SHE - Transmission

Transmission Reinforcement between Shetland and the Scottish Mainland

Cost Benefit Analysis Study

Final Rev 0
October 2018

Executive Summary

Shetland is an area rich in renewable sources - including onshore wind and more recently tidal energy. Wind speeds on Shetland are exceptionally high, with Shetland turbines some of the most productive in the world – the average capacity factor of the longest standing Shetland wind farm (commissioned 2000 & 2003) over the last five years was 53%, compared to a UK onshore wind average of 27% and offshore of 39%[1]. While Shetland has a significant comparative advantage in terms of renewable resource, this advantage cannot currently be exploited as Shetland is not connected to the GB mainland. However, a number of generation projects have contracted with SHE Transmission and are seeking to compete in the upcoming Contract for Difference (CfD) auction and aim to connect by April 2024 providing a transmission link is forthcoming.

Given that the main generation project supporting the reinforcement – the 'anchor' project – aims to compete in the 2019 CfD auction with the outcome uncertain, SHE Transmission is seeking a 'conditional' approval from Ofgem for its Needs Case, with approval conditional upon the anchor project securing a CfD.

Any planned transmission reinforcement project falling within the RIIO-T1 Strategic Wider Works (SWW) funding arrangements requires SHE Transmission to submit a 'Needs Case' to Ofgem justifying the project and explaining how the proposed reinforcement best meets the 'need' defined compared to alternatives. A key element of the Needs Case Submission is a cost benefit analysis (CBA). SHE Transmission has commissioned GHD to undertake this CBA for Shetland.

SHE Transmission has considered a number of transmission options to connect Shetland to the Scottish mainland, the options we have considered in our analysis include:

1. 450 MW High Voltage Direct Current (HVDC) subsea cable connection to Noss Head (260 km in length)
2. 600 MW HVDC subsea cable connection to Noss Head
3. 800 MW HVDC subsea cable connection to Noss Head
4. 800 MW HVDC subsea cable connection to Rothienorman, (350 km in length)
5. 1000 MW HVDC subsea cable connection to Rothienorman

To explore the long term 'need' for transmission reinforcement and assess future uncertainties we have developed scenarios to explore alternative paths of network use. To reflect the 'conditional' aspect of this CBA all scenarios assume the anchor project is developed but in addition differing and credible paths of growth have been developed for SHE Transmission to fully 'stress test' the requirement for transmission reinforcement in its Needs Case. The resulting scenarios show the following levels of new generation development on Shetland:

- Scenario 1: 414 MW
- Scenario 2: 581 MW
- Scenario 3: 656 MW
- Scenario 4: 742 MW

[1] Digest of UK Energy Statistics Table 6.5 'Load factors for renewable energy generation' July 2018

Our analysis shows that, when assessed as part of a ‘conditional’ Needs Case across a range of cost and output assumptions, Option 2, the 600 MW HVDC link, is the reinforcement option of least worst regret (LWR). We have tested our central case against a range of sensitivities including:

- Project capex – an increase of 20%.
- Lower wind capacity factor of 48%;
- The timing of the reinforcement option delivery dates and;
- Impact of onshore constraints;

Across almost all sensitivities Option 2 remains the reinforcement of LWR. The only exception arises when all options are delivered in 2024 – under this sensitivity the Option 3, the 800 MW link landing at Noss Head, is the option of LWR. Given this result SHE Transmission further scrutinised the estimated delivery of Option 3 and concluded that the option could not be delivered earlier than December 2025. As a result Option 2 remains the option of LWR.

We have also explored the ‘tipping point’ of generation between the reinforcement options, i.e. the amount of new generation required to ‘tip’ the optimum reinforcement size from one to another. We conclude that the tipping point between Options 1 and 2 (450 MW and 600 MW HVDC) is around 470 MW and between Options 2 and 3 around 700 MW.

Our central case results and sensitivities align with those of the System Operator (SO).

A final sensitivity has been explored that considers the costs and benefits of a transmission link to Shetland in association with distribution network development. Our analysis indicates that there is a net benefit of the transmission link securing supply.

Finally we have explored the socio-economic benefits that transmission reinforcement could offer Shetland – both via the transmission investment, but more significantly the renewable generation investment enabled. For Option 2 the present value of the socio-economic benefit to Shetland ranges from £143-204 million. This equates to a minimum annual benefit equivalent to £347 per household.

In summary our analysis concludes that ***Option 2 (the 600 MW HVDC link) is the preferred transmission connection option for Shetland***. This recommendation is fully aligned with the SHE Transmission Needs Case submission.

Summary report: key findings and recommendations

Background

The Shetland Islands ("Shetland") is an archipelago of 100 islands rich in renewable energy resource. Shetland's location, some 400 miles south of the Arctic Circle where the North Sea meets the Atlantic, ensures wind speeds are high and sustained whilst the potential for tidal generation is also significant. This potential is recognised by both commercial developers and the local community. However, new transmission system infrastructure is needed to ensure Shetland can exploit and benefit from its valuable renewable energy resource.

Overview of potential transmission requirement

The largest proposed wind farm on Shetland, Viking Wind Farm, intends to compete in the 2019 CfD Round 3 auction. As this project alone currently represents up to 457 MW of consented generation, SHE Transmission is submitting a 'Conditional Needs Case' to Ofgem, with the need conditional on the award of a CfD for this key 'anchor' project.

We have developed four scenarios to explore the optimum link investment against this conditional need. All scenarios include the common assumption that Viking secures a CfD. We supplement Viking in the different scenarios with varying levels of underlying private/commercial or community onshore wind development.

In total, nearly 875 MW of known projects at various stages of development have been identified. These include the projects identified in Table S-1 below.

