcement of the Beauly-Blackhillock Corridor is too limited and presents only a high level of detail.

The anticipatory investment (400MW capacity associated with the HVDC link) – SHE Transmission provided economic justification for the additional costs associated with the anticipatory capacity. We find that SHE Transmission approach is reasonable, however further clarifications need to be provided in the Project Assessment stage about the estimated cost of the anticipatory investment.

Risks – SHE Transmission has identified all the key risks associated with the options considered but it is unclear how the impact and cost of these risks are taken into account. For the AC option, all of the risks identified in their narrative are only qualified but not quantified in the Needs Case narrative. We do not consider the application of a general [redacted]% risk/contingency allowance adequate for options taken forward for a detailed CBA assessment. Key risks for the HVDC Option are both qualified and quantified but there is no clear link between the HVDC risk register and total cost of the risk.

Supply chain issues - Our assessment of supply chain considerations indicates that SHE Transmission has taken reasonable steps to identify and reduce supply chain risks.

Stakeholder engagement - We believe that SHE Transmission's stakeholder engagement plans lack transparency and based on the information provided we consider that SHE Transmission's approach does not cover all stakeholder issues adequately.

Capital costs - In order to assess the reasonableness of SHE Transmission's cost estimates, we have split the total costs associated with both the AC and HVDC option into "building blocks":

- ***Overhead Line -*** Taking into account the magnitude of the project and based on above analysis it appears that OHL costs are reasonable for the HVDC option but at the higher end of what we would expect reasonable for the AC option and BB400.
- ***Substation costs –*** Due to the lack of detailed scope and based on the description from SHE Transmission and our experience we find that cost estimates associated with onshore AC substations appear high.
- ***HVDC costs –*** We find that the costs for the Caithness HVDC cable are [redacted]% higher than the benchmark figure. Recognising the limitation of limited supply chain, inflation and potential risks, we believe that cost estimates for HVDC are at the higher end of what we would expect to be reasonable.

3.1 Introduction

In high level summary, the Needs Case is based on the following:

- Limited spare transmission capacity exists north of the Beauly Boundary B0;

- Under different scenarios of generation capacity in the area north of Beauly, renewable generation capacity could grow from around 550MW currently to between 1900MW and 3300MW by 2030;
- New generation connections will be at the extremity of existing network. With limited demand in the area, most of the new power produced by the new generation capacity will be exported south through the existing north of Beauly boundary B0, the north west boundary B1 and beyond;
- The north of Beauly boundary B0 and north west boundary B1 have limited transmission capability;
- With planned growth in generation capacity (and no corresponding increase in transmission capacity) the level of the constrained energy will increase significantly leading to an increase in system balancing costs; and
- Network reinforcement would relieve the power flows that would otherwise be curtailed and also enable connection of renewable generation from Scottish Islands and marine generation.

The proposed Caithness Moray reinforcement is the first stage in SHE Transmission's overall strategy to reinforce the transmission network in the north of Scotland to accommodate a forecast increase in renewable generation. SHE Transmission has indicated that while there are interdependencies between the proposed Caithness Moray project and other elements of its north of Scotland strategy (such as the proposed links to Shetland and Orkney), it can be assessed separately as it is independent of whether or not those other projects proceed.

Ofgem has requested DNV KEMA to assess the submission provided by SHE Transmission in support of the proposed Caithness Moray reinforcement and to review the need, scope and timing of the proposed project. In assessing the technical aspects of the reinforcement proposal made by SHE Transmission we have considered the following aspects:

1. The consistency of SHE Transmission's proposal with fundamental guiding principles for SWW proposals.
2. Review of the input assumptions used in the quantitative analysis determining the need for additional transmission capacity.
3. Consideration of the range of uncertainties taken into account when evaluating the long term need for transmission capacity, when optimising the scope of the planned reinforcement works (including any anticipatory investment) and when optimising the timing of delivery.
4. Review of the adequacy of SHE Transmission's proposal when considering alternative investment options and / or operational measures to accommodate the same need for transmission capacity.
5. Validation of other potential areas of the proposed costs in SHE Transmission's proposal.
6. Analysis of the generation background for the Needs Case.

This chapter is organised as follows:

- section 3.2 provides the background of the SHE Transmission proposal;
- section 3.3 provides our review of SHE Transmission's guiding principles for network reinforcement;
- section 3.4 provides a view on appropriateness of the optioneering and alternative operational measures;
- section 3.5 looks at other considerations relevant to SHE Transmission's proposal and overall strategy (risks, supply chain issues, stakeholder engagement etc.);
- section 3.6 provides our assessment of project and operational costs; and
- section 3.7 summarises our findings with regard to the technical submission of the Needs Case.

3.2 Background and overview of the SHE Transmission proposal

3.2.1 Generation background for the technical case

The most critical driver underpinning the "need" for the Caithness - Moray reinforcement project is the anticipated growth in renewables generation in the north of Scotland.

SHE Transmission is obliged by its transmission licence to provide a connection to parties seeking to use the transmission system. In making the connections, SHE Transmission needs to ensure that they are efficient, coordinated and economical and, where possible, maximising the utilisation of the existing infrastructure.

Based on the figures provided by SHE Transmission there is currently around 2,226MW of renewables generation that have a contracted connection to the transmission system north of Beauly boundary B0. As outlined in Table 1 below, around 33% of this generation is either connected to the network or is under construction and a further 3% has planning consent. The remaining 64% of contracted generation capacity is yet to obtain planning consent.

GENERATION STATUS	March 2013 [MW]	Sep 2013 [MW]
Connected or Under Construction	641	**756**
Consented but not yet Connected	177	**62**
Consent Submitted but not yet Determined	602	**776**
Consent in Scoping with The Highland Council	84	**84**
Marine Generation in Orkney/Pentland Firth	511	**511**
Not yet in Planning Process	37	**37**
Generation Contracted Total	**2,052**	**2,226**

Table 1 – Status of contracted generation north of Beauly

In addition to the contracted generation in Table 1, a further 65MW renewables project is currently in the connection application process and an additional 513MW of renewables generation projects are currently in consent scoping proceedings with The Highland Council (THC) but have not yet applied for connection to the grid.

In the Needs Case submission, SHE Transmission presented five scenarios for the growth of renewable generation in the north of Beauly area:

1. Contracted generation (CG) background as of February 2013.
2. The 'Gone Green' (GG) generation background prepared by NGET in May 2012 for the ENSG and for Investment Planning in general.
3. 'Slow Progression' (SP) generation background prepared by NGET in May 2012.
4. 'Slow Slow Progression' (SSP) which represent downside sensitivities of the SP scenario
5. 'Smoothed SSP' requested by Ofgem (Ofgem).

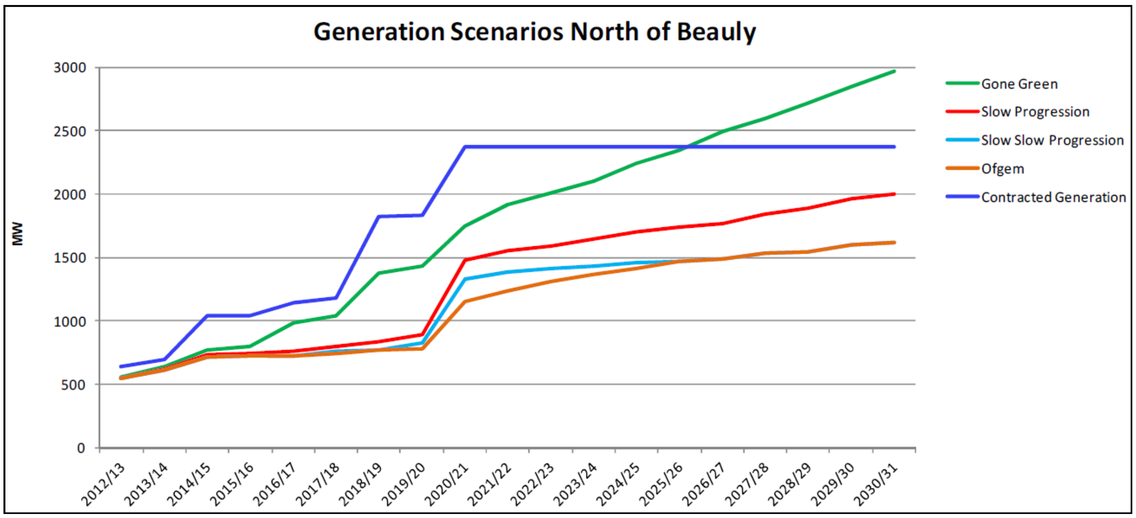

Figure 5 – Generation scenarios from Technical Needs Case

Both the Gone Green (GG) and Slow Progression (SP) scenarios try to capture a range of outcomes for the level of connection of offshore generation across Great Britain[4]. The generation that has signed connection agreements since the NGET issue of GG and SP generation backgrounds in May 2012 have been included in the scenarios.

[4] Gone Green (GG) and Slow Progression (SP) scenarios are developed by National Grid to capture a range of outcomes for the level of connection of the offshore generation across Great Britain. In the Caithness – Moray Needs Case only relevant generation under both scenarios has been considered

3.2.2 DNV KEMA observations on the generation scenarios

We make the following observations about the generation scenarios under consideration:

- **The Contracted Generation** (CG) background represents indicative dates for generation connection. We consider that this view of renewable development is an overly optimistic view of renewable capacity development as it fails to take into account experience with actual commissioning of new renewables generation projects. In general we observe a significant reduction in entry capacity and slippage in connection dates relative to the contracted position. We also note that the contracted dates between the project developer and the SO are not firm and can be modified to change connection dates.

- **The Gone Green** (GG) scenario is driven by the requirement to meet the government's 2020 renewable energy target and its assumptions on the contribution required from the electricity sector. The Gone Green scenario has anticipated a significantly higher rate of renewable growth than actual outturn development over the period 2008/9 to 2011/12. In our view, GG also shows an implausibly high rate of short term renewable generation growth in Scotland but it is useful as it captures optimistic view on renewable generation developments.

- **The Slow Progression** (SP) scenario is based on a generation scenario prepared by National Grid and represents slower progress towards environmental goals; e.g. the UK 2020 renewables target is missed and greenhouse gas reductions fall short of the 2050 carbon targets. The SP generation scenario in SHE Transmission's analysis represents a central case of likely renewable development in the north of Scotland based largely on known projects at various stages of development.

- **The Slower Slow Progression (SSP) scenario** represents a downside sensitivity of the SP scenario, although generation in the area north of Beauly more than doubles above current levels. DNV KEMA analysis presented in Figure 6 illustrates that the SSP scenario is approximately 9% lower than the SP scenario up until 2026, indicating only a limited divergence with the SP in the level of installed onshore wind capacity in Scotland.

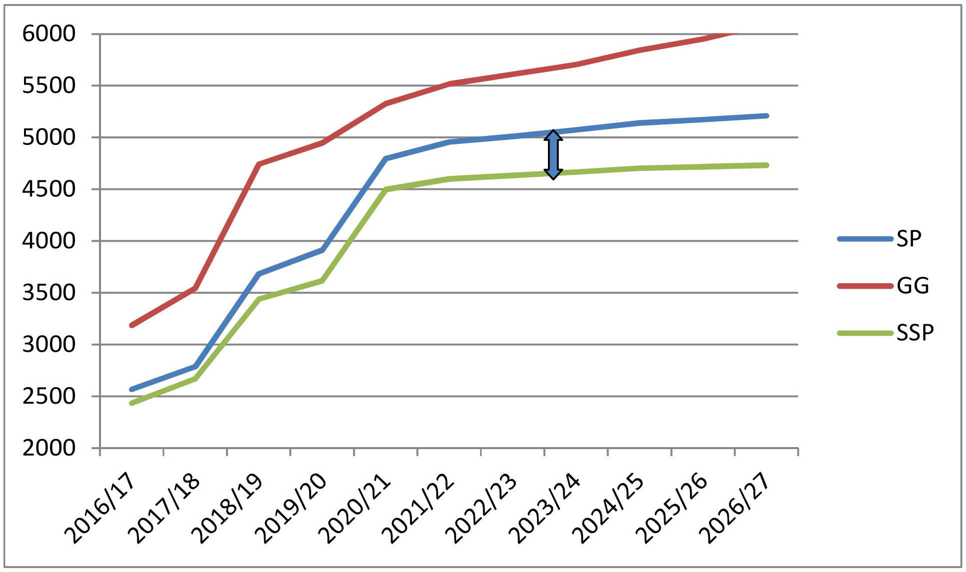

Figure 6 - Difference in assumed generation profile between SP and SSP

The three scenarios above developed by SHE Transmission were based largely upon contracted generation and NGET's scenarios. We believe that this view of wind farm development is not sufficiently robust as it does not fully take into account actual developments that often result in lower levels of generation projects that are completed in any given year. In our view the SSP scenario does not represent a sufficiently rigorous downside short term forecast upon which to base a long term scenario to assess the optimal timing of the Caithness Moray reinforcement. A lower level of renewables generation in the shorter term is a distinct possibility and such a risk should be recognised.

- **Ofgem scenario** - In order to test the potential impact of a slower development of generation, Ofgem requested SHE Transmission to add another scenario with sustainable growth rates by smoothing the commissioning of a considerable amount of generation included in the SSP scenario over the period 2017/18 to 2025/26. This scenario was put forward in order to provide a more balanced view of the potential risks of the proposed investment to a slower rate of development in onshore wind generation in the study area.

  Figure 7 below illustrates that the "Ofgem" scenario does not just follow Slow Progression but represents a more realistic downside short term generation forecast.

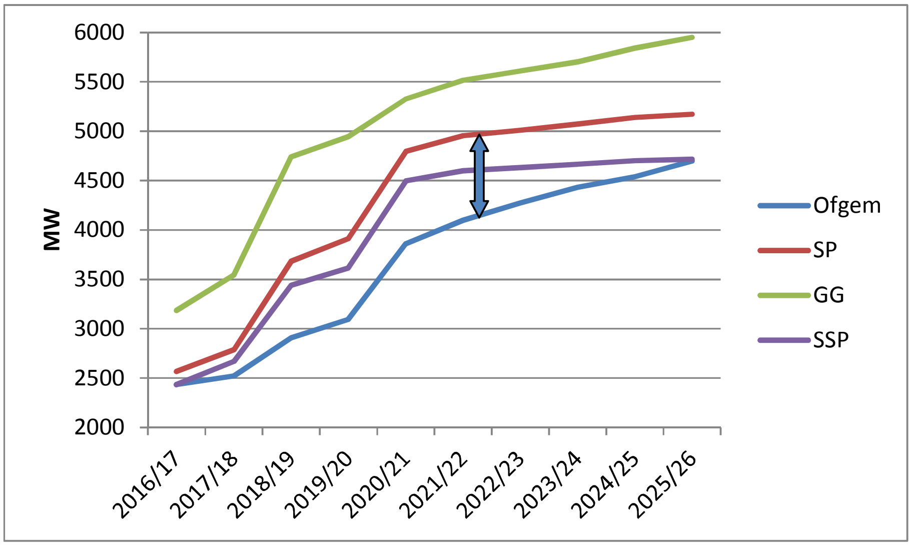

Figure 7 – Difference in assumed generation profile between SP and Ofgem scenarios

Considering all the information provided DNV KEMA believes that the five generation scenarios considered by SHE Transmission and their consultants capture the reasonable range of the possibilities for the development of generation in the area considered.

3.2.3 Level of certainty of new generation

Table 2 shows the status of all renewable development activity in the area north of Beauly and its treatment by SHE Transmission in its Need Case submission of proposed options for the Caithness-Moray reinforcement.

Generation Contract Status	Consent Status	Not directly connected to 275kV (MW)	Directly connected to 275kV (MW)	Subtotal
Contracted	Connected	389	137	526
	Under construction	115		115
	Consented	107	70	177
	Consent Application submitted	446	156	602
	Sub-Total	***1057***	***363***	***1420***
	Scoping	84		84
	Not In Planning	37		37
	Marine Generation	511		511
	Total	**1689**	**363**	***2052***
Not Connected	Applied for connection to grid and in Scoping with Highland Council			65
	In Scoping with Highland Council but not yet applied for grid connection			513

Table 2 – Generation status north of Beauly

Although other scenarios could be postulated, it is our view that the network reinforcement trigger point will be exceeded in all but the most pessimistic scenarios. We note, however, that planning consent has yet to be obtained for the majority of the generation capacity listed in Table 2 and it is unclear when the reinforcement trigger would be exceeded.

3.3 SHE Transmission guiding principles for network reinforcement

In this section we consider and review the guiding principles that have been adopted by SHE Transmission to support their reinforcement strategy, which is fundamental to the development and design of this proposed project. As part of our assessment, we consider the manner in which SHE Transmission applied these principles to support the strategy, their relevance and their practical impact on the proposed design. Our strategy review considers the following areas:

- Planning criteria to support the Security and Quality of Supply Standard ("SQSS") and how this is reflected in the cost benefit analysis;
- Analysis of the proposed scenarios and options used to mitigate an uncertain future (e.g. through anticipatory investment); and
- Treatment of other factors (e.g. supply chain considerations and planning issues) that were not captured in the quantitative analysis.

3.3.1 Deterministic planning criteria of the Security and Quality of Supply Standard

The National Electricity Transmission System (NETS) Security and Quality of Supply Standard (SQSS) defines the minimum standards that TOs must apply when planning and operating the transmission system. These criteria involve the type and combination of faults (or breakdowns) that the transmission system must be able to withstand, the allowable impact on customers in terms of maximum level of supply interruptions, and permissible impacts on supply quality.

In the Needs Case submission, SHE Transmission describes the methodology for determination of the required capability of the transmission system. This should secure demand and allow generation to access the energy market by applying the criteria within the NETS SQSS.

To determine the required capability of the transmission system to secure demand and allow generation to access the energy market, it is necessary to apply the criteria within the NETS SQSS. In the case of SHE Transmission's network in the north of Beauly Boundary B0 and B1, the following SQSS criteria have been applied:

1. **SQSS Chapter 4 criteria** -*the Main Interconnected Transmission System (MITS)*

This section sets out the design criteria against which the MITS should be planned. When assessing compliance of the system and planned developments of the system, SHE Transmission is obliged to consider all operating conditions that can be reasonably foreseen.

In order to examine the available capacity on the transmission network to accommodate renewable generation north of Beauly boundary B0, SHE Transmission provided load flow results with an installed generation background of 938MW north of Beauly which corresponds to a 2016/17 Gone Green background and comparison of SQSS required capacity with actual B0 boundary capability is presented in Figure 8.

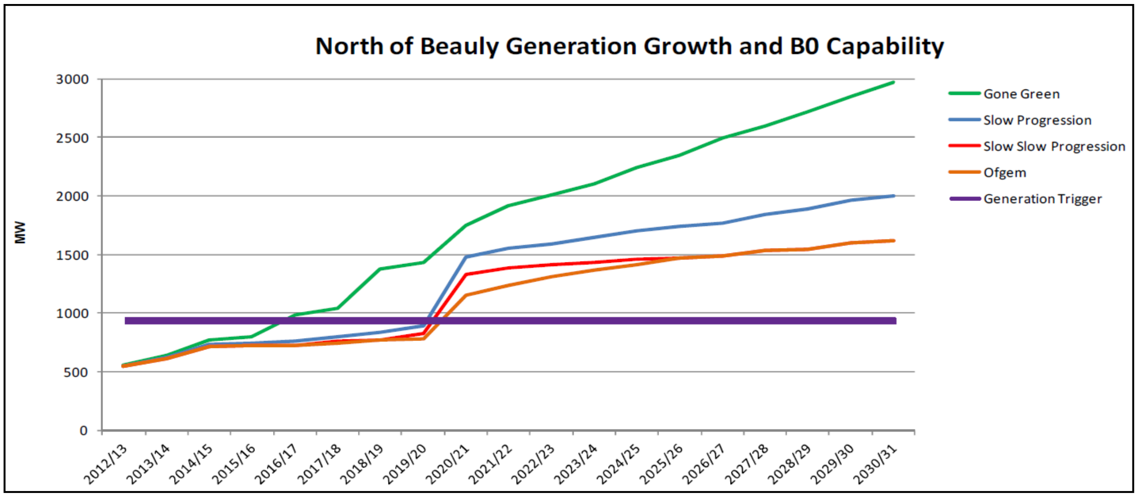

Figure 8 - B0 capability compared with SQSS requirement

SHE Transmission studies indicate that by 2016/17 under the Gone Green generation scenario, by 2020/21 under SSP or by 2021/22 under "Delayed SSP", the network does not comply with the criteria set out in Chapter 4 of the SQSS. The above SQSS assessment only indicates the need for the reinforcement, not the optimal timing for the reinforcement.

