Shetlands Strategic Wider Works

Needs Case: Cost Benefit Analysis

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National Grid

On behalf of Scottish Hydro Electric Transmission Limited (SHE Transmission)

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Contents Amendment Record

This report has been issued and amended as follows:

Issue	Revision	Description	Date	Approved by
First draft	1	First complete draft of report for feedback	27/09/2018	M Vincent
Second Draft	2	Added GB consumer welfare, CO2 and low wind sensitivity. SHE Transmission comments addressed	4/10/2018	M Vincent

Contents

1 Introduction

1.1 Context

As outlined in **the Guidance on the Strategic Wider Works arrangements in the electricity transmission price control, RIIO-T1**, published by Ofgem, when a TO wishes to bring forward a transmission project for consideration under the SWW arrangements, it must give notice to Ofgem, in its role as the government regulator for the electricity and downstream natural gas markets in Great Britain, that it is proposing a new network development for regulatory approval. It must also submit supporting information to justify the reinforcement and the efficient costs of delivering the proposed transmission project.

If the project proposal is eligible, Ofgem will assess the Needs Case. As part of this assessment the Regulator looks at the factors supporting the need for the new transmission project. This includes the expected increase in generation relative to the existing transmission capacity, as well as the forecast cost to consumers if transmission capability is insufficient and constraint payments are incurred. To ensure that the investment case is robust Ofgem will also review the uncertainties that have been taken into account, for example, different generation scenarios.

Within this context, this document presents the details of the CBA undertaken by National Grid on behalf of SHE Transmission to determine economic connection options.

1.2 Economic Objectives of the Project

This CBA uses a ‘savings approach’[1] to assess the optimal connection option and it’s optimal in service date. In order to use the savings approach, a counterfactual has been established. That is that no new link to the mainland is built, and any excess generation on the island, is constrained off by the System Operator. By assessing the total expenditure over the reinforcement’s lifetime, and the associated constraint savings this CBA aims to find the optimal connection option and associated connection date using the least worst regret methodology.

Within this scope, the overarching economic objectives of the project are twofold:

- Ensure value for money for GB consumers by delivering a cost effective connection option to the Shetlands.
- Timely delivery of the appropriate connection to minimise GB consumer exposure to either early investment or delayed implementation.

[1] The savings approach is where potential projects are compared against a base/counterfactual

1.3 Study Objectives and Scope

The context outlined above drives the CBA objectives and economic analysis for the Needs Case preparation process. Furthermore, consistent with the **Guidance on Strategic Wider Works arrangements in the electricity transmission price control, RIIO – TI,** the objectives of this CBA are to:

- promote economic and efficient investment
- present economic justification for the preferred option and an explanation of the proposed option compared with the alternatives
- present evidence on expected long-term value for money for consumers considering a range of sensitivities, and
- present evidence on optimal timing of the preferred connection option.

Driven by these objectives the scope of the CBA is outlined below:

- Model[1] and forecast the economic impact, measured as constraint cost savings versus investment costs, of a range of connection options, across the studied generation scenarios and sensitivities
- To undertake a CBA by:
  - Appraising the economic case of the options by adopting the Spackman[2] approach and determining respective net present values (NPVs) across the studied generation scenarios and sensitivities
  - Determining optimal timing of each option across each scenario and sensitivity
  - Establish the worst regrets associated with each option and Least Worst Regret (LWR) alternative(s)
  - Assessing the impact of credible local generation sensitivities relating to renewable generation on the Shetlands.
  - Undertake robustness analysis including a reduction or increase in capital expenditure among others.

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[1] The necessary modelling for the CBA is undertaken using the SO's electricity market modelling software, BID3. A description of the software and how the SO uses it is available at www.nationalgrid.com/noa/,

[2]The Joint Regulators Group on behalf of UK's economic and competition regulators recommend a discounting approach that discounts all costs (including financing costs as calculated based on a Weighted Average Cost of Capital or WACC) and benefits at the Social Time Preference Rate (STPR). This is known as the Spackman approach. Further details of our assumptions regarding WACC and STPR are presented later in this document.

- Where supported by the analysis, to make recommendation(s) on the preferred option(s), and optimal timing, noting any other pertinent considerations that best meets the project objectives outlined in 1.2.