Table S-1: Shetland generation background

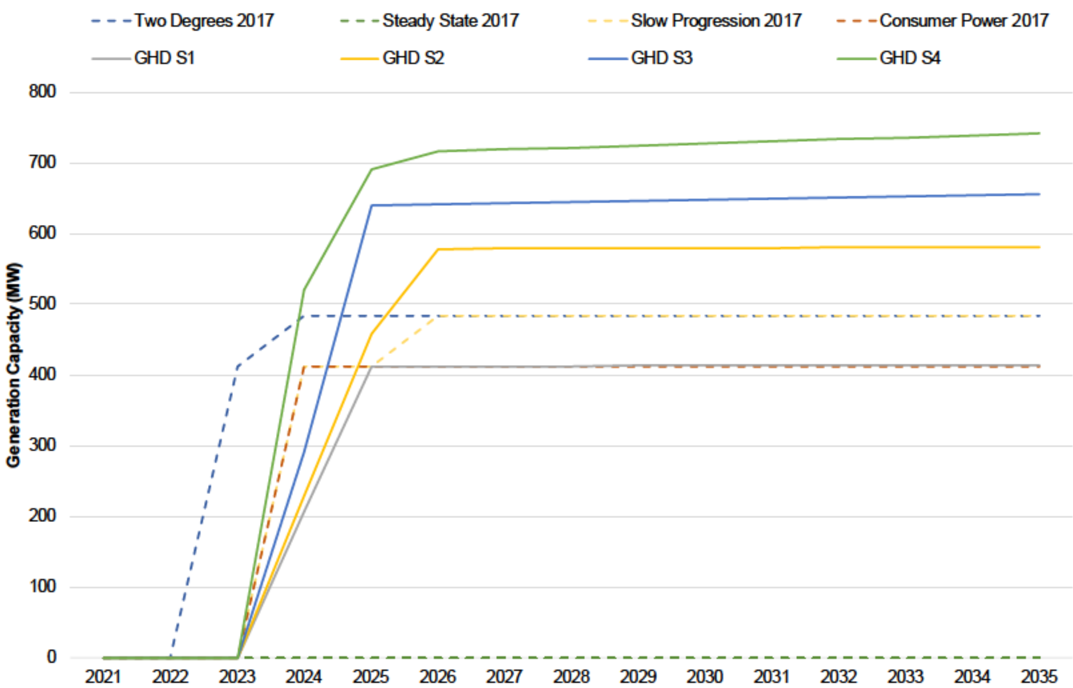
Wind Farm	Capacities Considered	Status
V king	412 - 457 MW	Consented at 457 MW, contracted at 412 MW, [redacted]
Beaw Field	57.8 - 82 MW	Consented at 57.8 MW, contracted at 72 MW, [redacted] . [redacted]
Energy Isles	120.3 - [redacted]	[redacted] not consented, [redacted]
Mossy Hill	50 MW	Planning application for 50 MW, [redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
Culterfield	2.7 MW	Consented at 2.7 MW, [redacted]
Hillhead	0.1 MW	Consented at 0.1 MW
East of Brae	0.1 MW	Consented at 0.1 MW
Swinster	0.5 MW	Pre-application planning enquiry made at 0.5 MW

Wind Farm	Capacities Considered	Status
Total	767.5 - 875.1 MW	

In addition, the generation background includes a modest amount of growth in small and large scale wind generation, consistent with the Shetland Islands Council's Supplementary Guidance for Onshore Wind Energy, as well as some growth in small scale solar PV and tidal energy.

Based on a range of development assumptions, we developed a range (Figure S-1) of generation scenarios (GHD S1 – S4). The chart also shows the Future Energy Scenarios (FES) developed by National Grid for Shetland. Although there are some similarities between the GHD scenarios and the FES these are limited due to the inclusion of only contracted, transmission level generation projects by National Grid[2].

Figure S-1: Generation scenarios for Shetland



Transmission options

As there is no existing transmission system connection between Shetland and the Scottish mainland SHE Transmission has performed an option development and screening process to identify potential transmission connection options. Through this process SHE Transmission has identified five potential transmission options that could support renewable generation developments on Shetland:

1. Option 1: 450 MW High Voltage Direct Current (HVDC) subsea cable connection to Noss Head, circa 260 km in length
2. Option 2: 600 MW HVDC subsea cable connection to Noss Head
3. Option 3: 800 MW HVDC subsea cable connection to Noss Head
4. Option 4: 800 MW HVDC subsea cable connection to Rothienorman, circa 350 km in length – 'point to point' (P2P)
5. Option 5: 1000 MW HVDC subsea cable connection to Rothienorman – P2P

[2] Only the Viking and Beaw Field projects are considered in the 2018 FES and only at their contracted capacities, which are some 55 MW below the capacities that they are seeking to connect in total.

The island termination point for all options will be in the vicinity of Kergord on Shetland. For Options 1 to 3 the mainland Scotland termination point for the Shetland HVDC cable will be in the vicinity of Noss Head where it will connect to a new three terminal HVDC switching station that connects the Caithness-Moray HVDC transmission cable. For Options 4 & 5 the mainland Scotland termination point will be in the vicinity of Rothienorman where it will connect to the existing SHE Transmission 275 kV transmission system via a new HVDC converter station.

The SHE Transmission Needs Case submission for the proposed Shetland transmission connection is being submitted on a 'conditional' Needs Case basis contingent on success of the Viking Wind Farm in the 2019 CfD auction. **For the initial CBA results we assume Options 1 and 2 will be delivered by the end of Quarter 1 2024 to enable renewable project developers to complete in the future CfD auction. Options 3-5 will incur additional work associated within SHE Transmission's onshore transmission system and at this stage we assume delivery at the end of Quarter 4 2025 i.e. start of 2026.**

SHE Transmission has provided initial capital expenditure (capex) and operational expenditure (opex) estimates for the considered transmission connection options, as shown below in Table S-2.