2. **SQSS Chapter 2** - *Local Transmission System*

The generation connection criteria must also be met at each point on the system where generation is being connected.

The existing double circuit 132kV overhead lines in this area, with summer post fault ratings of 101MVA per circuit, are well short of the required capability with the contracted generation background under (N-2) contingencies. Consequently, the part of the 132kV network between Dounreay and Mybster will also need to be reinforced. The lack of capacity is also evident for a single 132kV circuit outage condition (N-1) in this area where the remaining three 132kV circuits with a summer rating of 101MVA each would be connected to a 722MW cluster of generation. The lack of circuit capacity is compounded by the fact that the power distribution in the 132kV circuits is unevenly shared.

Based on the background of contracted generation it is clear from SHE Transmission's assessment that without reinforcement the transmission system will be overloaded beyond its capacity and would breach the SQSS requirements. The Technical Needs Case contains simple calculations based on SQSS that provide the approximate level of generation that triggers the requirement to reinforce the existing network.

	Transmission System with Beauly-Dounreay Phase-1 Works (MW)
Actual B0 Capability	245
Demand +Losses at winter peak	161
Sub Total	406
Divide by 0.7 to give approx MW of wind that can be connected (0.7 is SQSS scaling factor for wind)	580
275kV Directly Connected Generation	363
Total Generation Trigger Point	**943**

Table 3 – Reinforcement trigger point

The generation located north of Beauly also impacts on the power that can be transferred south and east of Beauly through the North West boundary, B1. The requirement to reinforce B1 is recognised by SHE Transmission during assessment of reinforcement options and in order to examine the need for reinforcement across B1 the NETS SQSS Section 4 criteria for assessing the main interconnected transmission system is used. The SQSS required transfer levels under each of the generation scenarios together with actual B1 capability are presented in Figure 9 below.

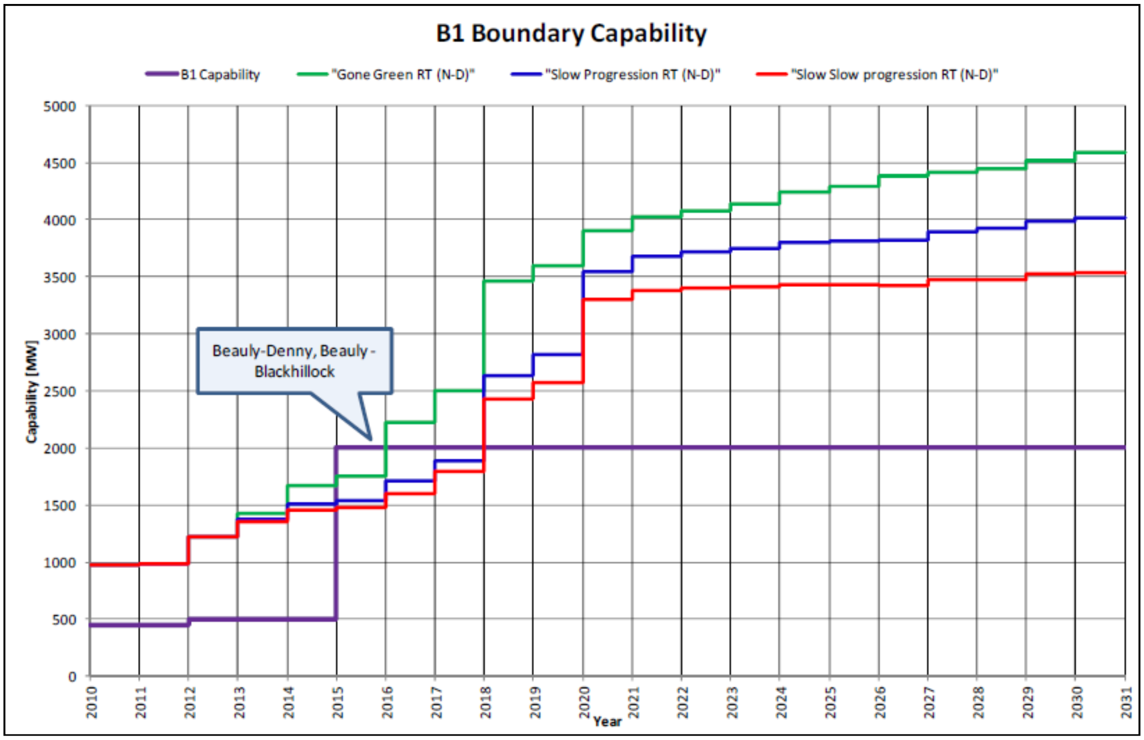

Figure 9 – Existing B1 boundary capability including existing works

Figure 9 demonstrates that the SQSS required transfer levels across the B1 boundary are in excess of the actual B1 boundary capability by 2018 in all generation scenarios, indicating the need for reinforcement across this boundary.

The approach taken by SHE Transmission is consistent with the SQSS planning criteria and it represents an adequate technical assessment of the existing capacity of the transmission network.

3.3.2 Optimisation assessment of potential options

In its Needs Case submission, SHE Transmission identifies a number of potential reinforcement options for the Caithness area. These are based on the two reinforcement options identified and presented in the Energy Network Strategy Group's "Our Electricity Transmission Network: A Vision for 2020 Full Report" of March 2009[5]:

[5] The Electricity Networks Strategy Group (ENSG) is a high level forum, which brings together key stakeholders in electricity networks that work together to support Government in meeting the long-term energy challenges of tackling climate change and ensuring secure, clean and affordable energy.

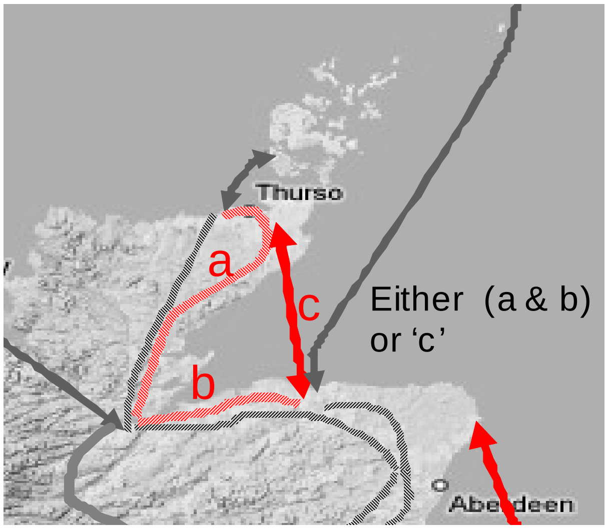

Figure 10 – Reinforcement options identified in March 2009 ENSG Report

1. Full re-build of AC circuits around "two sides of a triangle" from Caithness to Beauly, and from Beauly to Blackhillock (a & b),
2. "Cutting the corner" with an HVDC circuit from Spittal in Caithness to Blackhillock

Taking the above into account, SHE Transmission has considered various reinforcement options for the north of Beauly network from the two main technology options:

1. Onshore and offshore AC reinforcement – option 1, 2 and 10
2. Offshore HVDC subsea reinforcement - options 3 to 9

3.3.3 Review of optioneering methodology and rationale

In its Needs Case submission, SHE Transmission identifies ten possible reinforcement options which were considered during project development phase. These options and associated cost estimates are provided in Table 4 below:

Option	Reinforcement	Works Description	Cost	Reinforcing Boundary B1
1	AC Option- Restringing existing 132kV OHL with high capacity conductor	Full rebuild of existing 132kV line between Beauly and Dounreay over a distance of around 190km using high capacity 132kV conductors and towers. New 275/132kV substations at Loch Buidhe and Fyrish (near Alness).(This option triggers the need for reinforcement across boundary B1 between Beauly and Blackhillock at cost of £448M)	[redacted]	N
2	AC Option- Replacing existing 132kV OHL with new 275kV OHL	Full rebuild of existing 132kV line between Beauly and Dounreay, using high capacity 275kV conductors and towers and associated substation. (This reinforcement will also trigger reinforcement across boundary B1 between Beauly and Blackhillock at cost of £448M).	[redacted]	N
3	HVDC Option	Partial rebuild of existing 132kV line (Dounreay to Mybster and Shin to Beauly) over a distance of around 30km using a heavy duty 132kV tower construction, plus a new 275/132kV substation at Loch Buidhe and at Fyrish and a new 160 km long HVDC Link from Spittal to Blackhillock	[redacted]	Y
4	HVDC Option	Partial rebuild of existing 132kV line (Dounreay to Mybster and Shin to Beauly) using 275kV construction towers, plus a new 275/132kV substation at Loch Buidhe and a new HVDC Link from Spittal to Blackhillock.	[redacted]	Y
5	HVDC Option	Partial rebuild of existing 132kV line (Dounreay to Mybster) using high capacity 132kV construction, reconductor existing 132kV line between Shin and Beauly, new 275/132kV S/S at Loch Buidhe and Fyrish and HVDC Links from Spittal to Blackhillock (around 160km) and from Loch Buidhe to Beauly (around 70km).	[redacted]	Y
6	HVDC Option	Partial rebuild of existing 132kV line (Dounreay to Mybster) using high capacity 132kV construction, new 275/132kV S/Ss at Loch Buidhe and Fyrish, replace conductors on the 275kV west circuit between Loch Buidhe and Beauly and HVDC Link from Spittal to Blackhillock	[redacted]	Y
7	HVDC Option	Partial rebuild (Dounreay to Mybster) of existing 132kV line using high capacity 275kV construction to Spittal and high capacity 132kV construction between Spittal and Mybster, new 275/132kV S/Ss at Loch Buidhe and Fyrish (with existing Alness GSP transferred), replace conductors on the 275kV west circuit between Loch Buidhe and Beauly, and HVDC Link from Spittal to Blackhillock.	[redacted]	Y
8	HVDC Option	The same elements as in Option 7. In addition, remove Shin from the parallel 132kV network and connect to the newly established 132kV busbar at Loch Buidhe substation via a new radial 132kV double circuit.	[redacted]	Y
9	HVDC Option	Partial rebuild (Dounreay to Helmsdale) of existing 132kV line using high capacity 275kV construction. New 275/33kV substations at Mybster and Dunbeath, new 275/132kV substations at Loch Buidhe and Fyrish (with existing Alness GSP transferred), replace conductors on the 275kV west circuit between Loch Buidhe and Beauly, and an HVDC Link from Helmsdale to Blackhillock.	[redacted]	Y
10	AC Option - Subsea AC cable	Partial rebuild (Dounreay to Helmsdale) of existing 132kV line using high capacity 275kV construction. New 275/33kV substations at Mybster and Dunbeath, new 275/132kV substations at Loch Buidhe and Fyrish (with existing Alness GSP transferred), replace conductors on the 275kV west circuit between Loch Buidhe and Beauly, and a 1GW AC subsea cable connection from Helmsdale to Blackhillock.	[redacted]	Y

Table 4 – Reinforcement options[6]

The SHE Transmission optioneering rationale is based on selection of the best AC reinforcement option (from options 1, 2 and 10) and the best HVDC reinforcement option (from options 3 to 9) and to take these two options forward for more detailed analysis, both technically and economically. The appraisal of the different reinforcement options considers the following key criteria:

[6] Costs in this table are shown as presented in the technical part of the Needs Case submission. Please note that option 2 does not include £[redacted]M associated with Blackhillock substation reinforcement and additional SVC

- Capital costs;
- Planning and consenting risk;
- Environmental impact;
- Potential generation constraint costs;
- Capability to facilitate the initial Pentland Firth marine generation development;
- Technical capacity benefits across the north of Beauly boundaries B01/B02/B0 and the North-West boundary B1; and
- Technology Risk.

The scoring methodology allocated a score to each reinforcement option using the above mentioned key criteria and using different weighting factors presented in Table 5 to check the sensitivity and robustness of the results.

Criteria		Weighting 1	Weighting 2	Weighting 3
Costs	Capital costs	45%	40%	33%
	Operational costs			
Technical	Technical Benefit on B0	35%	40%	33%
	Technical Benefit on B1			
	Facilitate Marine Generation			
Planning	Planning and Consent Risk	20%	20%	33%
Environmental	Environmental Impact			

Table 5 - Weighting factors

SHE Transmission recognised that the HVDC option provides some useful capacity increase on this boundary B1, but the onshore AC alternative does not. Consequently, beyond the reinforcement of the Caithness and north of Beauly network, there is a requirement for a further reinforcement of the B1 boundary. SHE Transmission conducted actual scoring in two stages:

1. All the options presented in Table 4 without any reinforcement works across the B1 boundary.
2. All the options presented in Table 4 together with the impact of Beauly to Blackhillock 400kV reinforcement.

The result of the scoring exercise shows that Option 7 is ranked as the number 1 reinforcement option without reinforcement works across the B1 boundary. When the range of options considered for the Caithness-Moray upgrade are reassessed with the inclusion of BB400 as an integrated element, results of the scoring exercise indicate that option 2 is ranked as number 1.

Inclusion of the comprehensive list of key criteria coupled with the selection of the weighting factors reduces the subjective elements in the scoring process. In our view, the approach taken by SHE Transmission appears reasonable as it includes most of the standard option assessment criteria.

3.4 Review of the optioneering and alternative investment or operational measures

In this section we assess the adequacy of considering alternative investment options and / or operational measures to accommodate the same need including:

- the methodology and rational applied to the optioneering assessment;
- whether other feasible options should have been considered; and
- whether appropriate options were used in the CBA analysis.

3.4.1 Optioneering

The reinforcement options considered are listed in Table 7. As discussed in section 3.3.2, SHE Transmission identifies ten potential reinforcement options for the Caithness area based on the two main options:

1. **AC solution** - Re-build of circuits from Caithness to Beauly, and from Beauly to Blackhillock; and
2. **HVDC solution** – New HVDC circuit from Spittal to Blackhillock and associated onshore AC works

Six of the eight options from Table 4 – Reinforcement (1, 3, 4, 5, 6 and 8) have not been selected for detailed consideration by SHE Transmission and the reasons for this are discussed below:

3.4.1.1 Optioneering for the AC solution

As part of the optioneering for the AC solution, SHE Transmission considered the following options:

- **Option 1 -** Restring the existing 132kV line with a high capacity conductor
- **Option 2 -** Replacing the existing 132kV line with a 275kV line
- **Option 10 -** Partial rebuild of existing 132kV at 275kV with new 1GW AC subsea cable from Helmsdale to Blackhillock

It is worth highlighting that options 1 & 2 (but this is not the case for option 10) do not provide reinforcement of the boundary B1 which is one of the key factors in both optioneering and cost benefit analysis. The onshore AC option reinforces boundary B1 only with inclusion of the Beauly-Blackhillock 400kV reinforcement works (BB400). SHE Transmission identified a requirement for further reinforcement of the B1 boundary, and as only AC solutions were considered this is also discussed in this section.

Option 1 - Restring existing 132kV line with high capacity conductor- would have lower capital costs compared with option 2 and would limit the impact on the local 132/33kV substations. However SHE Transmission has pointed out that the increase in network capacity would be considerably less than the 275kV build option and would not provide sufficient capacity for the contracted or future generation in the area.

We requested that SHE Transmission clarify how much of the generation can be reasonably connected with option 1 as we believed this was not adequately explained in the initial submission. In response, SHE Transmission provided a calculation on the B0 boundary trigger point after the option 1, 2 and 7 reinforcements have been implemented. Table 6 summarises this calculation. The boundary transfer limit for option 1 is significantly reduced compared to the other two options. The high levels of reactive compensation and higher losses associated with Option 1 are an indication that the system is stressed at these transfer levels.

	Option 1 (MW) with reactive compensation @ Shin	**Option 2 (MW)**	**Option 3- 7 (MW)**
Actual B0 Capability	646	1340	1040
Demand +Losses at winter peak	176	152	106
Sub Total	***822***	***1492***	***1146***
Divide by 0.7 to give approx MW of wind that can be connected	1174	2131	1637
275kV Directly Connected Generation	710	710	710
Total Generation Trigger Point	**1884**	**2841**	**2347**

Table 6 – B0 Boundary trigger points

Our view is that although option 1 increases transfer across B0 boundary, the trigger point is below the 2051MW of contracted generation north of Beauly and would provide insufficient network capability to accommodate the onshore renewable generation in Caithness and any initial Pentland Firth marine generation developments. We concur with SHE Transmission's approach to exclude this option from further analysis.

Option 2 - Replacing existing 132kV line with 275kV line -
The other AC alternative considered is more expensive and carries slightly greater planning and environmental risk, but it is technically superior (lower losses, greater capacity) when compared to option 1. We identified the issue of the level of appropriateness of AC network reinforcement undertaken in a number of phases as that in itself would carry significant risk in terms of planning and route consenting. We believe that this approach would not be appropriate as it would most probably increase delivery risk, lead to an increase in costs and more importantly would not remove the majority of the constraints, leading to limited benefits.

It is our view, that of the AC options considered, option 2 is most appropriate, as it not only provides adequate capacity to connect all of the contracted generation, it also provides the highest boundary transfer across the main system boundary B0, as well as B01 and B02. Based on a comparison of the two options, we concur with SHE Transmission's selection of option 2 as the preferred AC option to be taken further.

Option 10 - Partial rebuild of existing 132kV at 275kV with new 1GW AC subsea cable from Helmsdale to Blackhillock
This option considers a shorter 220kV AC subsea route consisting of four cables between Helmsdale in Caithness to Blackhillock in Moray over a distance of approximately 93km (76km subsea and a land cable route of approximately 17km). The rationale for this option selection and technical implications are presented in separate feasibility study for a 1000MW AC cable connection between Moray and Caithness conducted by Cable Consulting International Ltd.

This option although technically feasible was discounted due to the high cost (£430m more expensive than the closest AC option), high number of subsea cables required (five cables indicated as possible solution) and an increased route length for the necessary OHL reinforcement. As a result of the significant technical challenges presented by this option, (high risk of transient voltages, low order harmonica resonance, voltage disturbances etc.) this option was not considered further.

Based on the information provided, we consider that the AC subsea cable option is technically inferior to option 2 and carries significantly higher cost and technology risk. We concur with SHE Transmission's approach to exclude this option from further analysis.

BB400 - Reinforcement options for the Beauly-Blackhillock Corridor - Works associated with the reinforcement of the Beauly-Blackhillock Corridor are required in order to ensure reinforcement of the transmission network across the boundary B1, as both of the onshore AC options discussed above alone do not satisfy this criterion. SHE Transmission's Needs Case provides information that indicates the following:

- SHE Transmission has recognised the potential requirement for an upgrade on the B1 Boundary; and
- There are a number of reinforcement options which involve rebuilding along existing overhead line corridors as well as new routes and hybrid combinations of the two. These involve 275kV and 400kV construction overhead lines that are shown in Figure 11 and presented in Table 7.