1.4 Structure of the Document

The structure of this CBA document is outlined below:

- **Chapter 1: Introduction**, outlines the aims and objectives of the study
- **Chapter 2: Background**, presents the scenarios being employed and the key sensitivities
- **Chapter 3: Options for Economic Appraisal**, summarises details of options considered in the CBA
- **Chapter 4: Modelling of Constraint Costs,** presents constraint cost forecasts under each connection option considered in the CBA
- **Chapter 5: Cost Benefit Assessment**, brings together the analysis presented in the earlier chapters using the Spackman approach to develop net present values (NPVs), and performs least regret analysis to determine the most economic option and optimal timing of delivery
- **Chapter 6: Sensitivities,** presents the impact of sensitivities on the LWR analysis of Chapter 5
- **Chapter 7: Conclusions** presents a summary of the preferred option

Supporting information is provided in appendices.

2 Background

2.1 Introduction

The Shetlands have long been recognised as an attractive area for potential renewable development given the high wind yields. Currently less than 15MW of renewable generation is connected in the Shetlands – almost all of which is relatively small scale onshore wind. A limiting factor to renewable development on the Shetlands has been the isolation of the islands from the Main Integrated Transmission System (MITS). Currently, there is no distribution or transmission connection to the GB mainland network. Without a substantial new transmission connection, development of larger scale renewable projects will not go ahead and as such, the renewable generation potential of the Shetlands will remain untapped.

Currently, approximately 600MW of generation has been contracted on the Shetlands. Further to this it is possible that up to 740MW of generation may be commissioned on the islands. Five potential connection options between the Shetlands and the mainland have been proposed by SHE Transmission to be analysed in this CBA.

SHE Transmission is required to submit a formal need case to Ofgem, through the SWW process for the proposed connection to the Shetlands. Full construction funding will only be granted if Ofgem approve the project need case, with the final scope and timing for delivery being determined through this process. As part of the SWW process a CBA of the options has been conducted by the System Operator. The objective of this CBA is to identify the most economic and efficient option from those identified by SHE Transmission. NGSO will be assessing the whole system impact on forecasted constraint costs as a result of each reinforcement, and comparing this with the total expenditure of each option. Whilst the proposed options do not provide wider boundary capabilities, and are primarily a connection for Shetlands based generation, it is important to consider the wider impact on constraint costs of greater amounts of generation flowing south. We therefore use our European market dispatch constraints forecasting tool, BID3, to model the system wide constraint cost forecasts for each option. The CBA approach of the NGSO is then to calculate NPV of each project by taking the constraint cost forecasts, described above, and the total costs of the projects, and perform least worst regret (LWR) analysis. Optimal timing analysis is then performed on the optimal solution.

Aside from the cost benefit analysis of each options effect on constraint costs, there is a wider consideration of whether generation of the scale already consented will connect on the Shetlands. The proposed generators are subject to the Contract for Differences (CfD) process, and the economic viability of the generators is highly dependent upon the result of this. As such SHE Transmission have proposed a conditional needs case approach which is dependent on the outcome of the upcoming CfD auction. The SO supports this approach to the needs submission and this CBA has been tailored to provide tipping point analysis such that further certainty over generation scenarios on the islands can result in the optimal connection option being developed.

2.2 Network Capabilities

The SO's Network Options Assessment optimises network capacity for future years based on TO submissions of possible reinforcements, future requirements as detailed in the Electricity Ten Year Statement, and the Future Energy Scenarios. This produces an optimised network per scenario, and therefore the systems boundary capabilities for each year and scenario. This study uses the output networks of NOA3, as published on the 31st of January. Please see www.nationalgrid.com/noa/ for more detail.

All proposed options studied in this CBA are comprised of a subsea cable extending from the Shetlands to the Scottish mainland. The first three options considered connect into a three-terminal switching station along with the Caithness – Moray HVDC project which is currently under construction. The last two options considered are point-point HVDC cables between Kergord and Rotheinorman substations. None of the options were considered to have a material impact on any major system boundaries.

For the purpose of modelling the options in this study, a new boundary was created in the SO's constraint forecasting tool BID3. This boundary has the transfer capability of the option being investigated, and associated demand and generation on the Shetlands are placed behind this boundary. Forecast flows across this boundary are therefore equivalent to forecast flows through the cables considered. All options considered in this CBA consider the build of a new GSP on the Shetlands such that Shetlands demand can be supported through the new transmission connection to the mainland during times of low renewable output.