Table S-2: Transmission reinforcement options & costs (2018 prices)[3]

Option	Description	Capex £m	Opex £m p.a.
1	450 MW HVDC Connection: Kergord to Noss Head (Earliest in-service date (EISD) End Q1 2024)	[redacted]	[redacted]
2	600 MW HVDC Connection: Kergord to Noss Head (EISD End Q1 2024)	[redacted]	[redacted]
3	800 MW HVDC Connection: Kergord to Noss Head (EISD End Q4 2025)	[redacted]	[redacted]
4	800 MW HVDC Connection: Kergord to Rothienorman (EISD End Q4 2025)	[redacted]	[redacted]
5	1000 MW HVDC Connection: Kergord to Rothienorman (EISD End Q4 2025)	[redacted]	[redacted]

Cost benefit analysis

Our analysis evaluates the cost and benefits of the five reinforcement options through detailed power flow modelling and cost benefit analysis (CBA). For each option and each generation scenario the flow modelling determines:

- The constraints that arise without the proposed transmission reinforcement; and
- Those constraints remaining after each reinforcement option commissions.

The benefits of the options are the avoided costs resulting from the reduction in constraints occurring over the economic life (45 years) of the project compared to a 'counterfactual' where no investment in a new Shetland transmission connection is forthcoming.

The results of our analysis show that a transmission connection to Shetland is strongly economically viable on this basis. All transmission options return significantly positive NPVs in

[3] These figures include £30m to create a GSP point that is common to all options

our central case[4] at both a £55/MWh and £70/MWh avoided constraint cost across the four scenarios as shown in Table S-3 and Table S-4 below.

Table S-3: Central case NPV with £55/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1020	1501	1624	1749
2	600 MW HVDC	983	1717	2031	2231
3	800 MW HVDC	882	1612	1932	2308
4	800 MW HVDC P2P	515	1245	1565	1941
5	1000 MW HVDC P2P	470	1200	1520	1896

Table S-4: Central Case NPV with £70/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1503	2115	2271	2431
2	600 MW HVDC	1466	2400	2800	3054
3	800 MW HVDC	1343	2272	2680	3159
4	800 MW HVDC P2P	976	1905	2313	2792
5	1000 MW HVDC P2P	931	1860	2268	2747

While the NPV analysis shows that the economic viability of a transmission connection to Shetland is robust, the results also show that the optimum reinforcement option differs depending on the generation scenario analysed (maximum NPV in each scenario is shown in yellow). To determine which reinforcement option represents the option of Least Worst Regret (LWR) across all scenarios, a regrets analysis has been undertaken. For each generation scenario out-turn, the regret of an option is the difference between the NPV for that option and the NPV for the optimum option under that scenario.

The LWR analysis is shown in Table S-5 and Table S-6. The option of Least Worst Regret is highlighted.

Table S-5: Central case LWR with £55/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	216	408	560	560
2	600 MW HVDC	37	0	0	78	78
3	800 MW HVDC	138	105	99	0	138
4	800 MW HVDC P2P	505	472	466	367	505
5	1000 MW HVDC P2P	550	518	511	412	550

[4] The central case includes SHE Transmission's central capital cost, operating cost and delivery date assumptions, an asset life of 45 years and a Shetland wind farm long term average capacity factor of 52%

Table S-6: Central case LWR with £70/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	285	529	728	728
2	600 MW HVDC	37	0	0	105	105
3	800 MW HVDC	160	128	120	0	160
4	800 MW HVDC P2P	527	495	487	367	527
5	1000 MW HVDC P2P	572	540	532	412	572

The option of Least Worst Regret is highlighted.

The results show that Option 2, the 600 MW HVDC link, is the reinforcement option of LWR under both constraint cost assumptions in the central case.

Sensitivities studies

A number of sensitivities to the central case have been considered, including:

- Project capex – an increase of 20%.
- Lower wind capacity factor of 48% and;
- Delay to project dates;
- Identical project delivery dates for all options
- Impact of onshore constraints;

Higher capex

A 20% increase to the capex costs of all transmission options has been considered. As opex is assumed to be a constant proportion of capex, the opex annual costs are also assumed to increase. Table S-7 presents the regret figures for this sensitivity using a constraint cost £55/MWh. Option 2 comfortably remains the option of LWR.

Table S-7: Higher capex LWR with £55/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	209	400	548	548
2	600 MW HVDC	44	0	0	73	73
3	800 MW HVDC	150	110	104	0	150
4	800 MW HVDC P2P	590	550	544	440	590
5	1000 MW HVDC P2P	645	604	598	495	645

The results under a £70/MWh constraint cost are similar, with Option 2 remaining the option of LWR by a substantial margin.

Low wind capacity factor

A lower capacity factor would typically favour lower capacity transmission options as fewer MWh are generated per MW installed. In this sensitivity we have adopted an alternative wind profile with a capacity factor of 48% (the central case wind capacity factor was just under 53%).

The results of the study show that Option 2 remains the option of LWR, however, the margin between it and the other options is reduced.

Delayed start

In this sensitivity we have considered a one year deferral to project operation – the entire capex profile of each option is delayed by one year. For all options, the NPV is lower than that identified under the central case. There is therefore no benefit from deferring any option by 1 year and Option 2 remains the option of LWR. The results for a £70/MWh constraint cost are similar, with Option 2 remaining the option of LWR.

We have also undertaken a sensitivity whereby the commissioning of each transmission option is deferred by two years. Under this sensitivity, the NPVs of each option are reduced further. Option 2 remains the option of LWR under both £55/MWh and £70/MWh constraint costs.

Identical delivery dates for all options

Options 1 and 2 (the 450 MW HVDC and 600 MW HVDC options) have EISD of 31st March 2024. The higher capacity options all have later EISD of 31st December 2025. To understand the implications of the impact of these timings we have assessed all options assuming they are all delivered in March 2024.

The results show a change from the central case – if all options are delivered in March 2024, then Option 3, the 800 MW option, is the option of LWR. We also explored the 'timing tipping point' for the 800 MW link, i.e. by how much later Option 3 could be delivered and remain the option of LWR?