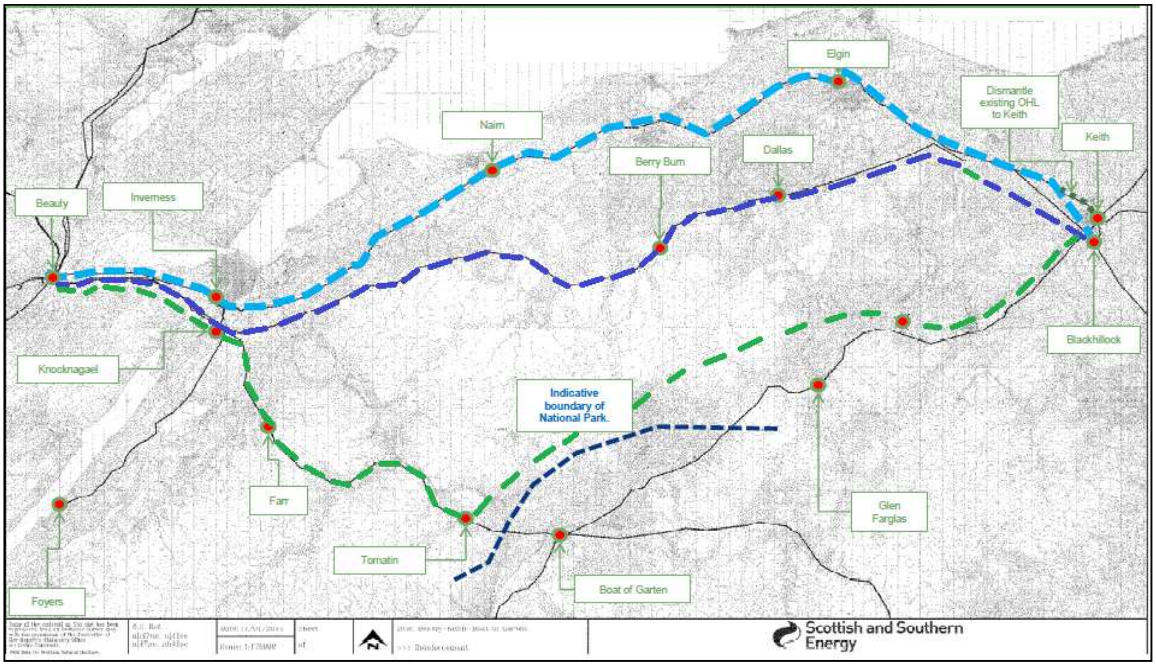

Figure 11 – Reinforcement options between Beauly and Blackhillock

	Reinforcement options for Boundary B1	Corridor	Estimated cost
1	400/275kV Double Circuit (DC) Overhead Line (OHL)	Moray Coast	£[redacted]M
2	400/400kV DC OHL	Moray Coast	£[redacted]M
3	275/275kV DC OHL	Moray Coast	£[redacted]M
4	400 SC OHL	Direct route	£[redacted]M
5	400/400kV DC OHL Direct Route	Direct route	£[redacted]M
6	275/275kV DC OHL	Direct route	£[redacted]M
7	400/275kV DC OHL	Boat of Garten	£[redacted]M
8	400/400kV DC OHL	Boat of Garten	£[redacted]M
9	275/275kV DC OHL	Boat of Garten	£[redacted]M

Table 7 – Reinforcement options for Boundary B1

- SHE Transmission has carried out further desktop assessment of the potential B1 reinforcement requirements. It has selected the 400kV option as it provides higher boundary capacities, better sharing of power through the transmission network as well as higher fault levels and improved transient stability performance.

Consequently, for the purposes of the Caithness-Moray reinforcement assessment a representative reinforcement in the form of a new 400kV overhead line between Beauly and Blackhillock (BB400) has been used, based on option 5 in Table 7 above. The Beauly to Blackhillock 400kV reinforcement has an estimated completion date of 2024 which includes no time allowance for a Public Inquiry.

Based on the information provided, SHE Transmission conducted the optioneering process on the BB400 only at a high level, providing a limited level of detail. There is no scoring methodology applied, limited number of selection criteria provided and no weighting factors to remove subjectivity from the selection process. In our view there is only limited confidence in the cost estimate associated with the proposed BB400 reinforcement considering that the route is not fixed and that there is potential for a new substation along this route. In comparison with optioneering for reinforcement of the B0 boundary it is clear there are deficiencies in the options identification process for the reinforcement of B1 boundary.

Given the limitations of the optioneering process we consider that there is a realistic possibility for both scope and costs to change. We also consider that the optioneering process does not cover the adequate level of detail that would be expected at this stage of the project development. As such, it is not in line with the approach taken in the technical Needs Case e.g. no evidence is available to show how SHE Transmission has considered a number of key criteria associated with different reinforcement options or of the weighting factors applied. It is also unclear how SHE Transmission has estimated the potential cost for the BB400 works, when there is no clarity regarding the recommended OHL route or requirement for a new substation.

Other AC technology options

In addition to the AC options mentioned above there are other technologies that are usually considered in development of the transmission network. The Needs Case submission would benefit from a brief description why other options, for example a Gas Insulated Line (GIL) or partial undergrounding of proposed OHL circuit, have not been considered. We do acknowledge that these options are significantly more expensive and technically inferior when compared to the AC options highlighted above, but should have been included for the completeness of the technology option selection.

We concur that SHE Transmission considered all of the reasonable AC options and technologies in their optioneering process.

3.4.1.2 Optioneering for the HVDC solution

As a part of the optioneering for the HVDC solution SHE Transmission considered options 3 to 9. All of the options include the HVDC link from Spittal to Blackhillock and all include the provision for multi-terminal capability to allow the future integration of generation from Shetland, Orkney or Caithness via an additional HVDC link. The level of the AC onshore works is the main driver of the difference between all of the HVDC options. These were all rejected due to the higher cost or because they provided a technically inferior solution. Of the reinforcement options considered, options 6 and 7 were assessed to be the most favourable. These options are similar except that in the northern part of the area, Option 7 proposes a 275kV rebuild of the Dounreay to Mybster circuits compared to a 132kV rebuild in Option 6.

A major weakness of SHE Transmission's optioneering analysis is that it did not consider different ratings for the HVDC link. This approach have better illustrated what is the minimum scheme required to satisfy the need for the reinforcement and which part of the HVDC solution represented anticipatory investment for future new generation north of Beauly boundary B0. In light of the previous Caithness Moray submission and in order to better understand the capacity need for the proposed solution, the following aspects were assessed by DNV KEMA:

- **Increasing HVDC Link Rating from 600MW to 800MW** – In a submission from SHE Transmission in 2011 (which it subsequently withdrew) it indicated that a 600MW HVDC link would provide sufficient reinforcement. In SHE Transmission's latest submission it is unclear why it has decided to increase the HVDC link capacity. We requested further information to clarify the situation. SHE Transmission's response indicated that the main reason for reviewing and increasing the rating of the HVDC link and associated substation arrangements is to *"secure network capacity to meet future generation requirements in an economic and efficient manner"*. They also estimated (as at May 2012) the cost of increasing the rating of the Spittal converter and HVDC cable between Spittal and Noss Head from 600MW to 800MW to be around £[redacted]M.

  The analysis showed that the increase in the HVDC link rating directly benefits B1 boundary transfers from the additional 200MW link capacity. However, based on the contracted generation position and our analysis this increase is not required to meet the minimum network requirements. SHE Transmission provided no evidence of the least regret analysis to support the proposed increase in HVDC link capacity from 600MW to 800MW.

Nonetheless, our view is that this is a reasonable approach given the positive aspects of the proposed increase in capacity, the anticipated level of the generation planning to connect north of Beauly and given the estimated cost. However, we would expect SHE Transmission to provide more justification in their submission that this anticipatory investment is economical.

- **400 MW of anticipatory HVDC capacity from Caithness to Blackhillock** -This anticipatory investment to increase the HVDC capacity is intended to accommodate further growth in renewable generation in the far north of Scotland.

  The indicative cost for a straight-through 800MW HVDC link with converters and AC substations at each end, is estimated at £[redacted][7]m. The additional cost of building-in an extra 400MW between the Caithness coast and Blackhillock and providing for a subsequent bussing point is estimated at £[redacted]m. The extra £[redacted]m is the cost of the optional extra capacity and so is referred to as the “Option” cost.

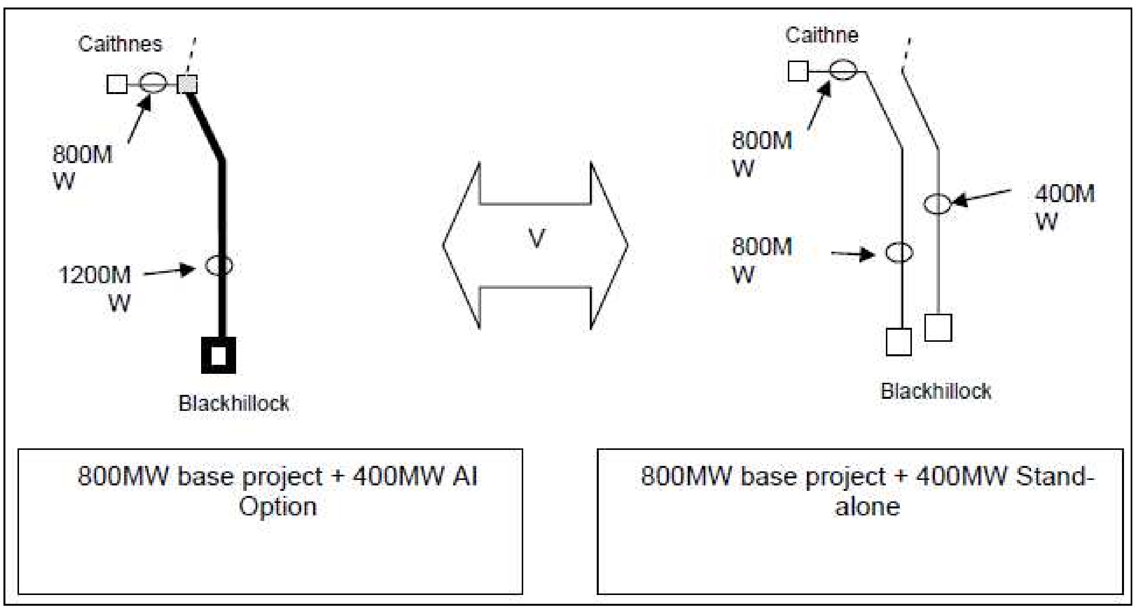

Figure 12 – Option comparison for anticipatory investment

The options under consideration compare the £[redacted]m spend against £[redacted]m spend later. The further into the future the £[redacted]m spend, the less its Present Value is today. Given the time difference, there may be value to incur the option cost now and provide the level

[7] Estimated cost for HVDC link with anticipatory investment of £[redacted]m does not correspond with total cost estimate for HVDC of £[redacted]m. It appears that costs in analysis of anticipatory investment hasn’t been updated with most recent figure. In our opinion this omission does not have material effect on analysis provided

of future proofing, but more analysis is required before a valid conclusion may be drawn. The approach adopted of subtracting from the 400MW cost the later investment to complete the bussing point gives a valid comparison between the two options because costs of the notional 400MW stand-alone scheme are discounted to take account of delivery at a future date.

An economic justification for the additional costs associated with the anticipatory capacity has been provided by conducting regret (opportunity loss) analysis. SHE Transmission has also carried out a sensitivity analysis to test the robustness of this conclusion using a range of discount rates (5.25% - 7.25%) and a + 25% / - 15% range for the capital cost of the stand-alone 400MW link.

Figure 13 shows the results of a regret calculation at a discount rate of 6.25%. DNV KEMA concurs that SHE Transmission approach is reasonable, however, we consider that further clarifications need to be provided in Stage 2 about the estimated cost of the anticipatory investment.

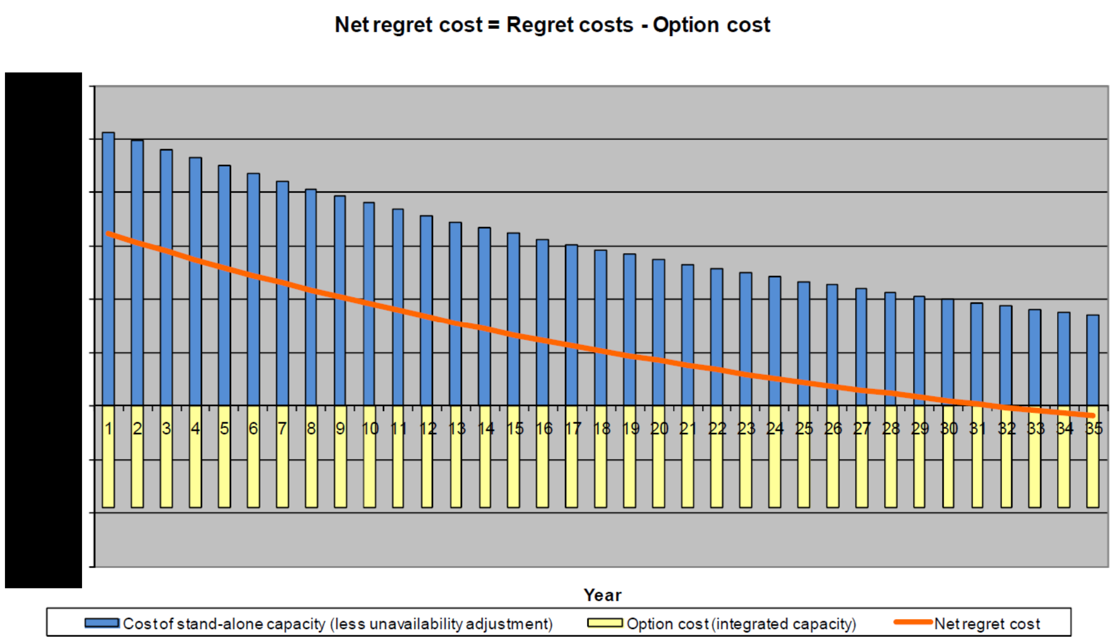

Figure 13 – Regret calculation

SHE Transmission's analysis also takes into the fact that in order to realise this anticipatory investment it is necessary to operate the link in a multi-terminal HVDC mode and the cable jointing bay at Noss Head will be a future DC bussing point in Caithness. This arrangement will allow the integration of (mainly) Shetland generation via an HVDC link but also brings additional risks.

To take into account these risks SHE Transmission conducted comparison of single circuit arrangement versus two circuits. The following assumptions have been made:

1. Distinct HVDC circuits on the same route are sufficiently separated for there to be no greater likelihood of unavailability of one in the event that an adjacent circuit has been damaged.
2. Switching time at a Noss Head HVDC bussing point to isolate a faulted section of HVDC circuit either from the north or from Spittal, and to restore a through circuit route to Blackhillock for the remaining circuit is short duration and negligible in respect of unavailability.
3. For cable circuits with the same number of cores and ratings, in the range 400MW-1200MW, fault rates and repair times are the same.
4. With the above assumptions, annual average circuit rating unavailability is the same for both left and right hand arrangements: 1200MW for [redacted][8] hours.

SHE Transmission has prudently assumed a higher level of control complexity on the multi-terminal arrangement may lead to more interruptions, and switching re-configuration procedures may amount to a number of hours (arbitrary annual average of 24hours of additional outages), assumptions which give the average annual estimated cost of £[redacted]m/year. Even if the average unavailability is doubled to 48 hours and the cost doubled to £[redacted]m the impact is to reduce the regret period by one year from 31 to 30 years.

DNV KEMA considers the above sensitivity analysis adequately explores the impact of anticipatory investment on HVDC availability but it does not capture all the risks associated with multi-terminal HVDC technology for which there is very limited international experience. The absence of this experience limits the ability to specify detailed requirements and negotiate technical detail with suppliers. This is particularly important if we take into the account the fact that the market is dominated by a small number of large suppliers with very limited interoperability and standardisation between supplier's designs. This limits competition between existing suppliers and restricts the potential for new entrants to the market. In addition there is a lack of adequate tools to understand all the issues and the expected impact of the planned multi-terminal HVDC solution on the existing network.

Based on the above we consider that adequate assessment of multi-terminal solution should as a minimum have the following risks identified and taken into the account when assessing anticipatory investment:

[8] The total average annual unavailability attributable to a section of HVDC cable circuit calculated by SHE Transmission between Noss Head and Blackhillock is [redacted]hrs/year. This calculation is based only on cable availability

- DC protection challenges –The protection must be equally fast and reliable. The challenge with currently available technology is to measure voltage and current, and there is no service experience available to indicate the reliability of the different proposed protective principles; and
- Lack of adequate tools to understand all the issues and expected impact of the planned multi-terminal HVDC solution on the existing network.

The recently awarded NIC project[9] indicates that SHE Transmission recognises some of the issues highlighted above, but it is unclear how they have taken these issues into account in the assessment of the anticipatory investment.

3.4.2 Appropriateness of options used in the CBA analysis

The two broad reinforcement options that SHE Transmission has taken forward for more detailed analysis are:

- Option 1 – the HVDC link- installation of a new 800/1,200MW HVDC submarine link together with associated onshore works; estimated costs between £[redacted]M and £[redacted]M (2013 prices); and
- Option 2 - the AC option – rebuilding existing 132 kV circuits from Beauly to Dounreay to 275kV - estimated costs between £[redacted]m to £[redacted]m (2012/13 prices).

Both options are initially identified to reinforce Boundary B0 but generation located north of Beauly also impacts on the power that can be transferred south through boundary B1, therefore reinforcement of B1 boundary becomes an important part of the analysis. In order to reinforce boundary B1, SHE Transmission is considering a new 400kV line between Beauly & Blackhillock as a possible future next stage of reinforcement for the B1 boundary at a total cost of £[redacted]m[10] (2012/13 prices).

Both Option 1 and 2 have been considered in this study with and without the optional BB-400 reinforcement:

- Option 1a – the HVDC link without BB-400
- Option 1b – the HVDC link with BB-400

[9] Ofgem awarded £11.33m to Multi-Terminal Test Environment for high voltage direct current (HVDC) Systems via Electricity Network Innovation Competition (NIC)

[10] Inclusion of BB400 with AC option also requires reinforcement of Blackhillock substation(£[redacted]m) and SVC(£[redacted]m)

- Option 2a – onshore AC without BB-400
- Option 2b – onshore AC with BB-400

It is our view that in principle the rationale for selection of Options 1a, 1b and 2b put forward for the further CBA analysis is appropriate and sound. However, the rationale for the selection of option 2a is not clear to us. SHE Transmission's assessment of reinforcement options for the north of Beauly area clearly identifies "Technical capacity benefit across the north-west boundary B1" as the key criterion for the option to be selected. The proposed option 2a would score low on this criterion as it does not increase transfer capacity over boundary B1. We therefore believe that Option 2a should not be further assessed as it does not provide a technical solution for the identified need.

3.5 Other considerations to support SHE Transmission's strategy

In our assessment, we reviewed SHE Transmission's treatment of a number of other considerations which are not captured in the quantitative analysis including the following:

- Planning and consenting risks;
- Deliverability of the proposed increase in renewable generation;
- Risks considered;
- Supply chain issues; and
- Stakeholder engagement.

3.5.1 Consideration of planning and consenting risks

In the assessment of reinforcement options for the north of Beauly, among the key criteria considered are planning and consenting risk. They are embedded into the optioneering process as they are jointly selected as a one of the key criteria for which different weighting factors are assigned to ensure appropriate sensitivity. In addition, the Indicative Reinforcement Programme schedule of activities for the options considered contain elements associated with both planning and consenting such as, for instance, the section 37 consent process and ecological surveys. It is clear from SHE Transmission's submission that these risks are taken into account as they have a significant effect on the project planning and delivery timescales for all options considered, and particularly for AC options. SHE Transmission expect 2026 as the earliest delivery date for the AC option.

The risk register for the HVDC element provided in Appendix K incorporated large sections covering technology and HVDC risks, as well as some of the other key risk areas including onshore/offshore planning and consenting. Our analysis shows that they have considered around 30 different consenting/wayleave/planning risks associated with HVDC options with reasonable risk actions and risk owners clearly identified.

SHE Transmission's submission indicates that there is a good awareness of the potential planning and consenting issues associated with both AC and HVDC options.

3.5.2 Deliverability of the proposed increase in renewable generation

SHE Transmission's SP and SSP generation scenarios project an increase in (primarily) onshore wind capacity in boundary zone B1 of over 2GW between 2015/16 and 2020/21 (a 5 year period) with a load factor of 28% being adopted.

If we assume an average rating for onshore wind turbines of 3MW, the SHE Transmission scenarios imply some 670 turbines being erected over a 5 year period (an average of 134 turbines per annum). All wind farms would require the appropriate planning consents and approvals to be in place before construction. The majority of the capacity under consideration in Caithness is not yet consented. By comparison, by the end of 2012 the total UK installed onshore wind capacity was 5.9GW, of which 1.2GW was installed during 2012.

Our assessment of the deliverability of the proposed increase in renewable generation indicates that it is extremely challenging but feasible to expect delivery of 2GW of wind farms over 5 years. We consider this approach to be reasonable, as even if there is a small delay in connection timescales, we do not expect this to have a material effect.