2.3 Future Energy Scenario 2017 Core Backgrounds

National Grid annually produces Future Energy Scenarios against which to plan the future system; while briefly summarised below, full details are available at: http://fes.nationalgrid.com.[3]

The Four Scenarios are based on flexing two main factors; prosperity and green ambition. This creates an envelope of credible futures that consider a range of possible network conditions; under a future with higher green ambition, more renewable power and volatility in flows can be expected, for instance. In general Two Degrees presents the highest constraint costs to manage and therefore justifies developing the most transmission capability, whilst Steady State has the lowest associated constraint costs and need for transmission capacity.

Most important to this study is the view of the generation background on the Shetlands under these scenarios, as this will drive usage of the cable; without transmission level generation this rating of cable is unneeded, whilst if generation capacity outstrips the cable capacity too much, then significant constraint costs could be incurred.

The generation on the Shetlands under each scenario is shown in the next section.

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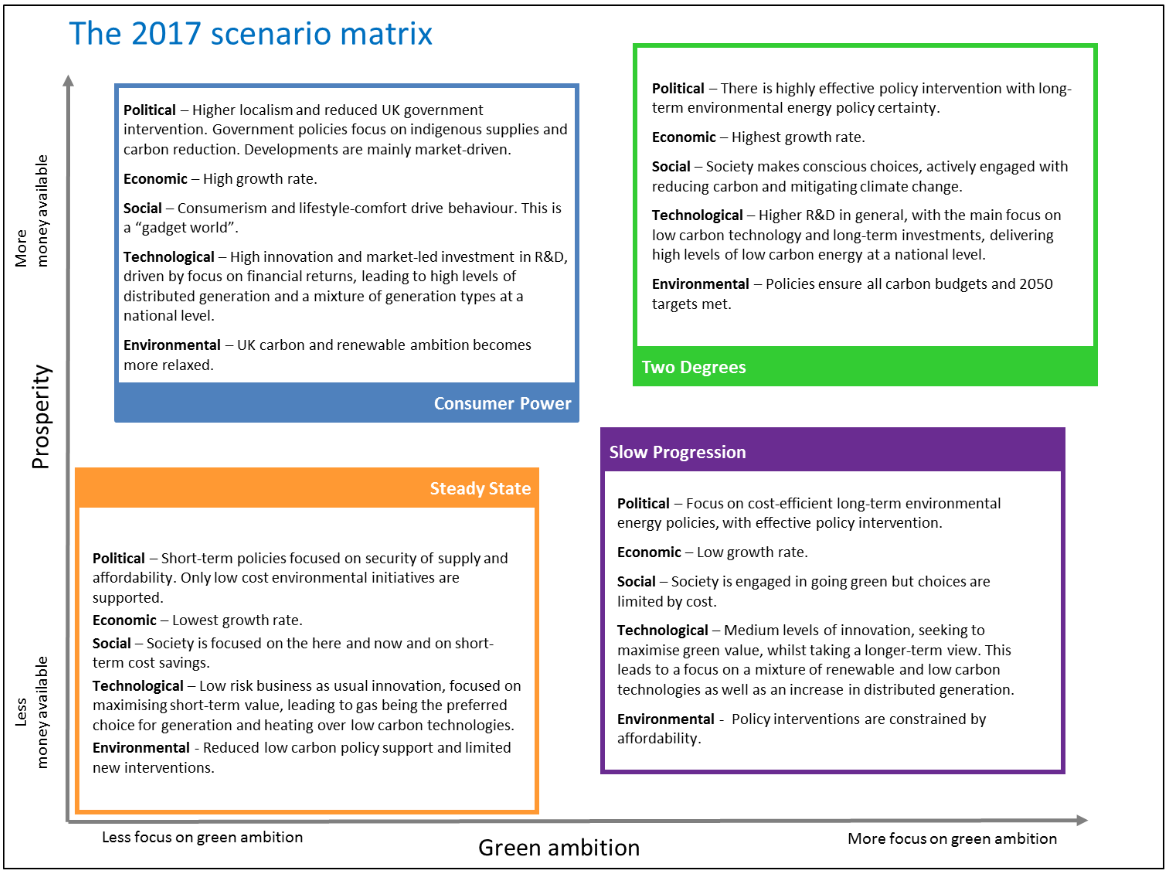
[3] While FES2018 scenarios have been released at the time of writing this report (October 2018), they are only available for use in investment planning processes once NOA2018 has been completed and the underlying transmission network has been optimised.