Our analysis concluded that the 'timing tipping point' is around 16-18 months – delivery after this and Option 2 would be the reinforcement of LWR. Following these results SHE Transmission explored in detail the potential to bring forward delivery of the 800 MW link and concluded that the earliest delivery of the 800 MW link would be 20 months later than the other options and therefore Option 2 remains the reinforcement of LWR.

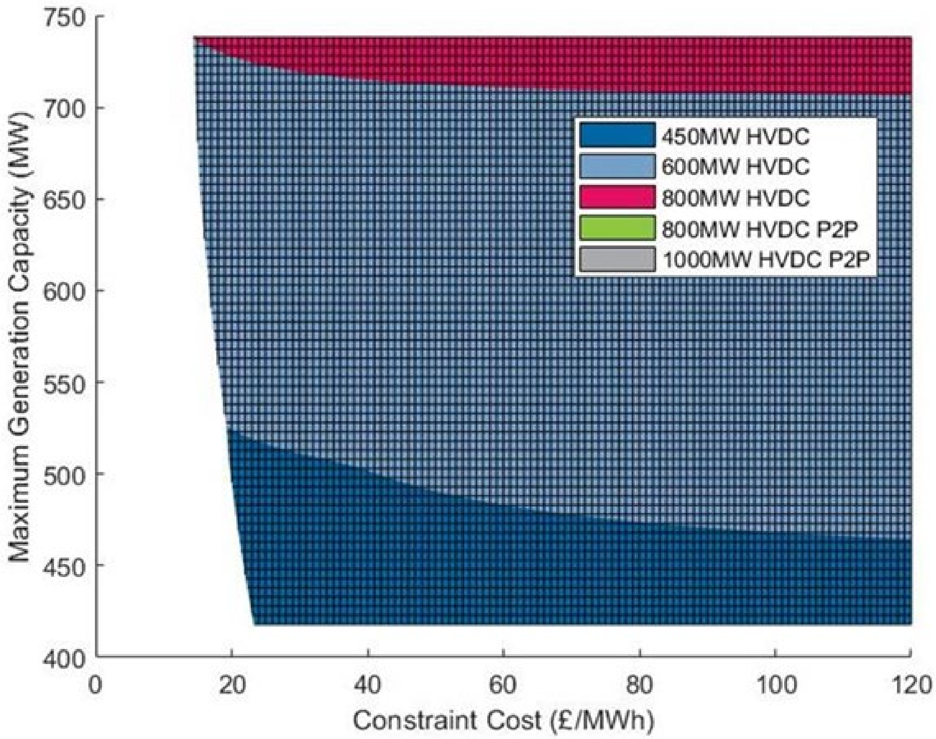
Impact of onshore constraints

Our initial analysis assesses flows across the reinforcement transmission link from Shetland to the mainland. However, it is possible that some further constraints may occur on the onshore network, particularly boundary B1 in the North of Scotland. Therefore we modified our flow model to include the impact, if any, of onshore constraints across B1. Taking into consideration onshore constraints on B1, the 600 MW HVDC link remains the option of LWR.

Tipping point analysis

GHD has carried out an analysis to determine the level of generation at which the optimum reinforcement size 'tips' from one to another. Figure S-2 shows the results of this exercise for variations in constraint costs and ranges of generation7 capacity.

Figure S-2: Impact of generation capacity and constraint costs on NPVs



The 'tipping point' between Option 1 and 2 is around 470 MW based on a £55-70/MWh constraint cost. Between Option 2 and 3 it is around 720 MW using the same assumptions. **The analysis also shows that Option 2 is the optimum reinforcement between 470-720 MW of generation.** There is a small dependence on constraint cost, with these tipping point values increasing slightly for lower constraint cost, as lower constraint costs favour inexpensive options.

Other considerations - local socio-economic benefits

An additional consideration relevant to the Shetland Needs Case submission is the 2017 'Islands (Scotland) Bill' that places a duty on relevant public bodies to have regard to island communities in exercising their functions – including an island communities impact assessment ('island proofing') of any new/revised policy likely to have a significantly different effect on islands communities from its effect on other communities. While not a specifically defined 'relevant' public body, Ofgem should be mindful of the socio-economic impact of transmission reinforcement on Shetland.

GHD has explored the socio-economic impact on Shetland of each of the transmission options and the associated enabled generation. Table S-9 shows the resulting total present value (PV) Gross Value Added (GVA) economic benefit for each generation scenario and transmission option considered in GHD's Central Case analysis. The economic impact includes all wind developments (large and small) and the transmission link, but excludes additional on-island transmission works.

Table S-9: Present value socio-economic benefit (£m, 2018 prices)

Transmission Options	Transmission (£m)	Generation (£m)				Total
		S1 - 414MW	S2 - 582MW	S3 - 655MW	S4 - 742MW	
Option 1 - 450MW HVDC	11	132	141	143	144	143 - 156
Option 2 - 600MW HVDC	12	132	183	191	193	143 - 204
Option 3 - 800MW HVDC	12	132	183	208	238	144 - 251
Option 4 - 800MW HVDC P2P	17	132	183	208	238	149 - 256
Option 5 - 1000MW HVDC P2P	18	132	183	208	238	150 - 257

The overall economic benefit to Shetland is substantial, ranging from £143 m to £257 m depending on the generation scenario and the reinforcement option considered. In terms of GVA impact, the benefit of the transmission link is small due to the relatively minor local content assumed. Conversely, the impact of wind generation is much larger. The larger the capacity of the transmission option, the greater the amount of generation enabled and resulting economic benefits during wind farm construction and operation as well as the establishment of further community funds directly related to the successful operation of renewable projects which directly benefit island residents and communities.