3.5.3 Risks

A key issue with the analysis undertaken to support the CBA is uncertainty including all the risks associated with options put forward for the CBA analysis. This section focuses on the risks associated with each particular option put forward and excludes uncertainties surrounding the rate of renewable growth as we discussed in section 3.2.

The Needs Case submission indicates that:
"*At the early stages of a project a desktop approach is taken where reinforcement options are proposed and then filtered. We do not carry out detailed risk assessment of the options at this stage and consequently a* [redacted]*% risk/contingency allowance is carried across all reinforcement options to allow comparison. Detailed specific risk assessment has not been carried out for the proposed project*"

In our view, this approach is adequate for early assessment of reinforcement options and selection of option for further CBA analysis. However, the proposed approach to evaluating the risk associated with various options is not adequate. Each of the options carries different level risks and in order to compare the relative merits of each option it is necessary that the different risks are identified and quantified. The [redacted]% contingency allowance contained within the estimated cost figures cannot be considered as a substitute for a risk assessment and a blanket increase on cost estimate does not reflect any particular or individual risks and cannot be seen as a substitute for formal and detailed risk management. We acknowledge that it is not prudent to expect a detailed risk assessment at this stage of the project, but SHE Transmission can identify those risks they are most likely to face with each of the options and place a financial value on them. For some of the potential risks SHE Transmission could have proposed mitigating measures which themselves would most likely have associated costs. In our view these costs need to be included in the overall cost of the option to correctly reflect the actual cost. In addition some risks might not have an impact on overall cost but could cause delays in project delivery. It would be prudent to consider capturing not only outright risks but also any other assumptions and dependencies in order to adequately monitor all of the elements that could potentially have a significant effect on project cost or timescales.

We believe that an adequate risk assessment would consist of a systematic approach to identify potential risks within a project and estimating the probabilities of these risks occurring. SHE Transmission's approach to the potential risks as presented in the Needs Case submission is not a balanced view, particularly when some of the risks are separately highlighted e.g. planning and consenting risk. Although these risks are important and relevant, there is a danger that if risks are only partially considered and there is no visibility of the total risks profile, the outcome of the optioneering process could be skewed.

Given the variety in options and technologies proposed, major risk can be considered in three broad categories:

- **Traditional AC technology with onshore build -**The key risk considerations in onshore infrastructure relate to planning and consenting, adverse constraints, unforeseen environmental and ecology considerations and access constraints and this was adequately covered in the narrative of Needs Case. While these risks are difficult to quantify, SHE Transmission has much recent and relevant experience in this area[11] and we believe that most of this risk is already covered in project timeline and cost[12].

- **HVDC technology** - The key risks in relation to HVDC options relate to bottlenecks in the supply chain, adoption of new technology, including lack of international standards and system integration. Appendix K gives an overview of the risk management process and identifies key risk categories which include converters, DC cable technology, multi-terminal development, commissioning and supply chain. We find that this register contains a comprehensive list of risk associated with HVDC development. At the same

[11] Beauly – Denny 400kV, Beauly – Mossford 132kV, Dounreay – Beauly 275kV

[12] Our analysis of costs presented in section 3.6 indicates that AC costs are high which could indicate that significant risk cost is already included in SHE Transmission cost estimate

time it is unclear how good identification and understanding of the risks is taken into account when developing total HVDC costs. The Cost Build-up table in Appendix K indicates that total risk costs are £[redacted]m. There is no explanation as to how this figure was derived and to identify the relationship between risk costs identified in the HVDC Risk Register and the total risk cost associated with HVDC solution.[13]

- **Offshore build -** The key offshore risks considered for a subsea option are mainly around inshore waters constraints, cable landing arrangements, subsea cable routing and installation. The narrative in Section 7 of the Needs Case shows good understanding of the key risks associated with offshore build. Key risks are also covered in Appendix K and the HVDC risk register provided separately[14] and our analysis of total risk costs for HVDC technology is applicable to offshore build as well.

We believe that SHE Transmission has identified all the key risks associated with the options considered, but it is unclear how the impact and cost of these risks are taken into account. For the AC option, all of the risks identified in their narrative are qualified but not quantified in needs case narrative. We do not consider application of a general [redacted]% risk/contingency allowance as adequate for the detailed CBA assessment. For the HVDC Option, the key risks are both qualified and quantified[14] but there is no clear link between HVDC risk register and total cost of the risk.

3.5.4 Capex Sensitivities

In addition to the risk assessment, SHE Transmission and their consultants introduced in their CBA the envelope of cost sensitivities to cover the different risk factors associated with the two main reinforcement options considered. The list of the sensitivities and our view on appropriateness of the figures is presented below:

- **Base capex plus 10% on HVDC costs** - SHE Transmission indicates that this lower figure is considered as they are in late stages of the tender negotiations and they have confidence in cost estimates provided. In our view this figure is low for a project of this size and complexity and a higher figure should have been considered. Our view is also

[13] Using information from the HVDC risk register we have conducted a simple analysis of current risk cost (after mitigation measures). Multiplying probability figures and minimum impact cost it is possible to calculate current cost for each of the risk identified. Total current risk should be the sum of the SSE owned individual current risk costs which based on information available is £[redacted]m. We understand that detailed Quantitative Risk Assessment would come up with lower figure but the difference is so significant that it needs to be highlighted

[14] The HVDC Risk Register has been provided as a separate file (Caithness-Moray HVDC Risk Register.pdf)

based on the Capex range considered previously for similar projects[15] as well as recent experience of the significant increase of the HVDC cost following receipt of tenders.

- **Base capex minus 10% on HVDC costs** – No explanation was provided to indicate why the proposed figure is considered as an adequate sensitivity. In our view this figure is not appropriate for a project of this size and complexity as it is highly unlikely that cost will be lower as they already have indicative costs from tender returns.

- **Base capex +10% on all costs** – The Needs Case does not provide any rationale as to why this figure might be appropriate. We believe that the proposed 10% is appropriate as a starting point in assessing the impact of the higher costs but in a addition higher figure should have been considered.

- **Base capex plus 20% on non HVDC costs and 10% on HVDC costs** – SHE Transmission indicates that a lower figure is considered for the HVDC option as they are in the late stages of the tender negotiations and they have confidence in cost estimates provided. In our view both options should be treated the same in terms of Capex sensitivity. The fact that one option is more developed than the other is already reflected in pricing of the risk therefore, in our view, lower capex sensitivity for the AC option is not appropriate.

In addition to the Capex sensitivity, CBA analysis contains additional sensitivities associated with the movements in delivery timescales, e.g. 1 and 2 year movement in the planned delivery date for the AC option, the HVDC option and for BB400. The following timing options have been assessed:

- Advance the onshore AC reinforcement by 1 and 2 years to 2025 and 2024;
- Advance the onshore BB 400 reinforcement by1 and 2 years to 2023 and 2022;
- Delay the onshore BB 400 reinforcement by 1, 2 and 3 years to 2025, 2026 and 2027;
- Advance both the BB 400 and AC reinforcements by 1 and 2 years;
- Advance both the BB 400 and AC reinforcements with combined delivery is 2021; and
- Delay HVDC by 1 & 2 years

The impacts of these additional sensitivities are discussed in more detail in section 4

[15] Needs Case submission for the Western HVDC Link from 2011 considered the impact of a 40% increase in project costs (it is important to note that the Western HVDC at the time was in earlier stages of the project development). This was deemed reasonable by Ofgem consultants at the time and there is no indication that supply chain issues and certainty of the costs have improved since.

3.5.5 Supply chain issues

The Needs Case submission in Appendix K identified key supply chain issues associated with the HVDC option and SHE Transmission's approach is presented in Table 8.

Key supply chain Issues	SHE Transmission approach
Currently expected demand for HVDCs outweighing supply	**REDACTED**
For supply chain delivery the key procurement risks are cable manufacturing availability, vessel availability and the limited market for convertor technology	**REDACTED**
Potential cost escalation due to future restrictions	**REDACTED**

Table 8 – Key supply chain issues for HVDC link

The information provided in Appendix K does not have any supply chain consideration for overhead line or substation works which to some degree is present with all the options considered. In response to our request for the additional information, SHE Transmission has indicated that in relation to the supply chain risks for Caithness Moray Project components, the following has been considered:

- **Overhead line works** - Due to the anticipated volume of overhead line works in the north of Scotland over the next 10 years, and the availability of resources to complete the works, it was important to ensure that SHE Transmission had access to sufficient capable resources for completion of the portfolio of work. A tender process is currently underway for a framework agreement for overhead line works. This will give the market certainty of future workload and will secure capable, experienced resources for SHE Transmission to use for future works. The OHL works listed above are to be delivered via this framework once it is in place.

- **Substation works** - Due to the planned substation works in the north of Scotland over the next 5-10 years, a tendering exercise was carried out to appoint multiple framework contractors on a committed basis for “lotted” works. This will give the market certainty on workload and will secure capable, experienced resources for SHE Transmission to use for future works.

Our assessment of supply chain considerations indicates that SHE Transmission has taken reasonable steps to reduce supply chain risks. The approach is consistent with the Needs Case and proposed works programme.

3.5.6 Stakeholder engagement

The stakeholder engagement and stakeholder management plans are included in Appendix O, with specific feedback from NGET as GBSO and from RenewableUK. Information on stakeholder engagement in Appendix O is split into three main sections: Early consultation with key stakeholder groups, continued engagement since October 2012 and future programme of engagement.

Early consultation with stakeholders is based on a stakeholder engagement programme which was launched as a part of the RIIO-T1 price control review. For major ‘SWW’ projects including Caithness Moray, the proposals were built upon the view of projects included in the ENSG reports as being likely to be required over the RIIO-T1 period. We understand that these consultation documents described the main elements of the Caithness Moray proposal (HVDC solution) without specifically focusing on other options available.

Engagement with electricity industry is only based on ENSG reports[16] and there are no further engagements with industry in regards to Caithness Moray proposals. Although we agree that ENSG reports are valuable documents in discussing options for the network development, they are covering many strategic reinforcements across GB with Caithness Moray only briefly mentioned. For the size, importance and complexity of the necessary reinforcement north of Beauly, we find that ENSG on its own does not show adequate engagement with the electricity industry. We would expect to see additional evidence that SHE Transmission was seeking industry wide views on what would be the most appropriate solution for the given problem. In our opinion it is difficult to imagine that some parts of the industry would not express preference for the AC solution due to the lower costs, technical and technology risk.

[16] Electricity Networks Strategy Group (ENSG) reports from July 2009 and February 2012.

Engagement with Local Authorities, Public Agencies and Industry was based on a set of presentations that have been made to a number of groups and forums. It appears that SHE Transmission contacted a reasonable spectrum of local groups but it is unclear if both options with all pros and cons have been presented to all of the groups. In addition apart from the preference for the subsea solution from The Princes Trust no other views were provided.

Engagement with the Developers is predominately based on requests from SHE Transmission to comment on generation growth scenarios. In our view this approach is a good example of good practice of stakeholder engagement as growth of renewable generation is the main driver for the Caithness Moray reinforcement.

Engagement with National Grid as System Operator is reflected in involvement with the project through joint planning committees and the work of the ENSG, together with the project being identified as enabling works in the making of connection offers to renewable generators. In addition, Appendix R contains letter from NG in which they present their views on SHE Transmission's Needs Case. In this letter National Grid clearly states that the "*proposed design is appropriate in meeting the existing and future system requirements*". They also indicate support for selection of VSC technology and against shorter subsea AC route. In our view this letter indicates that National Grid is well informed about SHE Transmission's plans to develop the network north of Beauly. On the other hand this letter does not give a National grid view on the HVDC proposal versus the onshore AC option and the risks to project delivery of the proposed HVDC technology.

In our view SHE Transmission provided reasonable evidence of broad stakeholder engagement on need for this project. On the other hand there is a limited evidence of good stakeholder engagement regarding option selection. Adequate engagement needs to contain clear communication of major risks and benefits associated with all the options considered. No evidence was provided to show whether SHE Transmission have presented both options to stakeholders and sought their views regarding the technology options. Good stakeholder engagement would also show how SHE Transmission flexed their plan to accommodate views from the stakeholders. Based on information provided, it appears that none of the stakeholders expressed any doubts about the proposed solution or provided support for other solutions, which we find difficult to understand. The prudent approach for a £1bn plus investment would be to include wider industry engagement to comment on the selection of options and the appropriateness of the option selected.

We believe that SHE Transmission's stakeholder engagement plans lack transparency and breadth of inclusion of all relevant stakeholders, and we therefore consider that SHE Transmission's approach does not cover all stakeholder issues adequately.

3.6 Review of project and operational costs

Consideration of the total lifetime costs is one of the crucial factors in the comparison of different investment options. Taking into account the project development stage, the following items are included in the lifetime cost:

- Capital costs;
- Operation and maintenance; and
- Electrical losses.

Details for each of the points raised are discussed below.

3.6.1 Operational running costs of proposed options

SHE Transmission indicated that annual operating costs estimated for the AC work elements (pure AC works) is around 0.1% of the initial capital investment which represents roughly £[redacted]M/pa including BB400 and £[redacted]M/pa excluding BB400.

In regards to the HVDC element SHE Transmission have indicated that operational costs remain under review and discussion with current HVDC tenderers. The information and discussions to date indicate an annual O&M cost of circa £[redacted]m for HVDC assets and a further £[redacted]m per annum for a preventative maintenance agreement provided by the HVDC manufacturer, providing an estimated annual cost of £[redacted]m. This is a recommended approach by the tenderers, but remains under further discussion and evaluation. If we take into account the O&M figure for BB400, the total cost for the combined HVDC option and BB400 options increases to £[redacted]M. In addition the pool of HVDC manufacturers and HVDC O&M providers is limited, leaving maintenance of the assets highly reliant on a single supplier. As a consequence there is a risk associated with availability of the spares and increase in maintenance costs.

Notwithstanding the observations above, and taking into account the stage of project delivery, it is considered that th SHE Transmission treatment of operational costs has been reasonably and robustly derived.

3.6.2 High level review of project capital costs

SHE Transmission has indicated that the costs for the options have been estimated using an internal database of unit cost items which are derived from historical costs and are updated by the most recent tender information and framework agreements as and when it becomes available. Some elements for bespoke or typical items, such as wayleaves and injurious affection claims, as well as bridge works for transport, are estimated from recent experience and professional judgement either within SHE Transmission or through consultants.

The cost of new transmission assets depend on many factors, including the amount of capacity required, commodity prices, and prices for transmission assets. We have therefore reviewed the cost estimates provided by SHE Transmission using documents available in the public domain, as well as our experience, to gauge whether SHE Transmission's cost estimates are appropriate for the purpose of this review.

The Needs Case submission provided more details of the latest costs, shown below in Table 9 for the preferred AC option and in Table 10 for the preferred HVDC option. SHE Transmission has also provided cost updates as and when it has received more accurate costs (for instance trough tendering processes). For comparative purposes, we include both initial and current cost levels, and calculate the percentage increase since March 2013.

AC options 2a and 2b	Cost estimates (£000s, 2013 prices)		
	Latest	Initial	% change
Fyrish substation	£[redacted]	£[redacted]	28.51%
Shin substation	£[redacted]	£[redacted]	10.68%
Loch Buidhe substation	£[redacted]	£[redacted]	28.51%
Thurso South substation	£[redacted]	£[redacted]	10.68%
Beauly -Loch Buidhe - Dounreay (Re-conductoring)	£[redacted]	£[redacted]	10.68%
Dounreay/Thurso/Mybster/Loch Buidhe/Beauly 275 OHL	£[redacted]	£[redacted]	10.68%
Mybster substation	£[redacted]	£[redacted]	10.68%
Dunbeath substation	£[redacted]	£[redacted]	10.68%
Brora substation	£[redacted]	£[redacted]	10.68%
Allowance for associated Public Inquiry costs	£[redacted]	£[redacted]	10.68%
Allowance for mitigation arising from consent conditions	£[redacted]	£[redacted]	10.68%
Total for option 2a	£946,558	£841,410	12.50%
REDACTED	£[redacted]	£[redacted]	£[redacted]
REDACTED	£[redacted]	£[redacted]	£[redacted]
REDACTED	£[redacted]	£[redacted]	£[redacted]
Total for option 2b	£1,546,783	£1,244,926	24.25%

Table 9 - Cost estimate for AC option with BB400 works

HVDC options 1a and 1b	Cost estimates (£000s, 2013 prices)		
	Latest	Initial	% change
Blackhillock substation	£[redacted]	£[redacted]	-6.20%
Fyrish substation	£[redacted]	£[redacted]	28.51%
Loch Buidhe substation	£[redacted]	£[redacted]	28.51%
Beauly -Loch Buidhe 275kV OHL	£[redacted]	£[redacted]	28.51%
Dounreay - Mybster 275kV OHL	£[redacted]	£[redacted]	22.14%
Caithness HVDC	£[redacted]	£[redacted]	26.41%
Total for option 1a	£1,268,144	£1,039,390	22.01%
REDACTED	£[redacted]	£[redacted]	£[redacted]
Total for option 1b	£1,714,769	£1,443,390	18.80%

Table 10 - Cost estimate for the preferred HVDC option

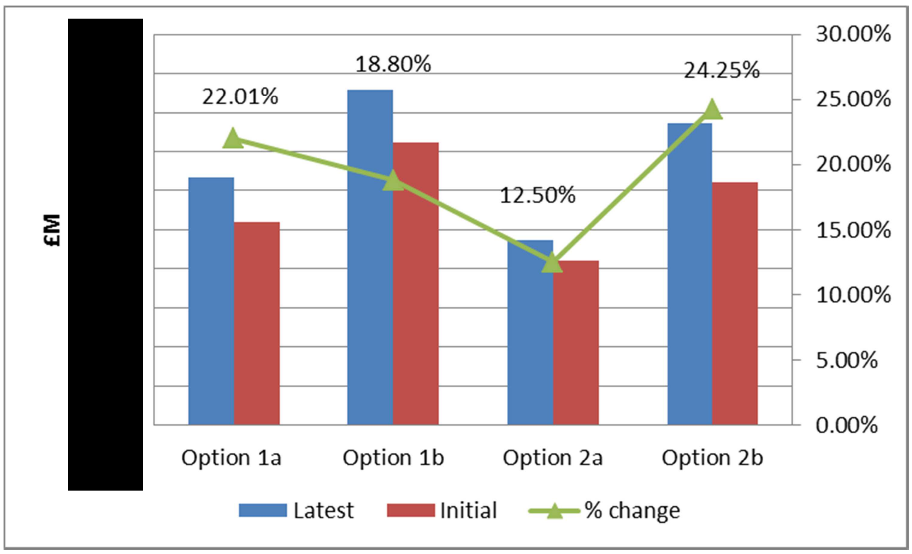

Figure 14 – Initial and latest cost estimate for the options considered

It is evident from Figure 14 that "cost creep" is a real risk with the cost estimate for each of the options considered increasing between 12.50%-24%. While cost increases for the HVDC elements are explained, with recent information reported from the tender returns, it is unclear what drives the increase in AC related cost. There is no indication of any recent AC projects that influenced increases in cost or any changes in the scope of work initially. In addition, aside from costs associated with Blackhillock substation,[17] we have not received any feedback form SHE Transmission relating to a rationale for the cost increase relating to the AC options.

[17] Cost associated with reinforcement of the Blackhillock substation(£[redacted]M) were included in total costs for the AC option in the December 2013 submission.

In order to assess the reasonableness of SHE Transmission's cost estimates, we have split the total costs associated with both the AC and HVDC option into the following "building blocks": Overhead line costs, Substation costs and HVDC cost. Our views are presented below:

Overhead line Costs- Capital costs for the two main reinforcement options had only limited granularity. In order to compare overhead line costs we had to make the following assumptions:

- The costs of reinforcing Mybster are the same for both AC and HVDC options, therefore Dounreay – Thurso – Spittal –Mybster OHL capital cost is estimated at £[redacted]M;
- Dounreay/Thurso/Mybster/Loch Buidhe/Beauly 275 OHL route length is estimated at 200km; and
- Substation works associated with Beauly Denny are 33% of total project cost[18].