Rules:
1) Security of supply (electricity): Abide by the security standard as prescribed by the secretary of state (currently three hours/year loss of load expectation)
2) Security of supply (gas): There will be sufficient capacity to ensure that the N-1 test will continue to be satisfied

Figure 1- Future Energy Scenarios 2017 descriptions

2.4 Local Generation Backgrounds

As the generation levels on the Shetlands are so pivotal to the correct sizing of the cable, a wider range of possible capacity profiles to study was deemed necessary. SHE Transmission therefore provided four local generation backgrounds, produced by the consultants GHD at SHE Transmission's behest. These provide more detailed insight into the future of generation on the Shetlands, increasing the robustness of the result obtained.

A full breakdown of the projects that make up the capacities in figure 2 can be found in Appendix A.

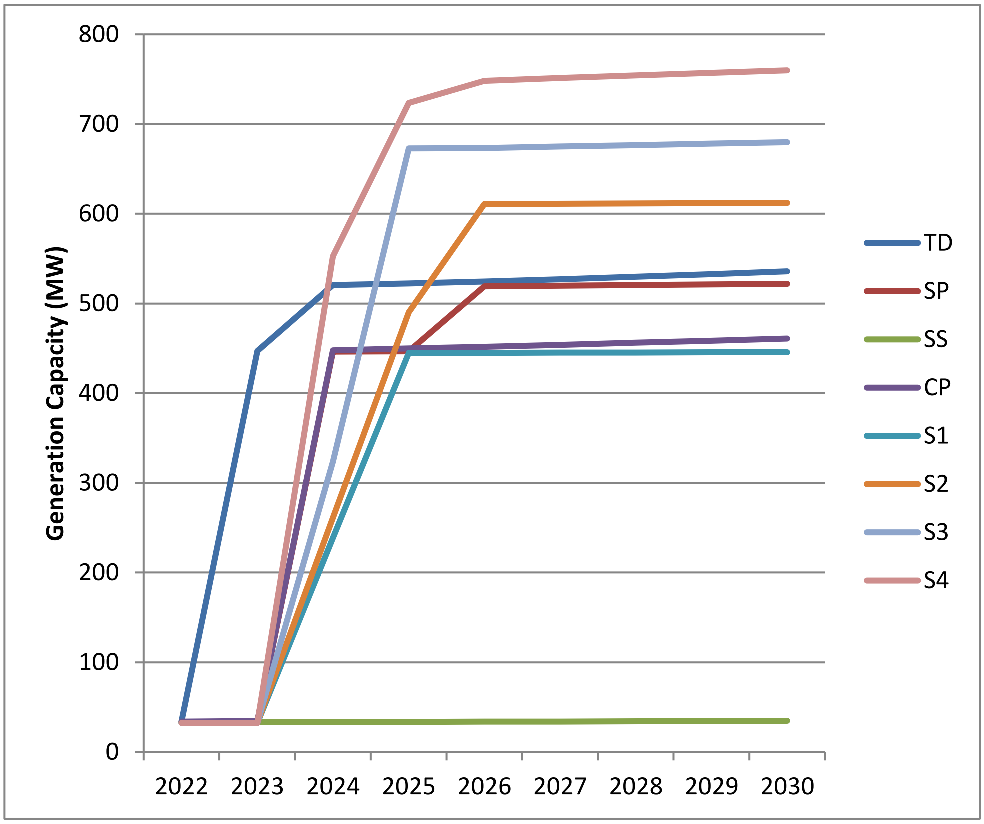


Figure 2- Generation scenarios on the Shetlands

For each SHE Transmission scenario, the rest of the GB network was set to the Slow Progression scenario. This allowed a comparison of the effect of different generation levels on the Shetlands, without a second degree of freedom in the scenario background.

2.5 The Counterfactual

The savings approach taken necessitates the definition of a 'do-nothing' option to compare the constraint costs against; it is therefore possible to demonstrate the savings obtained by constructing a cable. The implication is that if SHE Transmission were to not construct a cable, and the Shetlands generation were constructed anyway, the SO would be obliged to constrain off all generation on the island for its lifetime at a considerable cost.

Whilst this is unlikely to be the case in reality, in the event of the cable not being constructed, it is to a degree moot as to which of the cable options is the best. The economic calculations of the savings approach reach the same outcome as if an absolute approach was taken (one where no counterfactual is employed). The counterfactual provides an interesting reference point of the total constraint costs possible under each generation scenario tested.

2.6 Wind Profiles

In addition to the capacity of installed generation on the island, the weather profiles applied are of some importance; as almost all the new build generation on the Shetlands is in the form of onshore wind.