Whilst the identified economic benefit is significant it is worth putting the benefit into context. Table S-10 shows the minimum and maximum lifetime economic benefit of the reinforcement as derived from our analysis. The average lifetime economic benefit per annum has also been derived (based on a 45 year life). The economic benefit per annum ranges between £3.6 m and £6.4 m per annum. The minimum and maximum economic benefit per annum (based on the reinforcement option and scenario) has been compared to a number of Shetland-specific demographic and economic parameters including: population; number of households; regional GVA; average gross household income and average GDHI (gross disposable household income).

Table S-10: GVA benefit in relation to Shetland demographic and economic data (2018 prices)

Lifetime Economic Benefit (£m)	Economic Benefit Per Annum (£m)	Economic Benefit Per Capita Per Annum (£)	Economic Benefit Per Household Per Annum (£)	Economic Benefit Per Annum as a Proportion of Total GVA (%)	Economic Benefit Per Household Per Annum as a Proportion of Average Household Income (%)	Economic Benefit Per Household Per Annum as a Proportion of Average GDHI (%)
£143	£3.6	£154	£347	0.5%	1.4%	1.7%
£257	£6.4	£277	£624	0.9%	2.5%	3.1%
		...based on Population of Shetland in 2016	...based on No. of Households in Shetland in 2016	...based on Shetland GVA (£m, 2016)	...based on Shetland Average Gross Household Income (£)	...based on Shetland Average GDHI (£)
		23,200	10,283	£680	£24,600	£20,124

Our analysis indicates that the reinforcement options can be expected to create an annual economic benefit of between £154 and £277 per person per annum or around £347 to £624 of economic benefit per household per annum. The total Shetland GVA benefit of the project is likely to form between 21% and 38% of the total regional GVA (as of 2016) whilst on an annual basis the economic benefit would range between 0.5% and 0.9% of the total regional GVA. The economic benefit per annum is equivalent to between 1.4% to 2.5% of gross household income, whilst the economic benefit in relation to Gross Disposable Household Income (GDHI) is higher at between 1.7% and to 3.1%. Clearly the impact on a per capita, per household and overall economic perspective is substantial and has the potential to vastly improve the economic welfare and social well-being of the Shetland Islands.

The same amount of economic benefit arising in the Highlands or the City of Edinburgh would have a much smaller relative impact on the regional economy and on households. Considered another way, to derive the same economic benefit on a household-to-household basis in the Higlands would require a project that created 6 times more total economic benefit or, in the City of Edinburgh, would require a project that created over 13 times more economic benefit.

SHEPD

SHEPD is currently undertaking analysis aimed at evaluating a 'New Energy Solution' (NES) for Shetland. As part of its assessment SHEPD is considering a number of ways in which Shetland's future security of supply can be secured and potentially new generation enabled. Ofgem has asked SHEPD to undertake a CBA of the viable energy solutions for Shetland – and the options SHEPD is considering include a transmission link, a distribution link and a replacement power station. As SHE Transmission's proposed transmission link could form part of the NES for Shetland, we have adapted our CBA to consider the costs and benefits of it doing so. This 'all island' sensitivity is aligned with the analysis SHEPD is undertaking and based on the same cost assumptions. Our CBA sensitivity does not compare the costs and benefits of a transmission link with the security of supply alternatives for Shetland. Instead we take into consideration the costs and benefits of a transmission link forming part of the NES for Shetland.

Our results suggest a distribution link with standby generation is a more cost effective option than the on island generator, even when adopting arguably more competitive cost assumptions for the on island generator. The result is largely based on the ability to import lower cost electricity than that generated by the on island generator. We can also conclude that the additional costs associated with using the transmission link as part of the NES security of supply solution for Shetland is outweighed by the benefit of costs avoided by SHEPD – leading to a positive NPV impact of between £129 m – £618 m.

Summary

To support the SHE Transmission Needs Case assessment under the Strategic Wider Works process GHD has performed a cost benefit analysis of a range of proposed transmission connection options for Shetland across a credible range of potential generation development scenarios.

Our analysis shows that when assessed as part of a 'conditional' Needs Case across a range of cost and output assumptions Option 2, the 600 MW HVDC link, is the reinforcement option of LWR. The NPVs returned in our central case are strong and therefore sensitivity analysis of a 20% increase in project capex, while reducing project NPVs, does not change our conclusions and the project remains strongly economically viable. A similar outcome arises if the cost of mainland constraints is included or if the long term wind farm capacity factor is below 50%. Under all these sensitivities Option 2, the 600 MW link, is the option of LWR.

Only when all options are delivered at the identical, earliest date of March 2024 does the option of LWR change from Option 2, to Option 3, the 800 MW link, which then becomes the LWR reinforcement. However, SHE Transmission cannot deliver the 800 MW link before the end of Q4 2025 and therefore we can conclude that the 600 MW link remains the option of LWR

The transmission link to Shetland can also form part of the New Energy Solution (NES) for Shetland. We have assessed the costs and benefits of a transmission link as part of the NES and conclude that overall NPVs will improve – while additional standby generation investment will be required on Shetland, this is mitigated by the expenditure avoided by SHEPD on either a distribution link or an on island power station.

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1. Introduction

Scottish Hydro Electricity Transmission (SHE Transmission) as part of Scottish and Southern Energy Networks (SSEN) is considering a potential transmission connection between mainland Scotland and the Shetland Isles. The reinforcement will allow the export of Shetland's considerable renewable energy potential back to the mainland. The Shetland reinforcement is a relatively unusual situation as the requirement for the reinforcement is highly dependent on a small number of onshore wind projects that are dependent on an unsecured level of subsidy.

Any planned transmission connection project falls under Ofgem's RIIO-T1 Strategic Wider Works (SWW) funding arrangements. The RIIO-T1 price control classifies large transmission projects required to reinforce or expand the electricity network as 'wider works outputs'. Under the SWW framework, SHE Transmission must submit to Ofgem, for each scope of works it proposes, a 'Needs Case' submission that includes justification for the project and an explanation of how the proposed reinforcements would best meet the required need compared to the alternatives. A key element of the Needs Case Submission is a cost benefit analysis (CBA) study.