Analysing cost estimates provided in Table 9 and Table 10 together with the length of the circuit we conclude that total OHL costs vary between £[redacted]M/km[19] for the Dounreay/Thurso/Mybster/ 275 OHL circuit and £[redacted]M/km[20] for the Beauly Blackhillock 400kV OHL circuit.

	Lo capacity (3190 MVA); 400 kV AC, 3 km	***HVDC Option-*** *Dounreay – Thurso – Spittal - Mybster,*	***AC Option*** *Dounreay-Thurso-Mybster-Beauly*	BB400, 400kV	Beauly Denny[21]
Build costs £M	4.50	[redacted]	[redacted]	[redacted]	400.00
Route length (km)	3km	[redacted]	[redacted]	[redacted]	210.00
Build cost per km	**1.50**	[redacted]	[redacted]	[redacted]	**1.90**

Table 11 - Cost comparison for the AC OHL costs

[18] Around 600 new towers erected with 400kV overhead line and six substations to be either built extended or upgraded. Total project cost estimated at £[redacted]M (http://www.bbc.co.uk/news/uk-scotland-highlands-islands-23447401).

[19] Costs for Dounreay – Thurso – Spittal –Mybster route calculated using SHET estimates for this route and deducting £[redacted]M for costs associated with a new 275/132kV substation at Thurso South and Mybster

[20] Beauly Blackhillock route length estimated at 110km without sections with underground cable

[21] Assumed that 66% (£[redacted]M) of the works is associated with OHL and 33% (£[redacted]M) with substation works

If we compare these costs with the figure of £1.5M/km provided in *Electricity Transmission Costing Study-PB Power CCI & IET* it is clear that OHL line costs appear higher than a benchmark figure. Given the lack of a detailed description for the proposed AC options and the complexity of details in the SHE Transmission submission, it has not been possible to analyse the proposal in order to be certain about appropriate cost estimates for a project of this size.

We also note that the cost estimate for OHL works associated with HVDC options are more refined with a final risk provision of 8%. On the other hand, cost estimates associated with the AC option and BB400 works assume a [redacted]% contingency, which, when taken into account, reduces the gap in the benchmark figures between the HVDC and AC/BB400 options to within [redacted]%.

Taking into account the magnitude of this project and based on the above analysis it appears that OHL costs are reasonable for the HVDC option but at the higher end of what we would expect reasonable for the AC option and BB400, given that the level of risk relating to the technology is better known and understood.

Substation costs – There are a number of substations that need to be constructed/extended as a part of the proposed works. The scope of the work associated with each of the substations varies a lot, therefore there is a significant difference in costs. In absence of a more detailed scope, and based on the description from SHE Transmission and our view, the cost estimate associated with onshore AC substations appear high but within reasonable range.

HVDC costs- SHE Transmission has provided a single figure of £[redacted]M as an estimate for the HVDC option without any further granularity, for instance on the cost of submarine cable or on converter stations. To assess the appropriateness of the cost we have used *Electricity Transmission Costing Study-PB Power CCI & IET* report and in particular information for the 3GW HVDC VSC submarine link. In order to compare like for like solutions we have scaled it back to the capacity of 1.2GW[22] and our findings are presented in Table 12.

[22] The Figure used in scaling back the cost the of HVDC link and all the submarine cable represent DNV KEMA's engineering judgement and takes into account that costs do not change linearly with the change in capacity.

	±320kV DC (VSC), Subsea Cable 75km Route, capacity 3GW	±320kV DC (VSC), Subsea Cable 160km Route, capacity 1.2GW	***Estimate for Caithness HVDC***
Fixed build costs £M	717.90	510.51	[redacted]
Variable build costs £M	185.90	132.20	
Build Cost Total	**903.80**	**642.70**	[redacted]

Table 12 - Cost comparison for the HVDC costs

Although the above comparison does not take into account project specific configuration, estimates provided by SHE Transmission for Caithness HVDC cable are [redacted]% higher than the benchmark figure. Given the above analysis, and recognising the limitation of limited supply chain, inflation and potential risks, we believe that cost estimates for HVDC are at the higher end of what we would expect to be reasonable.

3.6.3 Electrical losses

The initial Needs Case submission did not contain any information to show whether the option costs have taken into consideration the electrical losses. We understand that determining the losses benefit is complex and sensitive to the location and output of the wind farms. However, we believe that assuming losses are zero was far too simplistic and we have requested additional information from SHE Transmission in regards to the losses.

In response SHE Transmission has provided a comparison of the total electrical losses arising from the AC and HVDC option with variable wind output and HVDC operational point.

	Wind @ 100% Output			Wind @ 70% Output			Wind @ 50% Output			
	HVDC Link Dispatch (% of 800MW)			HVDC Link Dispatch (% of 800MW)			HVDC Link Dispatch (% of 800MW)			
	HVDC-100%	HVDC-80%	HVDC-60%	HVDC-100%	HVDC-80%	HVDC-60%	HVDC-100%	HVDC-80%	HVDC-60%	HVDC-40%
HVDC Reinforcement Option estimate losses [MW]	123	130.9	144.3	63.2	61.9	65.7	45.7	38.8	36.8	39.8
AC Alternative Reinforcement with BB400 [MW]	137.1			65.4			34.2			

Table 13 - Comparison of electrical losses

The calculations from Table 13 show that although HVDC technology has higher electrical losses (at up to 60% loading) than the traditional AC option, the total losses associated with the two options are around 10% and in the case of lower despatch percentages HVDC losses are even lower. Based on the above we believe that the impact of electrical losses is not material in calculating the total benefits associated with any of the options considered.

3.7 Summary of findings on technical elements

DNV KEMA is satisfied that SHE Transmission provided sufficiently robust information and analysis to allow us to develop the high level findings as summarised below:

Deterministic planning criteria of the Security and Quality of Supply Standard - Based on the background of contracted generation it is clear that without reinforcement the transmission system will be overloaded beyond its capacity and would breach the SQSS requirements. The approach taken by SHE Transmission is consistent with the SQSS planning criteria and it represents adequate technical assessment of the existing capacity of the transmission network

Generation background - There is considerable uncertainty regarding the total renewable generation capacity and the rate of future growth. To cover the wide range of possibilities SHE Transmission presented four scenarios (and included the additional Ofgem scenario) for the growth of renewable generation in the north of Beauly area. Considering all the information provided, DNV KEMA believes that the five scenarios capture the reasonable range of possibilities for the development of generation in the area considered.

Connected capacity - planning consent has yet to be obtained for the majority of the generation capacity identified and it is unclear when the reinforcement trigger will be reached or indeed exceeded. In addition, there is no clear information regarding the minimum transmission capacity required for expected generation levels.

Technology assessment - It is our opinion that SHE Transmission has carried out a satisfactory analysis of the range of available technologies to address the reinforcement requirement and used this analysis to identify the most appropriate technical solution in the submitted Needs Case.

Optioneering – Detailed methodology with a comprehensive list of key criteria coupled with selection of weighting factors was considered for the option scoring for reinforcement of the B0 boundary. We find this approach reasonable and it represents good practice in optioneering process.

At the same time we find that the optioneering process for the reinforcement of the Beauly-Blackhillock Corridor is too limited and provides a limited level of detail. We also consider that the optioneering process does not cover the adequate level of detail that would be expected at this stage of the project development. There is only limited confidence in the cost estimate associated with the proposed BB400 reinforcement considering that the route is not fixed and that there is a possibility for upgrade of existing or construction of new substations along this route. In comparison with optioneering for reinforcement of the B0 boundary it is clear there are deficiencies in the options identification process for the reinforcement of the B1 boundary

The anticipatory investment (400MW capacity associated with the HVDC link) – SHE Transmission provided economic justification for the additional costs associated with the anticipatory capacity. We find that SHE Transmission's approach adequately explores the impact of anticipatory investment on HVDC availability but it does not capture all of the risks associated with multi-terminal HVDC technology for which there is very limited international experience.

Risks – SHE Transmission has identified all the key risks associated with the options considered but it is unclear how the impact and cost of these risks are taken into account. For the AC option, all of the risks identified in their narrative are only qualified but not quantified in the Needs Case narrative. We do not consider the application of a general [redacted]% risk/contingency allowance adequate for options taken forward for a detail CBA assessment.

Key risks, for the HVDC Option are both qualified and quantified but there is no clear link between the HVDC risk register and total cost of the risk.

Capex sensitivities – SHE Transmission introduced the envelope of cost sensitivities to cover the different risk factors that could lead to the cost increase. They have considered four sensitivities:

Capex +10% on HVDC costs - In our view this figure is low for a project of this size and complexity and a higher figure should have been considered.

Capex -10% on HVDC costs - In our view this sensitivity is not appropriate as it is highly unlikely that cost will be lower as they based this on information from tender returns.

Capex +10% on all costs - We find this sensitivity appropriate as a starting point in assessing the impact of the higher costs but in addition a higher figure should have been considered.

Capex +20% on non HVDC and +10% on HVDC costs - In our view both options should be treated the same in terms of Capex sensitivity. The fact that one option is more developed than the other is already reflected in the pricing of the risk therefore, in our view, lower capex sensitivity for the AC option is not appropriate.

Supply chain issues - Our assessment of supply chain considerations indicates that SHE Transmission has taken reasonable steps to reduce supply chain risks.

Stakeholder engagement - SHE Transmission provided reasonable evidence of a broad stakeholder engagement on need for this project but very limited evidence on option selection. We believe that SHE Transmission's stakeholder engagement plans lacks transparency and based on the information provided we consider that SHE Transmission's approach does not cover all stakeholder issues adequately.

Capital costs - In order to assess the reasonableness of SHE Transmission's cost estimates, we have split the total costs associated with both the AC and HVDC option into "building blocks":

Overhead Line - Taking into account the magnitude of the project and based on above analysis it appears that OHL costs are reasonable for the HVDC option but at the higher end of what we would expect reasonable for the AC option and BB400.

Substation costs – Due to the lack of detailed scope and based on the description from SHE Transmission and our experience, we find that cost estimate associated with onshore AC substations appear high.

HVDC Costs – We find that Caithness HVDC costs including subsea cable are [redacted]% higher than the benchmark figure. Recognising the limitation of limited supply chain, inflation and potential risks, we believe that cost estimates for HVDC are at the higher end of what we would expect to be reasonable.

It is important to note that in our view, the Needs Case submission does not offer a balanced view of both reinforcement options/technologies. The benefits associated with the HVDC option, including early deliverability and a higher boundary transfer capability, are clearly presented. At the same time there is very little information provided on the benefits associated with the AC solution e.g. traditional reinforcement enables easier connection of the future generation/demand when compared with point-to-point HVDC solution, risks associated with construction and operation are significantly lower and less dependent on a single supplier.

We would expect the Needs Case to provide a balanced view, clearly presenting all the pros and cons for the main options considered.

4 Assessment of cost benefit analysis in the Needs case

We have reviewed the CBA analysis and conclude that its calculations and underlying assumptions are mostly reasonable, although we believe cost sensitivities for the HVDC reinforcement do not fully capture the risk of cost overruns, and we note that they have not been taken into account in the main CBA analysis. We also note that the cost estimate for option 2a in the CBA analysis erroneously includes costs for the reinforcement of the Blackhillock substation, but the error does not affect the analysis of option 2b, and therefore it does not affect our overall conclusion

The results of the CBA analysis are strongly in favour of option 2b, which combines the AC reinforcement with BB400 and returns the highest NPV in all generation scenarios under base timing and capex assumptions, as well as in all sensitivities. Option 2b is therefore also the least worst regret option considered in the CBA analysis.

Option 1b is the closest competitor to option 2b, and the CBA report has put forward arguments that the potential risks and associated costs of delays in BB400 lend support to option 1b, and argues that the option of deferring investment in BB400 provides an additional benefit in favour of option 1b. These arguments are undermined by the outcome of the CBA analysis, which shows that BB400 adds benefits under all generation scenarios and we find the risks of delays to BB400 are manageable and in any case have a modest impact.

We have also investigated the claim in the CBA report that there are additional welfare benefits from constrained and frustrated renewable generation associated with the (early delivery of) the HVDC reinforcement. We believe the welfare figures proposed in the CBA report are significantly overstated due to double counting and a number of questionable assumptions. Moreover, the CBA report fails to acknowledge consumer surplus effects (price increases) associated with the frustrated generation argument, and is therefore inconsistent with the main CBA analysis. In addition to welfare benefits, the CBA report provides an overview of mainly socio-political considerations, with which we broadly agree, but find difficult to value.

We conclude that the overall benefits offered by options 1b and 2b are very similar. Option 2b returns a higher NPV in the “central case” as well as in all sensitivities explored, strongly suggesting that this option provides the most value from reinforcing the network and addressing network constraints. However, option 1b offers other benefits associated with earlier network reinforcement and the inclusion of anticipatory investment. The fact that options 1b and 2b return a much higher value than options 1a and 2a respectively is testament to the significant added value of the BB400 in reinforcing the B1 boundary.

We have assessed the Cost Benefit Analysis (CBA) of network reinforcement options for SHE Transmission's Caithness Moray area on the basis of the following documents:

- A Report of 11 February 2014 "Caithness Moray – Cost Benefit Assessment (CBA) of Network Reinforcement Options" ('the CBA report');
- An excel spreadsheet dated 10 February 2014 providing the calculations underlying the CBA; and
- Responses to specific questions posed by DNV KEMA.

As part of our assessment of the CBA analysis, we have reviewed (1) whether or not SHE Transmission's overall approach to determine the costs and benefits for the reinforcement options is appropriate; and (2) whether or not specific assumptions made in the calculation of costs and benefits are reasonable.

This chapter is organised as follows:

- Section 4.1 summarises the CBA analysis and its conclusions as provided in the CBA report;
- Section 4.2 reviews SHE Transmission's approach and assumptions regarding the costs of reinforcement options;
- Section 4.3 reviews SHE Transmission's approach and assumptions in determining the benefits from reinforcements;
- Section 4.4 reviews SHE Transmission's execution of, and conclusion from, the CBA analysis; and
- Section 4.5 summarises our findings with regard to the CBA.

4.1 Summary of SHE Transmission's Cost Benefit Analysis

The CBA report considers 4 technical options for reinforcing the Caithness Moray area (based upon the outcome of the initial technical review as described in section 3 above):

- A subsea HVDC link increasing boundary capacity across all B0 boundaries and the B1 boundary (option 1a), to be delivered in 2018;
- Reinforcement of the onshore AC network to increase boundary capacity across all B0 boundaries (option 2a), to be delivered in 2026; and
- In addition to either the HVDC link or AC reinforcement, the creation of a new 400 kV line (BB400) to increase boundary capacity in the B1 area (options 1b and 2b respectively), to be delivered in 2024.

For each of these reinforcement options, the CBA report compares the discounted costs and benefits as at 2013, whereby:

- The Spackman approach is used to annuitize capital expenses (assuming a WACC of 6.25%) and TO discount costs and benefits (using the Treasury's Social Time Preference Rate of 3.5%);
- The costs of the reinforcement option are defined as the annualised capital expenses and annual operating and maintenance costs over an assumed 40-year economic lifetime from the date it is completed;
- The benefits of the reinforcement are defined for each year of the reinforcement's economic lifetime as the product of:
    - the annual difference in constrained electricity (GWh) between a reinforced and unreinforced (counterfactual) grid north of the B1 and B0 transmission system boundaries; and
    - the cost placed on constrained electricity in £ per MWh.

The following sections summarise the main analysis as well as the sensitivities assessed in the Cost Benefit Analysis.

4.1.1 The cost of reinforcement options

Chapter 4 of the CBA report provides some information on the costs associated with the proposed reinforcement options, consisting of capital expenses and operating & maintenance costs, as well as the assumed investment profiles. We have discussed the cost of reinforcement options in detail in section 3.6 above, but for reference, the figures below show the base capex and opex assumptions for each reinforcement option.

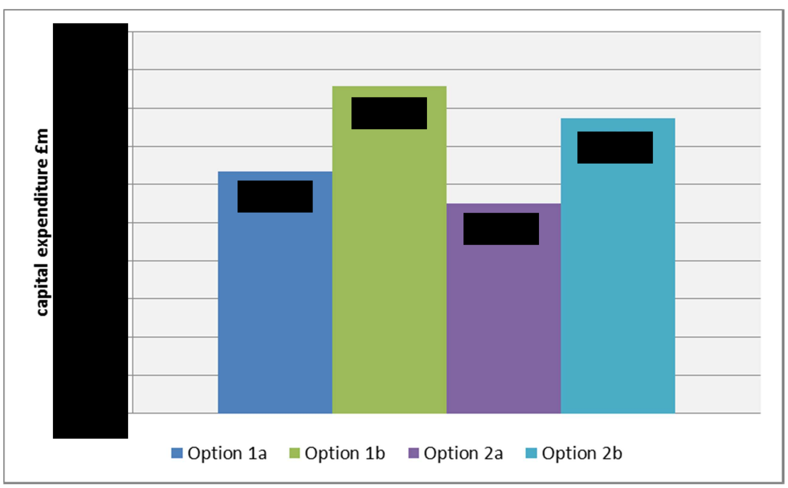

Figure 15: Base capex assumptions for reinforcement options (£m)[23]

[23] CBA report, p25.

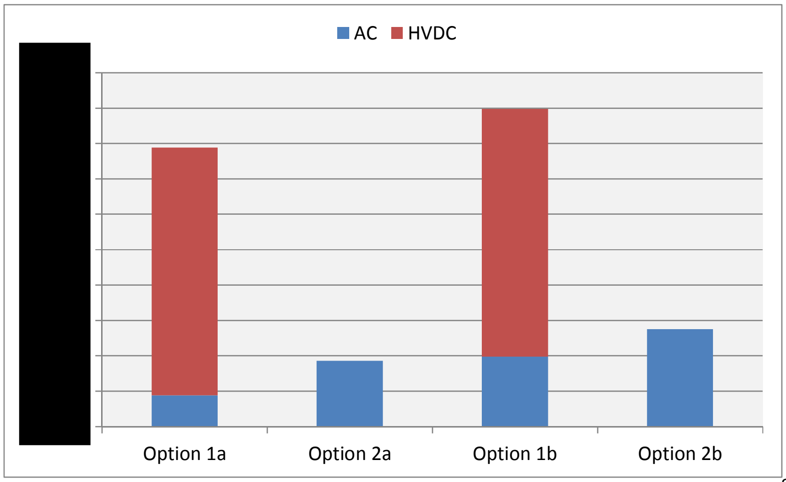

Figure 16: Opex assumptions for reinforcement options (£m)[24]

4.1.2 The cost of constrained electricity

Appendix C of the CBA report describes how the costs of constraining renewables generation in Scotland are calculated on the basis of difference in costs to consumers from (1) purchasing wind generation and (2) having to constrain wind generation and purchase thermal (gas) generation on the balancing market. The CBA report calculates the change in consumer surplus based on the following parameters:

- **The original cost to consumers of wind generation:**

- the wholesale electricity price; *plus*
- the value from Climate Change Levy Exemption Certificates (£5/MWh); *plus*
- (until 2017) the support paid for wind generators in the form of a Renewables Obligation Certificate (ROC), valued at £50/MWh;[25] ***or:***
- (from 2017 onwards) the support paid for wind generators under the Feed-in Tariffs with Contracts for Differences (FiT CfD) mechanism under the Electricity Market Reform (EMR) Programme.

- **The cost of balancing market transactions:**

- the costs of acquiring replacement electricity in the balancing market, which is equal to the wholesale electricity price *plus* a 30% margin;
- payments made to wind generators to be constrained down, which reflect the opportunity cost to wind generators of foregone income *plus* a 30% margin;

On the basis of the parameters set out above, the CBA report calculates a long-term constraint cost for onshore wind of £130/MWh.

[24] CBA report, p25.

[25] Factored in at 90% (0.9) from 2017 under the RO.

4.1.3 Summary results

Table 14 below provides the CBA results across all reinforcement options for different generation scenarios, assuming the cost of constrained energy equals £130/MWh.