SHE Transmission have provided 5 years' worth of historic measured wind power output data on the Shetlands which have been used to construct profiles for generation on the island. These were felt to provide wind load factors reflective of those that the developers expect for their projects. One weather year (2013) has been chosen for the main CBA as it provides average wind, solar, interconnector flows and constraint costs when comparted to the last 30 weather years. A sensitivity has also been conducted on a lower load factor wind profile to ensure to robustness of the recommendations.

3 Options for Economic Appraisal

3.1 Introduction

This chapter presents the options submitted for assessment by SHE Transmission to the SO. They consist of 5 subsea cable options of varying capacity and technology. The SO has reviewed the optioneering documents provided by SHE Transmission and agreed to study the two routes deemed most feasible by SHE Transmission.

Table 1- Options submitted to CBA process

Name	Description	Capability	EISD	Capex (£m)
Option 1	Kergord – Noss Head Switching Station HVDC (three terminal)	450MW	2024	674
Option 2	Kergord – Noss Head Switching Station HVDC (three terminal	600MW	2024	709
Option 3	Kergord – Noss Head Switching Station HVDC (three terminal	800MW	2026	753
Option 4	Kergord – Rothienorman HVDC (point to point)	800MW	2026	1,109
Option 5	Kergord – Rothienorman HVDC (point to point)	1000MW	2026	1,153

On top of the cost of the submitted options, the SO has included the cost of building a new GSP on the Shetlands in all the options, which adds £30.2m to the Capex of each option.

3.2 Option Capability

The range of capabilities above ensures that almost all of the generation in the most onerous scenario (756MW (this excludes current diesel and gas generation currently used to secure demand, as in section 2.4)) would be exportable by the cable, while testing a wide range of capabilities under that value.

3.3 Option Costs

A capital cost summary associated with the reinforcement options is shown below. These values represent Present Values of building the cables on their earliest possible dates, including cost of capital, and amortising and discounting the spend. In the sections of the CBA involving determining the optimal delivery date of the options, these values would thus change slightly as annuitized payments further in the future would be discounted at a greater factor.

Table 2- PV of CAPEX of submitted options

Option	PV of CAPEX
1	redacted
2	redacted
3	redacted
4	redacted
5	redacted

3.4 Financing Assumptions

Financing assumptions have been adopted to develop Spackman compliant cost estimates of the options. These estimates include the following assumptions:

- **Weighted Average Cost of Capital** or **WACC**, which is currently estimated at **Redacted** for SHE Transmission, and
- **Social Time Preference Rate** or **STPR**, which is estimated at **3.5% p.a**. by HM Treasury.

4 Modelling of Constraint Costs

4.1 Introduction

The Guidance on the Strategic Wider Works arrangements in the electricity transmission price control, RIIO-T1, states that a reinforcement option is economic when the cost of the project is less than the cost consumers would otherwise pay under the counterfactual case.

This section outlines the forecasts of constraint costs likely to be incurred by consumers for each option against each generation background, together with the corresponding counterfactual case.

4.2 BID3

The necessary modelling for the CBA is undertaken using the SO's electricity market modelling software, BID3. It is used to derive constraint costs based upon a given scenario and network background.

The model derives future constraint costs in a two-step process. First, it models the future market dispatch based upon whatever plants are most economical meeting demand first, subject to physical constraints. Next, it tests the resultant flows implied by the first step against the capabilities of the system boundaries. If it finds flows are excessive across any boundary, it finds the lowest cost solution to rebalance the network such that no boundary capabilities are being exceeded. The sum of these costs is called the Total Balancing Mechanism or Total Constraint Cost (TCC) for that run. The way TCC varies as network capabilities are altered (for instance, through the addition of the options assessed in this CBA) allows the SO to infer the value of constraint alleviation associated with network development options.

The use of this software for network planning purposes has been carefully validated through audit and back casting activities. The software has been successfully deployed in the SO's key network development processes, including the Network Options Assessment.

A more detailed description of the software, and how the SO uses it is available online: www.nationalgrid.com/noa/.

4.3 Forecasts of Constraint Costs: Counterfactual / Base

As discussed in section 2.5, to provide a reference value of total constraint costs a counterfactual has been simulated, wherein all generation on the Shetlands is curtailed all of the time as no cable has been deployed. This leads to very large constraint costs, of which the Shetlands curtailment is a significant factor. This is not the only factor, however- TCC is driven by modelled congestion across the entire GB network. The savings are modelled up to 2037, the end of the 20 year period to which the SO models as standard.