1.1 Scope

SHE Transmission has engaged GHD to examine the power flows and resulting economic justification of a new subsea transmission cable between Shetland and mainland Scotland. This study evaluates the cost and benefits of the reinforcement options proposed by SHE Transmission through detailed power flow modelling and cost benefit analysis (CBA). The CBA determines the constraints that would arise without the reinforcements and those remaining when the reinforcement options commission. The benefits of the options are the reduction in constraints occurring over the economic life (45 years) of the project compared to a 'counterfactual' (no investment in transmission infrastructure).

To determine the economic attractiveness of the reinforcement options, the total cost (capex and opex) of the options and the resulting benefits are determined and a net present value (NPV) calculated. We have developed a number of scenarios to assess the impact of various levels of plausible generation growth on the economic viability of the reinforcement options under consideration by SHE Transmission. The aim of the CBA study is to demonstrate whether the economic benefits of alleviating generation constraints outweigh the investment cost required for network reinforcement and the optimum reinforcement option.

This document presents the findings from the CBA study.

1.2 Report structure

The structure of this report is summarised in Table 1-1.

Table 1-1: Report structure

Section	Title	Content
1	Introduction	Contains this brief introduction
2	Study Background	Provides a background to the study
3	Approach	Outlines SHE Transmission's and GHD's approach to Shetland Needs Case submission
4	Generation Scenarios	A summary of the generation scenarios developed by GHD

Section	Title	Content
5	Reinforcement Options	Outlines the transmission reinforcement options identified by SHE Transmission
6	CBA Modelling	Discusses the methodology and key inputs in the CBA methodology adopted
7	CBA Results – Central Case	Presents the results of GHD's CBA study under central case assumptions
8	CBA Results – Sensitivities	Presents the results of GHD's CBA study under a number sensitivities to the central case assumptions
9	Conclusions	Outlines the conclusions of the CBA study
Appendix. A	Generation Scenarios	Provides a detailed description of GHD's generation scenario development, including comparisons with the National Grid Future Energy Scenarios.
Appendix B	Socio-economic Modelling	Provides a detailed description of GHD's approach to the socio-economic modelling of Shetland transmission reinforcement and associated wind generation projects.

2. Study Background

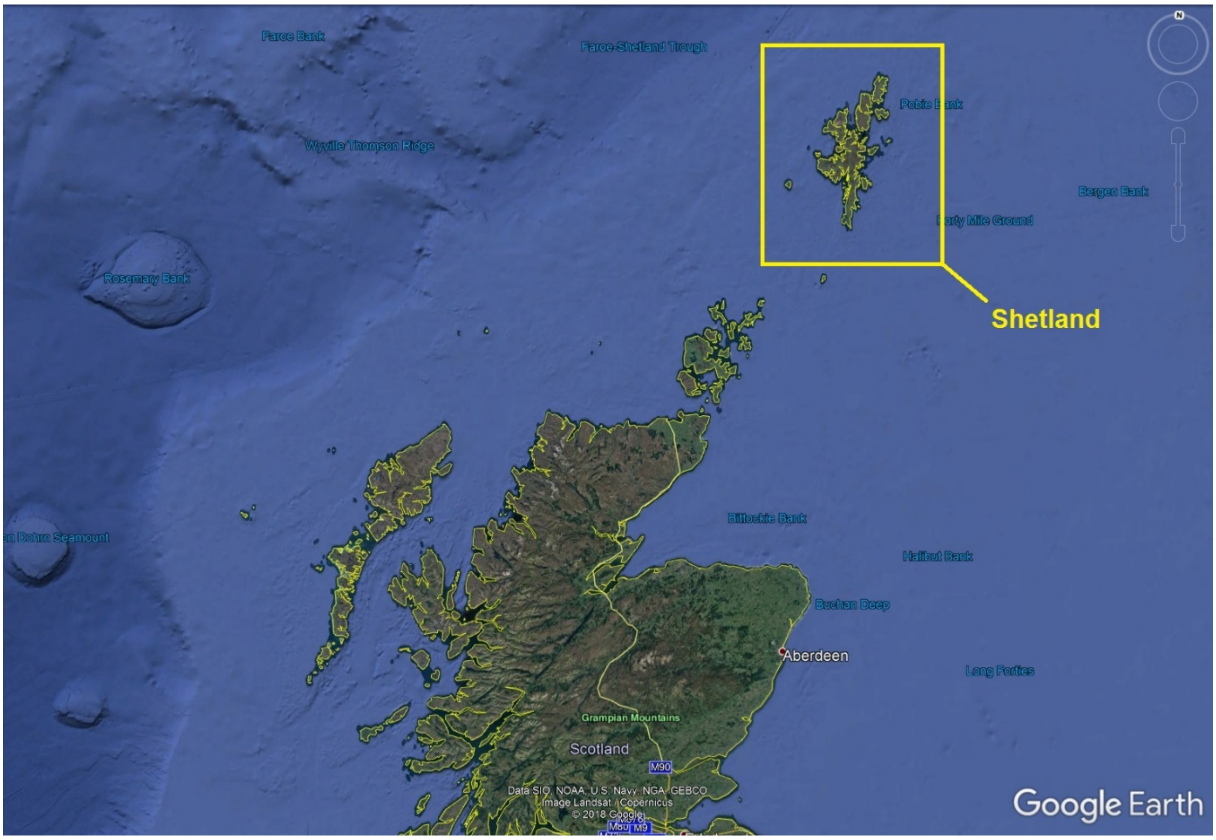
In order to assess the investment options and understand the generation scenarios developed in this report it is important to define the study area and underlying assumptions.