Main results	SP	GG	Ofgem	SSP
Option 1A	1122	2174	211	264
Option 1B	1854	3316	307	360
Option 2A	395	1082	-119	-138
Option 2B	**2094**	**3467**	**735**	**717**

Table 14 – CBA summary results (£m, 2013 prices) [26]

The numbers highlighted in red above indicate the reinforcement option returning the highest net present value for each generation scenario,[27] which for all scenarios is option 2b. On the basis of these results, the CBA report offers a number of preliminary conclusions: [28]

- There is a strong case for reinforcement of B0 and B1 boundaries;
- Comparing options 1a and 2a, option 1a provides greater overall constraint relief because of its implicit reinforcement of B1;
- If further reinforcement to B1 is required, option 2b returns the highest NPV, but option 1b also returns a strongly positive NPV; and
- The onshore AC option must include a simultaneous reinforcement to B1 (BB400) to return a positive NPV under all scenarios, the HVDC option always returns a positive NPV even without BB400.

4.1.4 Sensitivities on the timing of reinforcement options

To gauge the impact of advancing or delaying reinforcements, the CBA report investigates the effects of advancing and delaying (combinations of) the HVDC, AC, and BB400 projects. Table 15 below shows the NPV results of all timing sensitivities investigated in the CBA.

[26] CBA report, p5.

[27] Generation scenarios have been discussed in more detail in section 3 of our report.

[28] CBA report, p4-5.

Option 1A Timing	SP	GG	Ofgem	SSP
1a HVDC+1yr	1151	2177	245	292
1a HVDC+2yr	1138	2162	256	279

Option 1B Timing	SP	GG	Ofgem	SSP
1b HVDC+1yr	1884	3320	341	388
1b HVDC+2yr	1872	3305	353	376
1b BB+1yr	1832	3352	331	384
1b BB+2yr	1810	3238	302	354
1b BB+3yr	1787	3201	298	350
1b BB-1yr	1875	3355	300	362
1b BB-2yr	1895	3395	288	364
1b BB 2021	1914	3435	271	281

Option 2B Timing	SP	GG	Ofgem	SSP
2b BB + 1yr	2084	3520	**769**	**751**
2b BB + 2yr	2074	3430	729	710
2b BB+3yr	2021	3353	701	682
2b BB-1yr	2104	3486	729	720
2b BB-2yr	**2115**	3506	718	723
2b BB/AC-1yr	2084	3482	698	689
2b BB/AC-2yr	2093	3537	659	664
2b BB 2021	2090	**3605**	548	371

Table 15 – NPV results of timing sensitivities (£m, 2013 prices) [29]

The results in Table 15 show that for each generation scenario, the highest NPV is returned by a sensitivity of option 2b, whereby for lower growth scenarios (Ofgem, SSP) the result follows from a delay in the BB400 (+1year) and for stronger growth scenarios from an advancement in the delivery of BB400 (-2 years and 2021 delivery, respectively).[30] For all generation scenarios in Table 15, option 2b sensitivities yield a higher NPV than option 1b sensitivities.

The CBA report assesses timing sensitivities in terms of a Least Worst Regret (LWR) analysis, which measures the difference between the NPV of a reinforcement option with the highest NPV returned under a generation scenario. Table 16 below presents the results of the 'regret analysis' provided in the CBA report.

[29] CBA report, p65. In Table 15, the notation "+1yr" means delivery 1 year later and "-1y" means delivery 1 year earlier. In combined reinforcement options 1b and 2b, the component which is either bought forward or delivered late is identified, e.g. "1b HVDC+1yr" means that the HVDC component of the overall reinforcement option is delivered one year later (in 2019).

[30] We note that the sensitivities '1b BB 2021' and '2b BB 2021' in the CBA report do not follow the naming convention for other sensitivities in that they not only advance delivery of the BB400 ('BB'), but also the AC reinforcement.

LWR Main Results	SP	GG	Ofgem	SSP
Option 1a	993	1431	558	487
Option 1b	261	290	463	391
Option 2a	1720	2523	888	889
Option 2b	21	138	34	34

LWR Option 1A Timing	SP	GG	Ofgem	SSP
1a HVDC+1yr	964	1428	524	459
1a HVDC+2yr	977	1443	513	472

LWR Option 1B Timing	SP	GG	Ofgem	SSP
1b HVDC+1yr	231	285	428	363
1b HVDC+2yr	243	300	416	375
1b BB+1yr	283	254	438	367
1b BB+2yr	305	367	467	397
1b BB+3yr	328	404	471	401
1b BB-1yr	239	250	470	389
1b BB-2yr	219	211	481	387
1b BB 2021	201	170	498	470

LWR Option 2B Timing	SP	GG	Ofgem	SSP
2b BB + 1yr	31	85	0	0
2b BB + 2yr	41	175	40	41
2b BB+3yr	94	253	68	69
2b BB-1yr	10	119	41	31
2b BB-2yr	0	99	51	28
2b BB/AC-1yr	31	123	72	62
2b BB/AC-2yr	21	68	110	87
2b BB 2021	25	0	221	380

Table 16 – Least Worst Regret results (£m, 2013 prices) [31]

Table 16 illustrates that the regret costs for reinforcement option 2b and its sensitivities are lower than those for option 1b, meaning that, for a range of different projects timings tested, option 2b returns NPVs that are closer to the maximum NPV realised under any generation scenario. The CBA report acknowledges this result, and makes some additional statements around the timing of delivery for BB400 in SP:[32]

"For the AC alternative the optimum delivery for BB400 is on time with SP. The results also show that delaying BB400 under the AC alternative more than two years leads to relatively rapidly rising regrets"

"The AC alternative requires a full commitment to both Option 2a and BB400 in order to maximise project NPV, with no optionality over future B1 reinforcement if generation post

[31] CBA report, p65.

[32] CBA report, p66.

2020 is lower. Adopting the HVDC option alone (Option 1a) leads to a positive NPV under all generation scenarios – undertaking additional B1 reinforcement with BB400 further improves project NPV. Therefore the HVDC approach offers a two stage solution. The ability to defer expenditure on further B1 reinforcement could be a significant benefit as uncertainty over future levels of generation capacity increases with time."

4.1.5 Further sensitivities on costs

The CBA report provides an analysis of sensitivities around capital expenses and constraint costs in Appendix A, but does not discuss the results of this analysis elsewhere in the report. The key insights from the cost sensitivities might be summarised as follows:

- A 10% increase in HVDC capex lowers the NPV of options 1a and 1b vis-à-vis options 2a and 2b, respectively;
- A 10% reduction in HVDC capex improves options 1a and 1b vis-à-vis options 2a and 2b, respectively, but, except in the Gone Green generation scenario, Option 2b continues to return the highest NPV of all reinforcement options; and
- A 10% capex increase for all reinforcement options lowers the NPV of all options, but also lowers the NPV of options 1a and 1b vis-à-vis options 2a and 2b, respectively.[33]

Section A.1.4 of the CBA report present the results of a cost sensitivity in which capex for the BB400 and the AC reinforcement are increased by 20%, but only by 10% for the HVDC reinforcement, to account for *"greater certainty surrounding costs arising from the Costs and Outputs exercise reported by SHE Transmission and presented to Ofgem".*[34]

The results of this sensitivity show that after a risk-adjusted capex increase on all options, Option 2b continues to return the highest NPV in all generation scenarios.

	SP		GG		Ofgem		SSP	
	Original	+10% 1a 20% other	Original	+10% 1a 20% other	Original	+10% 1a 20% other	Original	+10% 1a 20% other
Option 1a	1,122	946	2,174	1,998	211	36	264	88
Option 1b	1,854	1,573	3,316	3,035	307	26	360	79
Option 2a	395	131	1,082	819	-119	-383	-138	-402
Option 2b	**2,094**	**1,725**	**3,467**	**3,098**	**735**	**366**	**717**	**348**

Table 17 – NPV 10% increase HVDC capex, all other capex 20% (£m 2013 prices) [35]

[33] Note that in table A3 on page 78 of the CBA report, the results for option 1b fail to take into account the effect of the 10% capex increase on BB400 and hence overstate the NPVs for this option.

[34] CBA report, p78.

[35] CBA report, p79.

Appendix A closes with the presentation in section A.2 of the NPV results assuming a lower level of constraint costs at £100/MWh (2013 prices). The results, presented in Table 18 below, show a significant reduction in benefits delivered by all reinforcement options, although option 2b continues to provide the highest returns in NPV terms.

Main results	SP	GG	Ofgem	SSP
Option 1A	441	1251	-259	-219
Option 1B	881	2005	-310	-269
Option 2A	4	525	-399	-414
Option 2B	**1180**	**2237**	**135**	**121**

Table 18 – NPV results £100/MWh (2013 prices)[36]

4.1.6 Wider considerations

Section 10 of the CBA report provides an overview of wider considerations relevant to the comparison of reinforcement options that have not been taken into account in the NPV calculations. Section 10.1 provides an overview of additional, quantifiable welfare benefits that the CBA report attributes to option 1 based on (1) its comparatively early delivery and (2) its association with a number of planned generation projects. Sections 10.2-10.7 highlight a number of other, socio-political considerations.

Welfare benefits

In sections 10.1 and 10.1.1, the CBA report discusses that early boundary reinforcement under option 1 leads to a welfare benefit in that it facilitates renewables generation and hence avoids the carbon costs and fuel costs of gas-fired generation. Based on DECC's central gas price projection and the Carbon Price Floor (CPF) trajectory, the CBA report calculates a welfare benefit of £122 million (2013 prices) accumulated over 2019 to 2024.

Frustrated generation

Section 10.1.2 calculates further benefits from frustrated renewable generation, i.e. wind generation that is dependent on works associated with the HVDC reinforcement, will be replaced by gas-fired generation if the HVDC reinforcement does not take place, but whose output is not subject to the CM boundary constraints and hence not included in the NPV comparison of reinforcement options. Over 2019 to 2024, the CBA report calculates a cumulative benefit equal to £1,124m (2013 prices), or 50% of this amount (£550m) when assuming only half of the affected capacity emerges.

Socio-political considerations

Sections 10.2 to 10.7 list the following other considerations in favor of the HVDC reinforcement:

[36] CBA report, p79,

- Early connection of wind generation projects facilitated by the HVDC reinforcement contributes to meeting the UK and Scottish renewable targets;
- Lack of timely investment in grid capacity affects the confidence of investors in renewable technologies in the north of Scotland;
- The HVDC reinforcement includes additional capacity to accommodate further growth in renewable generation;
- Reinforcement of the Caithness Moray network area is supported by the Scottish government and a candidate project for the Scottish National Planning Framework (NPF3);
- Difficulties for NGET in programming, and high cost of obtaining, system outages for upgrades and connection of renewables; and
- Subsea cables have a lesser visual impact than overhead lines, which caters to concerns raised over visual amenity with many onshore works, such as with Beauly Denny.

Given the wider considerations listed above, the CBA report concludes:[37]

"Taking into account the wider benefits of delivering the HVDC option 6-8 years earlier than the AC alternative, the results suggest that the HVDC option is the optimum investment."

4.1.7 SHE Transmission's conclusions from the CBA

The CBA report concludes that the HVDC reinforcement is the '*optimum investment'* in broad terms because it can be delivered sooner than the AC reinforcement, and because it returns a positive NPV in all generation scenarios, even in the absence of the BB400 upgrade. An additional benefit, according to the CBA report, is that the HVDC reinforcement offers the option of waiting to financially commit to the BB400 until the development of generating capacity beyond 2020 is more certain.

The fact that the HVDC reinforcement can be delivered 6 to 8 years before the AC option, leads, according to the CBA report, to a number of wider benefits (including meeting UK energy policy targets, visual amenity) as well as to potential welfare benefits amounting to £800-1,350m that have not been accounted for when comparing the NPVs of different reinforcement options. In addition, the CBA report mentions additional benefits from the HVDC reinforcement because its useful life is expected to exceed the 40 year economic life assumed in the CBA analysis.

With regard to optionality of the BB400, the CBA report argues that for option 2 *"a commitment to construct BB400 is an integral part of the investment decision"* and highlights the importance of timeliness in the delivery of BB400, as a delay of more than 2 years means

[37] CBA report, p74.

that *"annual regrets will rise up to £50m"*.[38] In addition, the CBA report cites the risk of delay of the AC option due to planning concerns and a possible Public Inquiry, which would have a negative impact on its NPV. Under option 1, the CBA report argues, "*each year of delay to BB400 the NPV of Option 1b decreases at around £20m pa from 2024, whilst NPV is eroded with delay, the commitment to invest in BB400 does not have to be taken at this stage."*

4.2 Review of project costs

Chapter 4 of the CBA report provides some information on the capital costs associated with the proposed reinforcement options. We understand that these capital costs are based on estimates provided by SHE Transmission and derived from an internal database of historic costs and are updated by the most recent tender information and framework agreements. Further detail on costs is not provided in the CBA report, but we have received a high level overview of capital costs for specific network assets included in each option.

In order to assess the reasonableness of SHE Transmission cost estimates, as discussed in more detail in section 3.6, we split the total costs associated with both the AC and HVDC option into the following "building blocks": Overhead line (OHL) costs, substation costs and HVDC costs. The main conclusions we have reached for each of the building blocks are:

- **Overhead line costs:** reasonable for the HVDC (1a/1b) option but at the higher end of what we would expect reasonable for the AC option and BB400 (2a/2b).
- **Substation costs:** we consider the cost estimate for the onshore AC substations to be high, but within a reasonable cost range.
- **HVDC costs:** cost estimates for the HVDC are at the high end of what we believe to be reasonable.

Another issue of specific relevance to the CBA analysis is the cost provided for the AC reinforcement option. Table 4-1 in the CBA report (see section 4.1.1 above) provides an overall cost for the AC option of £[redacted]bn. This is inconsistent with the figures provided in the technical part of SHE Transmission's proposal (see Table 9 in section 3.6 above), which shows £[redacted]m as the latest value. We understand the difference is due of the inclusion of £[redacted]m worth of costs associated with reinforcement of the Blackhillock substation and a Static VAR Compensator (SVC) module. We consider the inclusion of these costs to be erroneous, as these works are not required under option 2a, the standalone AC reinforcement.

[38] CBA report, p75.

The effect of this error has a minor significance in the context of the CBA analysis. It results in an overstatement of the costs associated with option 2a, the standalone AC option, and hence a reduction in the NPV of this reinforcement option. However, we consider that the AC reinforcement is really only feasible as part of a larger reinforcement involving BB400 (option 2b), which *does* require reinforcement of the Blackhillock substation. Hence, given that the error does not affect the results for option 2b, it does not affect our overall conclusion.

4.2.1 Conclusion

Based on the above assessment we believe that SHE Transmission's capital expenses estimates are on the high side of what is reasonable for the HVDC option[39], and higher than our benchmark for all of the AC option(s).[40]

We note that the cost estimate for option 2a in the CBA analysis erroneously includes costs for the reinforcement of the Blackhillock substation. Since this reinforcement is not required for option 2a, this error lowers the NPV of this option. However, since the error does not affect the results for option 2b, which we consider a more realistic option, it does not affect our overall conclusion.

4.3 Review of benefits

The CBA report defines the main economic benefits of the potential reinforcement options by reference to the savings in constrained energy vis-à-vis a counterfactual scenario, in which no reinforcement is undertaken. This is consistent with the requirement in the SQSS for transmission owners to make sure that network development proposals meet the economic criteria. The benefits from reinforcement are therefore evaluated against changes in the volume of constrained energy following reinforcement and the value placed on this energy. Sections 4.3.1 and 4.3.2 below provide our assessment of these parameters.

The CBA report also discusses wider considerations that include additional welfare benefits and other socio-political considerations. Section 4.3.3 provides our assessment of these wider considerations.

4.3.1 The magnitude of the (residual) constraint volumes

4.3.1.1 General comments

The CBA report provides an explanation of how network constraints are calculated using a modeling approach previously adopted for the evaluation of projects for Ofgem, specifically

[39] This is predominately due to the high cost estimates associated with HVDC costs

[40] Includes OHL works associated with 2a and BB400 reinforcement

the TIRG review and the Beauly-Denny project for SHE Transmission. At a high level, this approach involves:[41]

- Assessment of generation, demand, and subsequent power flows across network boundaries; and
- Comparison of power flows with seasonal boundary ratings compliant with N-1 planning standard requirements.

While we understand this approach in principle, we note that we have not had access to the actual calculations based on which the CBA report determines the size of the constraint in GWh per annum. Volumes of constrained electricity are a key parameter[42] in measuring the potential benefits that the network reinforcements may have. For this reason, we consider that it is of crucial importance not only that we understand the approach to calculating these constraints, but also that we can verify that the approach has been applied correctly and consistently across all scenarios.

Without access to SHE Transmission's calculations, we are not able to review the details of this part of the determination of the (annual) benefits of the reinforcement options. We understand that Ofgem is obtaining an alternative, independent view on the likely level of constraints under the counterfactual case and, if possible, under the reinforcement options, to gauge whether or not the figures provided by SHE Transmission are reasonable. Based on the information available to us, we are only able to comment on the effect of the value of the constrained volumes and reinforcement options, rather than the level of constraints themselves.

4.3.2 Assessment of the cost of constrained electricity

The CBA report calculates the costs of constraining renewables generation in Scotland based on the effect on consumer surplus, i.e. the change in costs to consumers from (1) purchasing wind generation and (2) having to constrain wind generation and purchase replacement thermal (gas) generation from the balancing market. We consider this a reasonable approach to measuring the relative merits of different network reinforcement options given that consumers ultimately bear the costs of these reinforcements. This approach is consistent with Ofgem's principal duty as a regulator to protect the interests of consumers.

Although the approach in itself is reasonable, there are a few points to note regarding the assumptions related to subsidies received by onshore wind generators under the FiT CfD

[41] CBA report, section 5.1.

[42] Together with the cost assumed for constrained electricity.

mechanism, although this is mostly due to new information on this mechanism made available by DECC after the information date for SHE Transmission's analysis:

- The analysis assumes the administrative strike price for onshore wind generators equals £95/MWh, but in the December 2013 EMR delivery plan[43], this was reduced to £90/MWh from 2017/2018;
- DECC's January 2014 Consultation on CfD Allocation[44] places onshore wind plants in a group of established technologies that will compete for contracts every year in a pay-as-cleared auction, where the price for a specific technology is capped at the strike price for that technology; and
- Competitive allocation may reduce the ability of onshore wind generators to be allocated a CfD contract, depending on the level of participation from cheaper technologies, and from budget limitations under the Levy Control Framework (LCF), given a split of the overall budget between established and less established technologies (principally offshore wind).

It is understandable that the current CBA report does not account for these developments in full, and the current approach that assumes onshore wind continues to receive payment equivalent to the administrative strike price is a reasonable proxy for expected future subsidies to onshore wind generators.

However, the recent downward adjustment of that strike price to £90/MWh, and the allocation risk for onshore wind generators suggest that effective subsidies to wind generators are lower than assumed in the CBA. We consider that the £100/MWh constraint cost sensitivity included (but not further discussed) in Appendix C of the CBA report can give insight[45] into the relative performance of reinforcement options under a lower constraint cost assumption. We will discuss this in more detail in section 4.4.3 below.

4.3.3 Assessment of wider considerations

4.3.3.1 Welfare benefits

The CBA report argues that the HVDC reinforcement offers additional welfare benefits by avoiding the cost of gas-fired generation and the externality of emitting carbon dioxide (CO_2)

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[43] P37, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/268221/181213_2013_EMR_Delivery_Plan_FINAL.pdf

[44] P6, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271919/Competitive_allocation_consultation_formatted.pdf

[45] At £100/MWh this overstates the effect of downward adjustment of FiT CfD subsidies, and hence would serve to provide high level insight only.

into the atmosphere. Avoiding this cost and externality can be considered a welfare benefit in that it increases the prosperity and well-being of (people in) the UK.

Constrained renewable generation

Section 10.1.1 of the CBA report claims that the HVDC reinforcement offers an additional £122m welfare benefit from avoiding the costs associated with gas-fired generation and the cost of emitting CO_2 into the atmosphere over the period 2019 to 2024.

This claim is based on the same principle as the main CBA analysis, which is a comparison of residual constraints under reinforcement options 1 and 2, albeit that during the period 2019 to 2024 neither the BB400 nor the AC reinforcement is in place. Hence, the assessment of welfare benefits from constrained renewable generation is not based on a new calculation.