Redacted

Figure 3- Counterfactual constraint costs (undiscounted)

4.4 Constraint Savings

The constraint savings associated with each reinforcement option is the difference between its base/counterfactual constraint cost and the corresponding constraint costs with the reinforcement active.

Redacted

Figure 4- Option 1 constraint savings (undiscounted)

Redacted

Figure 5- Option 2 constraint savings (undiscounted)

Redacted

Figure 6- Option 3 constraint savings (undiscounted)

Redacted

Figure 7- Option 4 constraint savings (undiscounted)

Redacted

Figure 8- Option 5 constraint savings (undiscounted)

5 Cost Benefit Assessment

5.1 Introduction

Fundamentally, the CBA compares the Present Value (PV) of reinforcement costs with the PV of forecasted constraint cost savings. Where constraint cost savings exceed the investment cost, the reinforcement may be considered economic. In order to develop robust conclusions a range of generation backgrounds, design options and sensitivities have been considered.

For each reinforcement option, the PV of both the annual constraint savings and the associated transmission reinforcement cost is calculated; their difference gives the option's Net Present Value (NPV). A positive NPV implies the investment could be cost effective.

This chapter brings together the analysis presented in sections 3 and 4 to establish an overall Net Present Value (NPV) for each of the different options. The options' NPVs are used to perform Regret analysis, and subsequently to determine the preferred reinforcement option based on a Least Worst Regret (LWR) approach.

5.2 Model Results, Extrapolation and CBA Timeframes

FES generation backgrounds do not extend in detail beyond 2037, and so that is the extent to which detailed BID3 constraint forecast modelling can project. Constraint savings have been extrapolated from 2037 until the end of the CBA assessment period, based on a 40 year asset life.

5.3 Present Value of Capital Costs

Under the Spackman methodology, future investment costs associated with reinforcement options and constraint savings both have to be represented by a PV.

To achieve this for the investment costs: -

- The annual investment costs across the construction phase are annuitised at a post-tax real WACC of **redacted** over 40 years in line with SHE Transmission values;
- Future payments on investments are discounted at HM Treasury's Social Time Preference Rate (STPR) of 3.5%.

5.4 Net Present Value of Reinforcement Options

NPV measures the value of an investment, with both costs and benefits properly accounted for.

To compare the relative economic merits of the reinforcement options, the investment PV is deducted from the constraint saving PV to give a relative Net Present Value (NPV) for each option.

Table 3- NPV of options

Redacted

All options demonstrate positive NPV, except in a SS scenario, when compared to the counterfactual where generation is infinitely constrained due to generation not having access to the market. The SS scenario had negative NPVs as there is negligible generation capacity growth on the Shetlands in this scenario. The large NPVs observed here are only designed to compare the options since they are built upon the basis of an unrealistic counterfactual.

Table 4- Optimal connection date of options

Redacted

5.5 Regret Analysis

Regret analysis is designed to identify solutions which are least likely to be wrong across the range of scenarios/uncertainties studied. Regret analysis does not pick options with the largest net benefit (NPV), although this could occur coincidentally. The approach provides a robust decision against the range of uncertainties examined, and minimises the chance of particularly adverse outcomes impacting consumers.

In this analysis the regret is defined as the difference in NPV between 'the option being considered' and 'the best possible option for that scenario', i.e. all options are considered against the option which provides the maximum NPV in that scenario (taking into account the investment and operational costs). It follows that the best alternative has zero regret against which all other options are compared.

This analysis is repeated for all scenarios, across which it is possible that different options represent the zero regret alternative in each scenario.

The Least Worst Regret (LWR) methodology requires that design preference is based on the option that is least likely to result in an adverse outcome across all the backgrounds considered. The underlying philosophy is that it is advantageous to pick the solution that has the lowest adverse consequence of being wrong across the range of eventualities, given uncertainties in forecasts and assumptions. This approach ensures that particularly unfavourable combinations are avoided. It assumes that all eventualities are possible at the investment decision stage. The LWR philosophy can also be seen as risk aversion in the face of an uncertain future we are unable to place a probability distribution on.