2.1 Background

Shetland (also known as the Shetland Islands) is an archipelago of about 100 islands situated on the extreme North East coast of Scotland. At its nearest point, it is approximately 170 km from mainland Scotland and 300 km to the west of Norway. The main islands are Mainland, Yell, Unst and Fetlar. The largest island, Mainland, is the third largest in Scotland and the fifth largest in the British Isles. Yell, Unst and Fetlar lie to the north of Mainland.

The population is widely dispersed across the islands. The 2011 Census showed 37% of the total population (some 8,600) lived within the Lerwick parish, which incorporates the main settlement and port of the Islands. A map showing Shetland in relation to mainland Scotland is shown in Figure 2-1.

Figure 2-1: A map of Shetland and mainland Scotland



Source: Google Earth Pro

2.2 Competitive advantage of onshore wind in Shetland

The underlying need for the proposed transmission subsea cable to Shetland considered within this Cost Benefit Analysis assessment is driven by the high average wind speeds experienced on Shetland in comparison with other parts of the UK. Table 2-1 compares the Burradale wind farm on Shetland with 5 wind farms in the Caithness area of Scotland. The average capacity for the Caithness wind farms was 26% over the 5 year period, while that of Burradale was almost

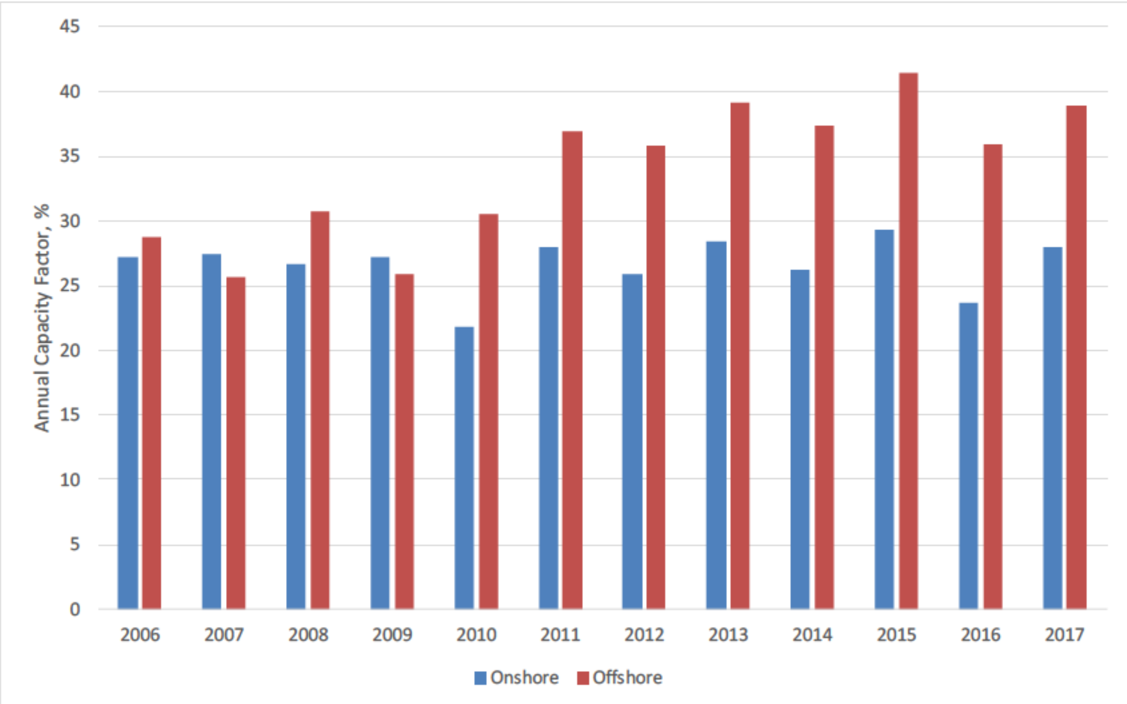
53%. The table also shows synthesised wind power curve outputs for 2017/18 output for three other wind farms on Shetland[5]. Capacity factors are consistently high (>48%) and significantly higher than Caithness.

Table 2-1: Shetland wind farm capacity factors versus the Caithness area (%)

Wind Farm	Capacity (MW)	2017/18	2016/17	2015/16	2014/15	2013/14	Avg.
Burradale (2000 & 2003)	3.65 MW (5 WTG)	55.3%	51.1%	52.0%	52.2%	53.9%	52.9%
Garth (2017)	4.5 MW (5 WTG)	49.2%					
Luggie's Knowe (2015)	3 MW (1 WTG)	52.5%					
North Hoo (2014)	0.5 MW (1 WTG)	48.0%					
Caithness WF 1	50 MW	22.0%	19.5%	23.7%	23.4%	28.3%	23.4%
Caithness WF 2	15 MW	28.0%	23.6%	24.8%	25.7%	28.9%	26.2%
Caithness WF 3	29 MW	24.7%	23.6%	23.2%	24.3%	28.4%	24.8%
Caithness WF 4	67.5 MW	30.0%	27.7%	29.8%	30.4%	31.8%	29.9%
Caithness WF 5	38 MW	24.2%	18.1%	25.4%	27.7%	27.3%	24.5%

The average annual capacity factor at Burradale has been 52% since commissioning and further data from Burradale's owners (Shetland Aerogenerators) confirms that the annual capacity factor has only dropped below 50% twice since 2001 (in 2012 and 2009)[6].

Figure 2-2: Historic annual UK wind farm capacity factors



[5] The output data gathered for the four additional Shetland wind farms for 2017/18 could not be used in 'raw' form due to their inclusion (as relatively new WFs) in the NINES ANM, therefore wind speed data at these locations was gathered and a resulting indicative power curve for the WFs developed to offset the impact of ANM impacts
[6] https://www.burradale.co.uk/data

The comparative advantage of Shetland as a wind farm location is further shown when it is compared to the wider UK. The average UK onshore wind farm capacity factor in 2017 was 28% and for offshore wind farms, with higher average wind speeds and larger turbines, the average annual capacity factor was 39% (Figure 2-2[7]). These compare to the average in Shetland for 2017/18 of over 51%. In simple terms Shetland is an excellent wind farm location, where one MW of wind farm capacity is broadly equivalent to two MWs in the rest of the UK.