Moreover, the main CBA analysis involves a calculation of the cost of constrained electricity (summarised in section 4.1.2 above), which recognizes that when constraining wind generation replacement energy needs to be acquired from the balancing market, at a price equal to the wholesale electricity price plus a 30% margin. This wholesale price includes the cost of generating electricity – for a gas generator it includes the cost of fuel (gas) and the costs associated with carbon emissions, given by the price of an EUA and the tax on fuel (the Carbon Price Support rate) from the Carbon Price Floor instrument. Hence, constraining wind generation results in additional costs that would otherwise have not been incurred (a welfare effect) and are ultimately paid for by consumers (a consumer surplus effect).

Since the main CBA analysis calculates the benefits of reinforcement options based on their ability to avoid the cost of constraining generation, which includes avoiding the carbon and fuel costs associated with gas-fired generation to replace wind generation, the welfare benefit of avoiding these costs is already accounted for.

Section 10.1.1 of the CBA report confirms there is double counting, and offers a piece of analysis that is meant to address this issue. The "two stage process" described in section 10.1.1 is as follows:[46]

- *Determine the proportion of constraint costs in each year over the period 2019-2024 that can be attributed to carbon and gas costs (based on the carbon and gas prices outlined in Table 10-1) and assuming gas-fired generation replaces constrained renewables*;
- *Adopted DECC's future generation mix – which shows a declining contribution of carbon generation over time (based on the assumptions that low carbon generation grows to meet the UK's renewable and carbon targets) to evaluate carbon savings*; and
- *Assume that the generation displaced by renewable generation from the north of Scotland is only 50% gas.*

[46] CBA report, p69.

The point of this analysis seems to be that wind generation only displaces gas generation 50 percent of the time, and therefore saves only 50 percent of the (fuel) cost of gas. In addition, the analysis seems to suggest that, since wind displaces not just gas but also other generation technologies, the carbon costs it avoids are based on the weighted average carbon emission factor across all technologies, and not just based on gas-fired generation.

These assumptions are highly questionable. An increase in generation from wind generation, with zero marginal cost, pushes plant with non-zero marginal cost further up the merit order, and displaces the output of the marginal generator that balances wholesale supply and demand of electricity. In the GB wholesale electricity market gas-fired plant operates at the margin the majority of the time, followed by coal, depending on the level of demand.

The (unexplained) assumption that "*the generation displaced by renewable generation from the north of Scotland is only 50% gas*" therefore does not reflect GB wholesale market outcomes. By extension, the adoption of an average carbon emission factor based on DECC's future generation mix is inappropriate, since wind generation does not displace other low carbon generation (e.g. nuclear, wind, solar), and hence any carbon costs avoided are from fossil fuel generation (gas, coal). There is therefore no reason to change the assumption that wind generation on most occasions displaces gas-fired generation. In any case, changing this assumption does not adjust for the double counting of welfare benefits.

Taking the above considerations into account, we consider that the welfare benefits identified in section 10.1.1 of the CBA report have already been accounted for in the main CBA analysis. We therefore do not agree that there are any additional welfare benefits from constrained renewable generation to be taken into account in the assessment of the HVDC reinforcement.

Frustrated generation

Section 10.1.2 calculates further benefits from around 1600MW of renewable generation capacity that might not be realised until at least 2024 if the HVDC reinforcement is not made by 2018. The (potential) output of this additional generation capacity is not subject to the B0 and B1 boundary constraints and hence is not included in the generation scenarios used in the CBA to calculate the NPV of reinforcement options.

To the extent that some of the generation capacity identified in the CBA report is 'frustrated' by the absence of, or delay in, the reinforcement of the wider transmission system, there is a negative welfare effect from a missed opportunity to avoid the carbon and fuel costs of thermal generation. However, the inclusion of two major generators that jointly account for around 80 percent of potentially frustrated generation capacity is questionable:

- **Beatrice offshore wind farm (1000MW):** Currently, the completion of the HVDC reinforcement is classified as an enabling work to connect the 1000MW Beatrice offshore windfarm to the Blackhillock substation. Beatrice is meant to connect directly to the Blackhillock substation, and its connection is therefore only dependent on the investment required to reinforce Blackhillock (£[redacted]m[47]), not on the overall HVDC reinforcement (£[redacted]bn). Necessary reinforcement of Blackhillock to connect Beatrice can be delivered independent of the adopted SWW solution.

In any case, to the extent that a large generation project like Beatrice is dependent on enabling works that are a relatively small part of a much larger investment (at £[redacted]m it is less than 10% of total capex for option 1a) required for the HVDC reinforcement, it is difficult to accept that its connection cannot be realized through a dedicated enabling works investment if the HVDC reinforcement does not take place.[48] We therefore think the most likely consequence of the HVDC reinforcement not being delivered might be a minor delay in the connection of this generation capacity until the completion of dedicated enabling works, although we are not convinced that a delay is unavoidable.

- **Shetland (412MW):** The delivery time of the Shetland wind farm, which forms a significant part of the other 'Onshore Wind' capacity identified in the CBA report, is highly uncertain. In September 2013 the decision to grant planning consent to Shetland was overturned in court,[49] although the developers are appealing the outcome of the judicial review.[50] In addition, there is still uncertainty regarding the construction of an HVDC link to connect Shetland with Scottish mainland.[51] For these reasons we consider that the connection date for the Shetland wind farm project is highly uncertain, and we note that a potential delay will absorb some potential welfare benefits from facilitating an early connection.

Based on the above, we consider that the HVDC reinforcement provides only a small part of the £1,124m of welfare benefits calculated in section 10.1.2 of the CBA report. Lack of further information combined with the uncertainties about the Beatrice (alternative enabling works) and Shetland (planning and connection) projects prevents us from making a more informed estimate.

Moreover, we consider that the welfare calculation in itself overstates the potential welfare effect of avoiding carbon emissions. Section 10.1 calculates this welfare effect by reference to the trajectory of the UK government's carbon price floor (CPF), i.e. the sum of forward

[47] As per figures provided by SHE Transmission, without downward adjustment of this figure to reflect works at Blackhillock not directly aimed at connecting Beatrice.

[48] In particular the fact that the output of the potentially frustrated capacity is not subject to the constraints that the bulk of the investment for the HVDC reinforcement is meant to address, indicates that the potential loss of the HVDC reinforcement is not crucial for the connection of the capacity involved.

[49] http://www.scotcourts.gov.uk/opinions/2013CSOH158.html

[50] http://www.shetnews.co.uk/news/8068-sustainable-shetland-wind-farm-warning

[51] It is not known when the Needs Case for this interconnector will be submitted, and reviewed.

prices for EUAs and the Carbon Price Support (CPS) rate, which is levied as a tax on fuel used for the purpose of generating electricity as part of the Climate Change Levy. Since the CPS rate is a tax, it constitutes a transfer payment between public (the UK government) and private (consumers) agents in the UK, and is therefore neutral in welfare terms.[52]

Accounting for this effect significantly reduces[53] the welfare benefits attributed to avoiding carbon costs, which (based on comparing the average 'carbon value' and 'gas value' in table 10-4 in the CBA report) account for around 20-25% of the potential cumulative welfare benefit. This, in turn, reduces the overall welfare benefit from facilitating frustrated renewable generation even further.

Consumer surplus effects

The analysis of potential frustrated generation is inconsistent with the analysis of constrained generation. The CBA report offers a core analysis that focuses on the consumer surplus effects of constraining wind generation (sections 7-9), which it supplements with an analysis of additional welfare effects (section 10.1.1). Section 10.1.2 offers an analysis of welfare effects from potential frustrated generation, but does not consider the potential effects on consumer surplus.

To the extent that the HVDC reinforcement does indeed facilitate the connection of renewables generation capacity whose output displaces fossil fuel generation, the price to consumers will increase as they pay the wholesale electricity price *plus* subsidies to renewables generators (ROCs, uplift to CfD strike price). Since the core analysis of the CBA report investigates the merits of different reinforcement options based on consumer surplus effects, it should also take account of this effect.[54]

4.3.3.2 Socio-political considerations

Sections 10.2 to 10.7 provide an overview of other considerations that advocate the benefits of early network reinforcement through the HVDC option. While we agree that most of the considerations put forward have some merit, we find the discussion of some considerations to be incomplete or one-sided. The following provides our views on each of the considerations.

2020 renewable targets

[52] The tax *redistributes* wealth between economic agents in the UK, namely between consumers and the government, but does not reduce overall welfare.

[53] Depending on development of the differential between the CPF and the forward EU ETS carbon price, which determines the value of the CPS rate in the Climate Change Levy.

[54] This argument does not reflect our view on UK energy policy objectives to encourage investment in renewables generation, but merely serves to point out an inconsistency in the analysis presented in the CBA report.

The argument in this consideration is that early connection of wind generation projects facilitated by the HVDC reinforcement contributes to meeting the UK and Scottish renewable targets. Although we agree that from a political point of view it is important that renewable targets are met, the argument put forward in section 10.2 of the CBA does not provide a convincing case that without the HVDC reinforcement, these targets will be missed:

- As explained in section 4.3.3.1, we believe the additional renewable generation that is not behind the constrained B0 and B1 boundaries, such as the 1000MW Beatrice offshore wind farm, can be connected without HVDC reinforcement (although it might be delayed), and we consider the 2019 connection date for the 412MW Shetland plant to be uncertain; and
- We have not reviewed the status of the other plants mentioned in section 10.2, but since the CBA report did not specify these in its analysis of frustrated generation, this capacity does not seem to depend specifically on the HVDC reinforcement and might be connected through alternative enabling works.

Even if we assume all of the capacity listed might not connect without the HVDC reinforcement, the CBA report does not explain whether missing out on this capacity will cause the UK and Scotland to miss 2020 renewables targets, or if these targets would be missed (or met) regardless. Nor does the CBA report discuss what the potential cost of missing renewables targets might be.

Despite these considerations, we agree in principle that UK energy policy demands an increase in electricity provided from renewable sources, and the HVDC reinforcement can facilitate this sooner than the AC reinforcement.

Investor confidence

The CBA report cites SHE Transmission's own experience and a comment by RenewableUK to make the point that a lack of timely investment in grid capacity affects the confidence of investors in renewable technologies in the north of Scotland.

We consider this a reasonable argument in that early clarity about the timing and nature of network reinforcements will provide certainty to potential investors, potentially increasing investment in renewable generation capacity and avoiding unnecessary project costs associated with changes or delays in grid reinforcement timings.

Additional HVDC link capacity – anticipatory investment

The HVDC reinforcement includes additional capacity to accommodate further growth in renewable generation and might generate additional benefits depending on how fast the need for extra capacity firms up.

We reviewed SHE Transmissions analysis of the potential regret costs of anticipatory investment included in the HVDC reinforcement in section 3.4.1.2 and concluded that it is reasonable. Appendix N to the Needs Case mentions a number of projects that may require the additional capacity and *"could credibly require investment decisions to be taken within the first five years of the Caithness"*[55] and hence provide a benefit of between £130m and £162m.

Appendix N also mentions that the potential generation developments it refers to are not part of the main CBA analysis, and cites uncertainties around connection agreements, including *"the nature of financial support for renewables, generation technology development, energy markets, environmental and consenting issues, as well as the investment appetite of project sponsors."*[56]

On the basis of the information provided in Appendix N, we agree that the inclusion of anticipatory investment in the HVDC reinforcement is likely to be beneficial. However, given the uncertainties around the size and timing of generation capacity that could potentially connect, and in the absence of concrete information on the generation developments identified, we cannot be certain of the value of this benefit. A reasonable assumption would be to factor in 50 percent of the maximum benefit, i.e. £81m.

Scottish government support

The CBA report states:[57]

"In particular the Caithness-Moray project is identified as a candidate project for the National Planning Framework (2014), (NPF3), and as such is regarded as a project of national importance with the need being taken as pre-determined for planning purposes in meeting Scottish objectives on energy and related infrastructure matters."

Much like the argument around meeting 2020 renewables targets, the consideration here is that the possible endorsement from the Scottish government through NPF3 confirms the need for network reinforcement to meet (renewable) energy objectives.[58] While we understand this argument, to our knowledge the means (technology type) to provide the reinforcement is not specified. Therefore, the potential government endorsement is not specifically for the HVDC reinforcement, although from a timing perspective, that is likely to provide the most effective solution.

Outages

This argument cites difficulties for NGET in programming, and high cost of obtaining, system outages for upgrades and connection of renewables. The point seems to be that NGET can avoid some of the costs and difficulties if the Caithness Moray area is reinforced.

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[55] Appendix N to the Need case, p124.

[56] Appendix N to the Need case, p124.

[57] CBA report, p72.

[58] An argument not dissimilar to the argument around meeting 2020 renewables objectives.

We consider that constraint costs have been accounted for in the main CBA analysis, but agree that CM reinforcement would facilitate NGET carrying out upgrades and connections. Although these benefits might be realised with either the HVDC or the AC option (the CBA report does not discuss this point), we would agree that the HVDC reinforcement would deliver these benefits sooner.

Visual amenity

We agree that onshore works often attract concerns over visual amenity, and that from that perspective, the submarine HVDC reinforcement offers a more desirable solution than the AC option.

4.3.3.3 Conclusion on wider considerations

We conclude that although the early connection of the HVDC reinforcement offers some welfare benefits compared to the AC option, a number of questionable and/or incorrect assumptions presented by SHE Transmission means that the figures calculated in the CBA report are significantly overstated:

- The proposed welfare benefits from constrained renewable generation have already been accounted for in the main CBA analysis; and
- Much of the potentially frustrated capacity is not dependent specifically on the HVDC reinforcement (Beatrice) and the timing of other capacity is highly uncertain due to legal issues regarding planning permission (Shetland).

Based on the above, we consider that the HVDC reinforcement provides only a small part of the £1,124m of welfare benefits calculated in section 10.1.2 of the CBA report. Lack of further information combined with the uncertainties about the Beatrice (alternative enabling works) and Shetland (planning and connection) projects prevents us from making a more informed estimate. However, the welfare calculations should in any case be reduced to account for the erroneous inclusion of the tax effect of the Carbon Price Floor, which is welfare neutral.

In addition, the analysis of frustrated generation does not take account of consumer surplus effects, as electricity costs to consumer increase from subsidising renewable generation. These effects are also relevant for the results of the main CBA analysis that compares the benefits of reinforcement options based on changes in consumer surplus.

In addition to welfare benefits, the CBA report provides an overview of mainly socio-political considerations. We broadly agree with these considerations, of which the main message is that the sooner the Caithness Moray network area is reinforced, the sooner the benefits may be realised. Also of added value is the inclusion of anticipatory investment in network capacity within the HVDC reinforcement, although the size of this benefit is uncertain.

4.4 Assessment of the Cost Benefit Analysis

4.4.1 Main CBA results

Section 7 of the CBA report provides the results of the main CBA analysis, comparing the costs and benefits of reinforcement options 1a/1b and 2a/2b. This analysis assumes:

- Base capex levels for the reinforcement options;
- Base timing assumptions in delivering the HVDC (2018), BB400(2024) and AC (2026) reinforcement works; and
- £130/MWh constraint cost.

The CBA analysis compares the reinforcement options by calculating net present value in 2013 of the costs and benefits of individual reinforcement works. In calculating the NPV, the CBA report follows the Spackman approach, which is supported by Ofgem and uses the WACC (6.25%) to annuitise capital expenses and the Treasury's Social Time Preference Rate (3.5%) to discount costs and benefits. We consider this approach to be reasonable.

Table 19 below provides the CBA results across all reinforcement options for different generation scenarios, assuming the cost of constrained energy equals £130/MWh.

Main results	SP	GG	Ofgem	SSP
Option 1A	1122	2174	211	264
Option 1B	1854	3316	307	360
Option 2A	395	1082	-119	-138
Option 2B	**2094**	**3467**	**735**	**717**

Table 19 – CBA summary results (£m, 2013 prices) [59]

Based on these numbers the CBA report reasonably concludes that there is a strong case for reinforcement of B0 and B1 boundaries (given that the NPVs are mostly positive), that option 2b (AC + BB400) returns the highest NPVs, but also that the AC option must be accompanied by the BB400 to return a positive NPV under all generation scenarios.[60] Although the results across all generation scenarios clearly favour option 2b, the closeness of the results for options 1b and 2b (particularly in Slow Progression, which is the "central case" in the CBA) suggest it is worthwhile to investigate the impact of project risks, such as delays or cost overruns, to gauge to what extent these risks affect the main CBA results.

[59] CBA report, p56.

[60] On page 56, the CBA report also states that the AC option *"requires BB400 as a concurrent reinforcement to be an economic option"*. We assume this statement pertains to results of the Ofgem and SSP scenarios only, since under GG and (the central case) SP scenarios the AC option (2a) is economic.

4.4.2 Timing option sensitivities and Least Worst Regrets

4.4.2.1 Timing option sensitivities

Section 8 of the CBA report investigates the effects of changing the delivery time for reinforcement works, to gauge the impact of unforeseen project delays, or whether there is any merit in advancing any of the reinforcement where possible.

The modelling of these sensitivities is to some degree an academic exercise, in that effects of changing the delivery time of reinforcements can generally be attributed to:

- Differences in the counterfactual (the amount of constrained electricity without reinforcement) between years; and
- The trade-off in NPV terms of bringing forward, or pushing back, the value of constrained electricity and the annualised costs of the reinforcement option.

Other factors that affect the impact of timing sensitivities are that changes in the timing of reinforcement might affect overall project costs (which we understand applies to the HVDC reinforcement) as well as any effects from the interaction of reinforcements, such as the performance of BB400 when it operates alongside either the HVDC or AC reinforcement.

HVDC and AC timing sensitivities

The following text summarises the conclusions regarding HVDC and AC reinforcements and provides our commentary:

- Advancing the AC reinforcement in option 2a is not beneficial as it reduces the NPV
    - This reflects the fact that the costs of bringing forward the AC reinforcement outweigh the benefits, as the counterfactual in 2027 is higher than in 2025 and 2026.

- Advancing the AC reinforcement in option 2b is not beneficial as it reduces the NPV
    - Table 8-2 of the CBA report shows the same reduction in NPV as under option 2a (-51m and -104m, respectively), indicating an error in the underlying calculation. Bringing forward the AC reinforcement increases power flows to the B1 boundary, where the presence of BB400 produces an incremental benefit as it remediates constraints on the B1 boundary and allows the incremental power flows to pass unconstrained. The CBA report fails to show this effect.

- Taking account of increases in base capex for the HVDC reinforcement, there is a benefit of around £30m in delaying the reinforcement by one year, but the benefit is less for a two year delay.
    - This observation can be attributed to a step change in the volume of constraints in the counterfactual from 2019 (343GWh) to 2020 (1410GWh), and a more gradual increase after that, suggesting that delivery in 2018 is suboptimal for the HVDC

reinforcement, although part of the benefit is offset because of increased capex due to the delay.

BB400 timing sensitivities

The CBA report also investigates the effects of delaying or bringing forward delivery of BB400, and compares the results between options 1b and 2b.

BB400 Timing	SP	GG	Ofgem	SSP
Option 1b	1854	3316	307	360
Option 2b	2094	3467	735	717
1b BB +1yr	1832	3352	331	384
2b BB +1yr	2084	3520	769	751
1b BB +2yr	1810	3238	302	354
2b BB +2yr	2074	3430	729	710
1b BB +3yr	1787	3201	298	350
2b BB +3yr	2021	3353	701	682
1b BB -1yr	1875	3355	300	362
2b BB -1yr	2104	3486	729	720
1b BB -2yr	1895	3395	288	364
2b BB -2yr	2115	3506	718	723

Table 20 – BB400 timing sensitivity NPV results (£m, 2013 prices)[61]

Table 20 reproduces the results of BB400 timing sensitivities for all generation scenarios and shows that option 2b returns a higher NPV (indicated in red) than option 1b in all cases. Comparing options 1b and 2b, the results also show that:

- Bringing forward BB400 is more beneficial under option 1b, given the change in NPV relative to option 2b (higher increase in NPV for SP and GG, smaller decrease for Ofgem and SSP); and
- The cost of delays is similar for options 1b and 2b, but 1-2 year delays are less costly to option 2b than to option 1b, and a 3 year delay is more costly to option 2b.