Table 5- Regret analysis of options

Option regrets (£m)	TD	SP	SS	CP	S1	S2	S3	S4	Worst Regret
Opt1 - 450MW	*0*	*0*		*0*	*0*	*84*	*180*	***262***	**£262m**
Opt2 - 600MW	*14*	*20*		***50***	*37*	*0*	*0*	*0*	**£50m**
Opt3 - 800MW	*104*	*118*		***122***	*104*	*66*	*73*	*39*	**£122m**
Opt4 - 800MW	*391*	*368*		***426***	*372*	*292*	*283*	*223*	**£426m**
Opt5 - 1000MW	*415*	*406*		***453***	*412*	*336*	*324*	*265*	**£453m**
Least Worst Regret:	***Opt2***								***£50m***

This table shows that under the current range of scenario uncertainty, option 2 is the least regret option. SS has been excluded from the regret analysis as it isn't deemed appropriate for regret analysis since it is a scenario that would result in no connection to the Shetlands being built. The inclusion of SS in the regret table does not however change the result.

5.6 Drivers of the optimal solution

The reasons that option has come out on top across this wide range of scenarios can be attributed to:

- Options 4 and 5 are never favourable due to their higher Capex costs
- The large regret of building options 3, 4 and 5 in TD, SP, CP and S1
- The large regret of building option 1 in the highest generation scenarios (S3 and S4)
- Option 3 can't be delivered until 20 months after options 1 and 2

The delay of option 3 over option 2 is quite significant to the LWR analysis. Regret analysis shows that if all options could be delivered on the same EISD of 2024, option 3 would be favourable. The regret analysis for this sensitivity is shown below.

Table 6- Regret analysis of options with aligned EISDs of 2024

Option regrets (£m)	TD	SP	SS	CP	S1	S2	S3	S4	Worst Regret
Opt1 - 450MW	*0*	*0*		*0*	*0*	*84*	*181*	*338*	£338m
Opt2 - 600MW	*14*	*20*		*50*	*37*	*0*	*1*	*76*	£76m
Opt3 - 800MW	*20*	*38*		*56*	*55*	*22*	*0*	*0*	£56m
Opt4 - 800MW	*309*	*291*		*361*	*324*	*250*	*212*	*188*	£361m
Opt5 - 1000MW	*333*	*329*		*388*	*364*	*295*	*255*	*229*	£388m
Least Worst Regret:	***Opt3***								***£56m***

In this LWR table, it can be seen that the 800MW option is favourable over option 1 and 2 to support exporting generation capacity off of the Shetlands. Option 2 is favourable in the main analysis due to the fact it can be delivered almost 2 years earlier. Analysis has been conducted in section 6 to study the tipping point in delivery dates between options 2 and 3.

5.7 Optimal Timing Analysis

To perform the optimal timing analysis the year which the cable(s) will be delivered has been varied and the subsequent Net Present Value of each option was calculated. This revised NPV takes into account reduced CAPEX from finance timing savings and reduced OPEX savings due to forfeited constraint benefits of the delay.

Redacted

Figure 9 - Optimal timing analysis option 2

Figure 9 shows the optimal timing analysis for the commissioning of option 2 across the full range of scenarios. The year of 2024 is being driven by the sharp build up in generation in this year. This is due to the connection of Viking wind farm in most scenarios in this year and drives the preferred solution of option 2 due to its earlier EISD compared to option 3.

5.8 Additional benefits: GB consumer welfare and CO_2

Alongside the avoided constraint costs, any cable to the Shetlands facilitates the connection of renewable resources with the potential to positively impact the market as marked by two further indicators- consumer welfare and CO_2 reduction. These figures are derived from runs assuming the FES levels of generation arise in future years, and counterfactuals with the Shetlands generation removed entirely.

Consumer welfare (or increase in consumer surplus) measures the money saved by consumers through wholesale price reductions driven by the generators on the Shetlands. As with most renewable projects, as the short run marginal cost for these technologies is so low they always serve to reduce the wholesale price during high renewable periods. This benefit would be eroded by any subsidies given to the generators funded by the UK consumer, and the amount of curtailment of this power that may occur (again at a cost to the consumer). This figure is directly output from the BID3 software package, and is not used to evaluate the merit of specific projects over alternatives by the SO.

Table 7- Maximum lifetime GB consumer welfare associated with generation on the Shetlands

Redacted

The transmission level generation on the island is all from renewable technologies, and therefore liable to displace carbon generating technologies in the overall GB market under certain conditions. This effect is quantified by measuring the total CO_2 emissions with and without the Shetlands generation, and attributing the reduction in emissions to the presence of Shetlands generation in future years.

Table 8- Lifetime CO_2 reduction associated with the Shetlands generation

Redacted

6 Sensitivities

6.1 EISD Analysis

This section compares the LWR CBA result when the EISD of option 3 is varied. As noted in the main results, option 3 appears optimal in the LWR analysis if its EISD is brought forward to 2024 to be aligned with option 2. In the table below the EISD of option 3 is varied by 3 months at a time between the start of 2024 and the end of 2025 in order to find the point at which it becomes optimal to delay the build of a connection to the Shetlands in order to build the higher capacity link.

Table 9 below presents the results from this sensitivity. Each row in the table represents a full iteration of the CBA with column 2 presenting the LWR recommendation given each EISD of option 3.

Table 9- EISD Analysis LWR results

EISD of Option 3	Recommended Option
Q1 2024	Opt 3
Q2 2024	Opt 3
Q3 2024	Opt 3
Q4 2024	Opt 3
Q1 2025	Opt 3
Q2 2025	Opt 3
Q3 2025	Opt 2
Q4 2025	Opt 2

As shown in the table, option 3 becomes optimal in the LWR analysis if it can be brought forward by 9 months to the start of Q2 in 2025.

6.2 Tipping Point Analysis

Given the fixed EISDs of the original analysis, only 2 options ever appear favourable in the CBA: Options 1 and 2. In the highest generation scenario (S4), option 3 is not be recommended under the original EISDs. This implies the tipping point for the 800MW option is above 750MW. Option 3 appears favourable when EISDs are aligned to 2024 so in the interest of comparison of optimal export capacity, option 3 has been moved forward to 2024 to find the optimal export capacity within the options considered. This analysis studies generation capacities on the Shetlands in increasing 10MW blocks of onshore wind to find the tipping point between options 1, 2 and 3. All studies in this section were performed on an SP background as in the main analysis for the GHD scenarios.

Table 10- Tipping points

MW capacity of new build generation on the Shetlands	Recommended Option
460	Opt 1
480	Opt 1
490	Opt 2
550	Opt 2
600	Opt 2
640	Opt 2
650	Opt 3
660	Opt 3

6.3 Lower wind load factors

Sensitivity analysis was conducted using wind load factors slightly lower than those used in the main CBA. The purpose of this was to test the LWR analysis for robustness in the case that the larger scales wind developments on the Shetlands were unable to capture the higher load factors currently measured on the island due to their large arrays. The original CBA used a load factor of 53%, in this section a load factor of 41% was used. This data was sourced from Pöyry management consultancy and built using measured satellite wind speed data with power curves overlaid to provide hourly load factors. Table 11 below has the results of the LWR analysis using this load factor. Only options 1, 2 and 3 were studied in this analysis as options 4 and 5 were never close to be optimal in the main CBA.

Table 11- LWR analysis using lower wind load factors

Option regrets (£m)	TD	SP	SS	CP	S1	S2	S3	S4	Worst Regret
Opt1 - 450MW	*0*	*0*		*0*	*0*	*0*	*43*	*110*	**£110m**
Opt2 - 600MW	*34*	*26*		*30*	*31*	*1*	*0*	*0*	**£34m**
Opt3 - 800MW	*131*	*124*		*113*	*101*	*74*	*94*	*117*	**£131m**
Least Worst Regret:	***Opt2***								***£34m***

As shown in the table above, option 2 is still optimal in the LWR analysis due to the large regret of building option 1 under the higher generation scenarios S3 and S4. This result solidifies the original result of the CBA as it demonstrates across a range of captured wind power outputs, option 2 is recommended.

7 Conclusions

This report demonstrates that building a 600MW HVDC link between the Shetlands and the Scottish mainland (Option 2) is the most economic option for connecting renewable generation on the islands, given the current uncertainty in future generation scenarios on the island. This result is largely influenced by the high regret of not building a large link in generation scenarios S2, S3 and S4.

While the main CBA under the current range of uncertainty recommends the 600MW link, it is clear to see from this CBA that this recommendation should be reconsidered once the CfD auction provides further clarity on the future of the Shetland islands generation.

The tipping point analysis presented in this report demonstrates that 800MW becomes the preferred option if it can be built 9 months earlier than originally stated, with the option providing a more optimal capacity for the Shetlands over its lifetime. However, due to the EISD of this option being stated as Q4 2025, the 600MW option is still recommended in order to facilitate earlier export of generation off the Shetlands.

It is important to note that this report does not assess whether a connection to the islands is in the economic interest of the GB consumer and only compares the economic benefit of each connection option relative to each other.

8 Appendix A: Breakdown of Scenarios

Table 12- Breakdown of new connected Transmission level generation on the Shetlands

Redacted