With regard to the effects of delays in the delivery of BB400, the CBA report observes:[62]

"Any delay to BB400 has a negative impact on both the HVDC and AC options. A delay of more than two years to BB400 has a relatively large negative impact on the AC option as flows increase into B1 as Option 2a is commissioned and BB400 is required. These results

[61] Taken from CBA report, p65, table 9-9.

[62] CBA report, p61.

suggest that the project is sensitive to any delay reinforcing boundary B1 as without it there is no enhanced capability over the B1 boundary, leading to high constraints."

This observation is in principle correct, and reflects the relatively large importance of BB400 in resolving network constraints when paired with the AC reinforcement, as compared to when it is paired with the HVDC reinforcement. A three year delay in BB400 under option 2b pushed its completion year (2027) one year beyond the completion of the AC reinforcement (2026), and as a result, option 2b foregoes a year's worth of the incremental benefit that the BB400 delivers when operating alongside the AC reinforcement.

However, we would diminish the importance of this observation in the context of the CBA analysis, for the following reasons:

- At a three year delay of BB400, the cost impact on options 1b and 2b is very similar, and option 2b still returns over £200m more than option 1b. We consider that (1) option 2b could still take a few more years' of BB400 delay before option 1b catches up, and (2) longer delays are less likely to occur than short delays.
- The performance of option 2b relative to option 1b under long delays of BB400 can be improved by postponing delivery of the AC reinforcement to coincide with the (delayed) BB400. This simply illustrates that delivering the AC reinforcement without, or before, BB400 is a suboptimal solution.

Joint advancement of AC and BB400

Section 8.2.4 and 8.2.5 investigate the impact of simultaneously moving forward the AC reinforcement and BB400 by one or two years, or to deliver both reinforcements by 2021.

The results of moving forward AC and BB400 by one or two years show that moving forward the AC reinforcement is not beneficial, given, as shown before, a decrease in NPV for option 2a. Moving forward BB400 is beneficial, as also modelled before, given an increase in NPV for option 1b and only a small decrease for option 2b, making up for the cost of moving forward the AC reinforcement.

The results for delivering both the AC reinforcement and BB400 in 2021 show small NPV increases for options 1b and 2b in optimistic generation scenarios (SP, GG), and significant NPV reductions in conservative scenarios (Ofgem, SSP).

Under all sensitivities, option 2b delivers the highest NPV, although the difference with option 1b decreases in most cases.

Conclusion

We conclude that the optimum timing to deliver the HVDC reinforcement is 2019, that bringing forward the AC reinforcement in itself is not beneficial, but given an error in the calculations, we cannot conclude on the benefits of bringing forward the AC reinforcement as part of option 2b.

With regard to BB400, we conclude that bringing forward BB400 is slightly more beneficial in option 1b than in option 2b, but does not greatly change the relative benefits of these options. Delays in BB400 come at a cost to both options 1b and 2b, which is very similar for short delays, but becomes relatively costly to option 2b for a delay of more than three years. Given that the NPV benefit of option 2b over option 1b can accommodate a few years delay in BB400, given the decreasing likelihood of long term projects delays, and on the assumption that incremental delay costs can be avoided by coordinating the delivery of BB400 and the AC reinforcement, we do not believe the cost of delays in BB400 greatly affect the relative merits of options 1b and 2b.

Bringing forward both the AC reinforcement and BB400 does not change the relative benefits of options 1b and 2b, although the difference in NPVs returned by these options decreases in all but the most optimistic scenario (GG).

4.4.2.2 Least Worst Regrets analysis

Section 9 of the CBA report investigates the impact of timing sensitivities in terms of a Least Worst Regret analysis. The regret of a reinforcement option in a particular generation scenario is defined as the difference between the NPV for that option and the best possible reinforcement option in that scenario.

Main results

The results, reproduced in Table 16 in this report, show that option 2b is the Least Worst Regret option in each generation scenario, although the optimum timing of its components differs between scenarios:

- In the “central” generation scenario SP, option 2b returns the highest NPV if BB400 is delivered in 2022;
- In the optimistic GG scenario, option 2b returns the highest NPV if both the AC reinforcement and BB400 are delivered in 2021. We do not consider this a feasible option given the timing and planning risks, but it suggests that in Gone Green, the optimal strategy is to deliver the AC option and BB400 simultaneously, and as soon as possible; and
- In the conservative Ofgem and SSP scenarios, the best strategy for option 2b is to delay BB400 by 1 year, which returns the highest NPV across all options.

Analysis of BB400 timing

In section 9.2, the CBA report returns to a discussion of the relative merits of reinforcement options when delivery of BB400 is delayed:[63]

"*Delays to BB400 lead to relatively small regrets if the delay is less than two years, a delay of more than two years will lead to more rapidly rising regrets. Given the nature of the onshore reinforcement and the experience of Beauly Denny, delays to project implementation are genuine risk that must be taken into consideration when assessing the different reinforcement options."*

Although we agree with the point that delays to project implementation must be taken into account, as we explained in section 4.4.2.1 above, the comparative benefit of option 2b vis-à-vis option 1b is such that it can absorb the costs of reasonable delays and still emerge as the most beneficial option. Moreover, by coordinating the delivery of BB400 and the AC reinforcement, much of the delay costs can be avoided.

The CBA report then goes on to conclude that:

"The AC alternative requires a full commitment to both Option 2a and BB400 in order to maximise project NPV, with no optionality over future B1 reinforcement if generation post 2020 is lower. Adopting the HVDC option alone (Option 1a) leads to a positive NPV under all generation scenarios – undertaking additional B1 reinforcement with BB400 further improves project NPV. Therefore the HVDC approach offers a two stage solution. The ability to defer expenditure on further B1 reinforcement could be a significant benefit as uncertainty over future levels of generation capacity increases with time."

We consider this conclusion to be misguided for a number of reasons. Firstly, while it is true that the AC reinforcement (option 2a) does not return a positive NPV in the Ofgem and SSP generation scenarios, it is clear that the CBA report, through the adoption of SP as its "central case" does not consider Ofgem and SSP the most likely scenarios. A more important observation is that building the AC reinforcement on a standalone basis is not a realistic consideration in any generation scenario given its inability to reinforce the B1 boundary. As a result, there are considerable opportunity costs associated with not building BB400 alongside the AC reinforcement, but the same can be said for the HVDC reinforcement. Table 21 illustrates this point.

[63] CBA report, p66.

Options	SP	GG	Ofgem	SSP
Option 1A	1122	2174	211	264
Option 1B	1854	3316	307	360
BB400 Opp. Cost	-732	-1142	-95	-96
Option 2A	395	1082	-119	-138
Option 2B	2094	3467	735	717
BB400 Opp. Cost	-1699	-2385	-854	-855

Table 21 – BB400 opportunity costs

The numbers in Table 21 show that although the opportunity costs[64] of not building BB400 are largest in option 2, in both options the opportunity costs are large relative to the size of the benefit delivered by the standalone HVDC or AC reinforcements. This suggests that whichever reinforcement option (HVDC or AC) is in place, it is always beneficial to build BB400.

The CBA report argues that *"the ability to defer expenditure on"* BB400 can be beneficial given "*uncertainty over future levels of generation capacity"*. The CBA analysis has tested the benefits of BB400 in a number of different scenarios, both conservative (Ofgem, SSP) and optimistic (SP, GG), and the results (see Table 14) have shown that option 2b returns the highest NPV across all scenarios, which is largely due to BB400. Similarly, when paired with the HVDC reinforcement, the presence of BB400 leads to a higher NPV than that of the standalone HVDC reinforcement.

Timing sensitivity analysis (see Table 20) gave the same result, and illustrated that changes in the NPV of option 1b from bringing forward or delaying BB400 mirror the changes in the NPV of option 2b. To the extent that deferring investment affects the timing for delivery of BB400, the costs or benefits from deferral are similar for options 1b and 2b.

Conclusion

Option 2b is the least worst regret option across all generation scenarios. Given the reliance of option 2b on boundary B1 reinforcement from BB400, we conclude that the BB400 always adds value to whichever reinforcement option (HVDC or AC) it is paired with.

The CBA report presents an argument that uncertainty over future generation gives rise to a benefit from deferring investment in BB400. This argument is undermined by the main CBA results, which has tested the benefits of reinforcement options across both conservative and optimistic generation scenarios, and consistently demonstrated that option 2b returns the highest NPV, as well as that BB400 always adds value to the standalone HVDC and AC reinforcement options.

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[64] The foregone benefits of not building BB400, measured as the difference between option 1b and 1a, and option 2b and 2a, respectively.

4.4.3 Other sensitivities

The CBA report provides an analysis of sensitivities around capital expenses and constraint costs in Appendix A. Although the CBA report mentions in a number of places that this analysis has been undertaken, its results or implications are not referred to in the body of the report and appear not to have been taken into account in its conclusions.

Capex sensitivities

We provided our view on the appropriateness of these sensitivities in section 3.5.4 and concluded that the 10 percent sensitivities applied to the HVDC reinforcement are low and do not fully capture the risk of cost overruns for this project. However, SHE Transmission considers a 10 percent sensitivity a reasonable figure informed by recent tender negotiations and has modelled sensitivities on this basis, which provide some further insight into the relative performance of reinforcement options.

In the absence of discussion in the CBA report, the key insights from the cost sensitivities can be summarised as follows:

- A 10 percent increase in HVDC capex lowers the NPV of options 1a and 1b vis-à-vis options 2a and 2b, respectively;
- A 10 percent reduction in HVDC capex improves options 1A and 1B vis-à-vis options 2a and 2b, respectively, but, except in the Gone Green generation scenario, Option 2b continues to return the highest NPV of all reinforcement options;
- A 10 percent capex increase for all reinforcement options lowers the NPV of all options, but also lowers the NPV of options 1a and 1b vis-à-vis options 2a and 2b, respectively; and[65]
- For all these sensitivities, option 2b returns the highest NPV in virtually all generation scenarios.[66]

Section A.1.4 of the CBA report present the results of a cost sensitivity in which capex for the BB400 and the AC reinforcement are increased by 20%, but only by 10% for the HVDC reinforcement, to account for *"greater certainty surrounding costs arising from the Costs and Outputs exercise reported by SHE Transmission and presented to Ofgem".*[67] Of the cost sensitivities presented in Appendix A, this is presented as the most informed sensitivity, making an implicit assumption on the relative risk of cost overruns for options 1 and 2, respectively. Table 22 below presents the results.

[65] We note that in table A3 on page 78 of the CBA report, the results for option 1b fail to take into account the effect of the 10% capex increase on BB400 (the results for 1b are the same as those in table A1.) and hence overstate the NPVs for this option.

[66] With the single exception of the -10% HVDC sensitivity, which we consider inappropriate, where in the Gone Green generation scenario option 1b returns a marginally higher NPV.

[67] CBA report, p78.

	SP		GG		Ofgem		SSP	
	Original	**+10% 1a 20% other**	**Original**	**+10% 1a 20% other**	**Original**	**+10% 1a 20% other**	**Original**	**+10% 1a 20% other**
Option 1a	1,122	946	2,174	1,998	211	36	264	88
Option 1b	1,854	1,573	3,316	3,035	307	26	360	79
Option 2a	395	131	1,082	819	-119	-383	-138	-402
Option 2b	2,094	1,725	3,467	3,098	735	366	717	348

Table 22 – NPV 10% increase HVDC capex, all other capex 20% (£m 2013 prices) [68]

Table 22 shows that even for an informed capex sensitivity that assumes a lower capex increase for the HVDC reinforcement than for other reinforcements, option 2b continues to return the highest NPV in all generation scenarios.

£100/MWh constraint cost sensitivity

Section A.2 of the CBA report provides NPV results assuming a lower level of constraint costs at £100/MWh (2013 prices). The results, presented in Table 18 (section 4.1.5 of our report) show a significant reduction in benefits delivered by all reinforcement options, but option 2b continues to provide the highest returns in NPV terms.

Although not discussed in detail in the CBA report, this sensitivity provides a useful insight into the relative performance of reinforcement options at a lower constraint cost, for instance after adjusting for a lower CfD strike price and risks around the ability of onshore wind generators to obtain a CfD contract (as described in section 4.3.2).

4.5 Summary of findings on the CBA

We have reviewed the CBA analysis and conclude that its calculations and underlying assumptions are mostly reasonable, although we believe cost sensitivities for the HVDC reinforcement do not fully capture the risk of cost overruns. In addition, we note that the cost sensitivities, as well as the £100/MWh sensitivity on constraint costs, have not been taken into account in the main CBA analysis.

We note that the cost estimate for option 2a in the CBA analysis erroneously includes costs for the reinforcement of the Blackhillock substation. Since this reinforcement is not required for option 2a, this error lowers the NPV of this option. However, since the error does not affect the results for option 2b, which we consider a more realistic option, it does not affect our overall conclusion.

[68] CBA report, p79.

The results of the CBA analysis are strongly in favour of option 2b, which combines the AC reinforcement with BB400 and returns the highest NPV in all generation scenarios under base timing and capex assumptions. Option 2b also returns the highest NPV for the vast majority of timing sensitivities modelled, as well for capex and constraint cost sensitivities. Option 2b is therefore also the Least Worst Regret option considered in the CBA analysis.

Option 1b is the closest competitor to Option 2b, particularly in more optimistic generation scenarios (SP and GG), where there is often less than 10 percent difference in NPV terms. The CBA report has put forward arguments around the potential risk of delays, and associated costs for BB400 lend support to option 1b, which is less reliant on the benefits delivered by BB400 than option 1b. Based on this argument, and citing uncertainty over future levels of generation, the CBA report argues that the option of deferring investment in BB400 provides an additional benefit in favour of option 1b.

We consider these arguments are undermined by the outcome of the CBA analysis, which shows that BB400 adds benefits under all generation scenarios. In the “central case” generation scenario (SP) assumed in the CBA report, BB400 delivers greater benefits if it is delivered earlier, and it improves the case for option 1b relative to 2b. In the more conservative scenarios (Ofgem and SSP), should slow generation growth be a concern, the relative benefits delivered by option 2b compared to option 1b increase.

Moreover, our analysis of the effects of delays in BB400 shows that only with extreme delays might option 1B return a higher NPV than option 2b. Moreover, a lot of the opportunity costs from delays in BB400 might be avoided in option 2b by co-ordinating the delivery of BB400 and the AC reinforcement.

We have also investigated the claim in the CBA report that there are additional welfare benefits from constrained and frustrated renewable generation associated with the (early delivery of) the HVDC reinforcement. We believe the welfare figures proposed in the CBA report are significantly overstated:

- Proposed welfare benefits from constrained renewable generation have already been accounted for in the main CBA analysis; and
- Much of the potentially frustrated generation is not specifically dependent on the HVDC reinforcement (Beatrice) and the timing of other generation is highly uncertain due to legal issues regarding planning permission (Shetland)

Based on the above, we consider that the HVDC reinforcement provides only a small part of the £1,124m of welfare benefits calculated in section 10.1.2 of the CBA report. Lack of further information combined with the uncertainties about the Beatrice (alternative enabling works) and Shetland (project delays) projects prevents us from making a more informed estimate. However, the welfare calculations should in any case be reduced to account for the erroneous inclusion of the tax effect of the Carbon Price Floor, which is welfare neutral.

In addition, the analysis of frustrated generation does not take account of consumer surplus effects, as electricity costs to consumer increase from subsidising renewable generation. These effects are also relevant for the results of the main CBA analysis that compares the benefits of reinforcement options based on changes in consumer surplus.

In addition to welfare benefits, the CBA report provides an overview of mainly socio-political considerations. We broadly agree with these considerations, of which the main message is that the sooner the CM network area is reinforced, the sooner the benefits may be realised. Also of added value is the inclusion of anticipatory investment in network capacity within the HVDC reinforcement, although the size of this benefit is uncertain.

We conclude that the overall benefits offered by options 1b and 2b are very similar. Option 2b returns a higher NPV in the "central case" as well as in most of the sensitivities explored in the CBA analysis. This strongly suggests that this option provides the most value from reinforcing the network and addressing network constraints. However, option 1b offers other benefits associated with earlier network reinforcement and the inclusion of anticipatory investment.

5 *Summary of findings*

The key objectives of the Needs Case assessment are to determine:

- There is a demonstrable need and robust case for investment given a credible range of uncertainties, including the potential development of the future generation capacity;
- The technical scope of the proposal is appropriate and represents an economical response to the need relative to the alternative options and the status quo;
- The timing of the investment is appropriate given that there is a satisfactory case for need and that the scope of investment is appropriate; and
- The proposed reinforcement is in the interests of existing and future consumers.

Based on our review of the technical and economic elements of the Needs Case put forward by SHE transmission, we are satisfied that there is a need for reinforcement in the Caithness Moray area that must be met through investment in additional transmission capacity across the B0 and B1 boundaries. We note, however, that we have not had access to the calculations based on which SHE Transmission has determined the volumes of constrained generation. We understand that Ofgem is obtaining an alternative, independent view on constraint volumes, and have not undertaken a detailed assessment of our own.

The technical scope of the proposal, a combination of onshore AC works and an offshore HVDC link, is appropriate in that it offers a mostly efficient solution to meet the requirement for additional network capacity, although we do consider cost estimates for the HVDC link including Caithness subsea cable are at the high end of what we consider to be reasonable. Furthermore, we recognise that it also includes an element of anticipatory investment to facilitate connections for additional generation capacity in the future, which is likely to offer additional benefits, although some further clarification of its costs would be required

We note that an alternative reinforcement option investigated in the optioneering process, the AC option that rebuilds circuits from Caithness to Beauly and from Beauly to Blackhillock, combined with reinforcement of the Beauly-Blackhillock Corridor (BB400), can be similarly efficient in delivering additional network capacity. However, we consider the optioneering process for the BB400 reinforcement to be too limited and lacking in detail, which prevents us from determining the full efficiency of this option.

We have reviewed the CBA analysis to establish whether or not the proposed solution is the most economic and whether or not it is appropriately timed. The results of the CBA analysis, including all sensitivities and across all generation scenarios strongly support the combined AC-BB400 reinforcement (option 2b). Only option 1b (HVDC + BB400) delivers close to the same benefits as option 2b, indicating that:

- The HVDC reinforcement on a standalone basis is not in the best interest of existing and future consumers; and
- Unless the HVDC reinforcement is paired with a subsequent investment in BB400, it does not come close to offering the benefits of option 2b.

Although SHE Transmission's current proposal pertains to the HVDC reinforcement only (option 1a), the CBA report does recognise the merit in further reinforcement of the B1 boundary through BB400 in the future (as part of a "two stage solution"). The CBA report makes arguments around the potential risk of delays and associated costs in BB400, as well as uncertainty over future levels of generation, to lend support to option 1b, in which the decision to invest in BB400 might be deferred.

We consider these arguments are undermined by the outcome of the CBA analysis, which shows that BB400 adds benefits under all generation scenarios. Early delivery of BB400 in the "central case" scenario results in greater benefits and strengthens the case for option 1b relative to 2b, and in scenarios with slower generation growth (Ofgem and SSP), the relative benefits delivered by option 2b compared to option 1b increase. Hence, SHE Transmission's analysis shows there is no benefit in waiting to reinforce boundary B1 through BB400, and the potential to defer BB400 is not an argument in support of option 1b.

We conclude that, on a standalone basis, the HVDC reinforcement option proposed by SHE Transmission is not the most efficient solution and so is not in the best interest of existing and future consumers. However, in combination with B1 boundary reinforcement through BB400 at the earliest feasible date, the benefits provided by the HVDC option are close to those provided by the combined AC-BB400 option. Taking account of welfare benefits and socio-political considerations of the early network reinforcement provided by the HVDC option, as well as its inclusion of investment in anticipatory network capacity, we consider that both the HVDC-BB400 (option 1b) and AC-BB400 (option 2b) options would provide broadly similar benefits. We must observe that although the current proposal does not include investment in BB400, it does not preclude this investment either. If the BB400 investment were to be combined with the proposed reinforcement, the resulting solution would be effective and efficient both in terms of technical solution and value for money, hence the overall solution would be in the best interest of consumers.

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