2.3 The existing electricity network

At present the electrical distribution network on Shetland is isolated from mainland Scotland with no existing transmission connection. The highest existing electrical network voltage on Shetland is 33 kV which is used connect the main load centre (Lerwick) plus industrial demand (Sullom Voe). All existing overhead lines are owned and operated by Scottish Hydro Electric Distribution (SHEPD).

Figure 2-3 provides an overview of the existing SHEPD electricity distribution network on Shetland, green indicates the 33 kV distribution network plant and red indicates where the 11 kV distribution network connects to the primary substations.

As of May 2018[8], there is approximately 29.2 MW of installed generation capacity connected on Shetland as a whole. Of this some 11.2 MW is onshore wind (Burradale WF and Garth WF), with 18 MW of thermal (fuel oil) generation located at Lerwick (as shown in Figure 2-3).

In addition, gas turbine generation (four Frame 5 units) located within the Sullom Voe oil terminal (also shown in Figure 2-3) has historically supplied around half of the existing Shetland islands' demand. Although this generation continues to provide a similar proportion of the islands' electrical demand the longer term ability to rely on such generation is now questionable given the declining nature of oil and gas fields located in the North Sea in the area around Shetland.

Demand on Shetland is relatively small, with a 2017 peak demand of 43.8 MW and a minimum demand of around 11.3 MW. SHEPD estimate peak demand will rise to approximately 46.9 MW by 2021.

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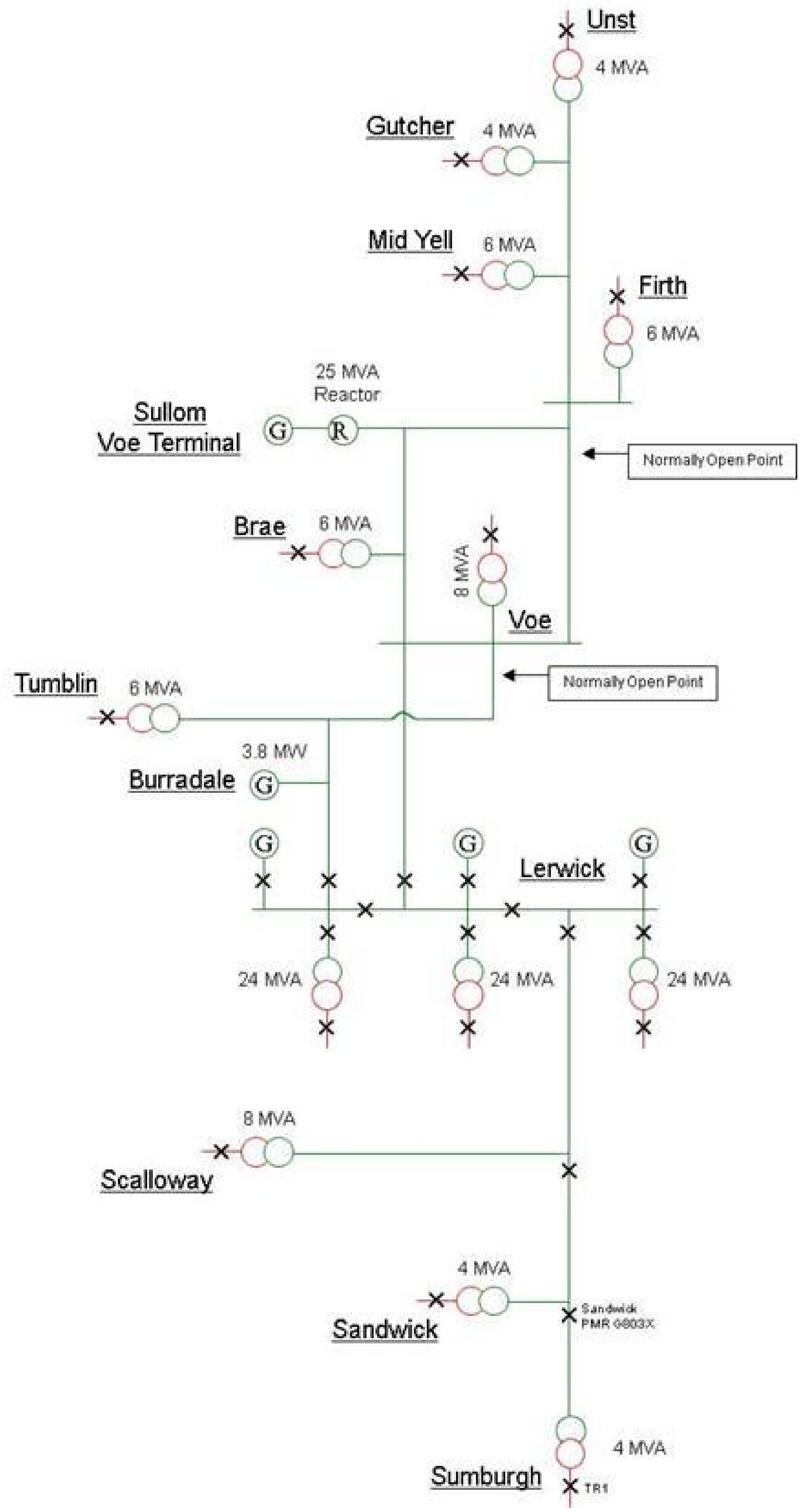
[7] Digest of United Kingdom Energy Statistics, Load Factors for Renewable Generation, 26th July 2018.
[8] SHEPD Long Term Development Statement, May 2018

Figure 2-3: Existing SHEPD Electrical Network (Shetland)



3. Approach

3.1 GHD approach

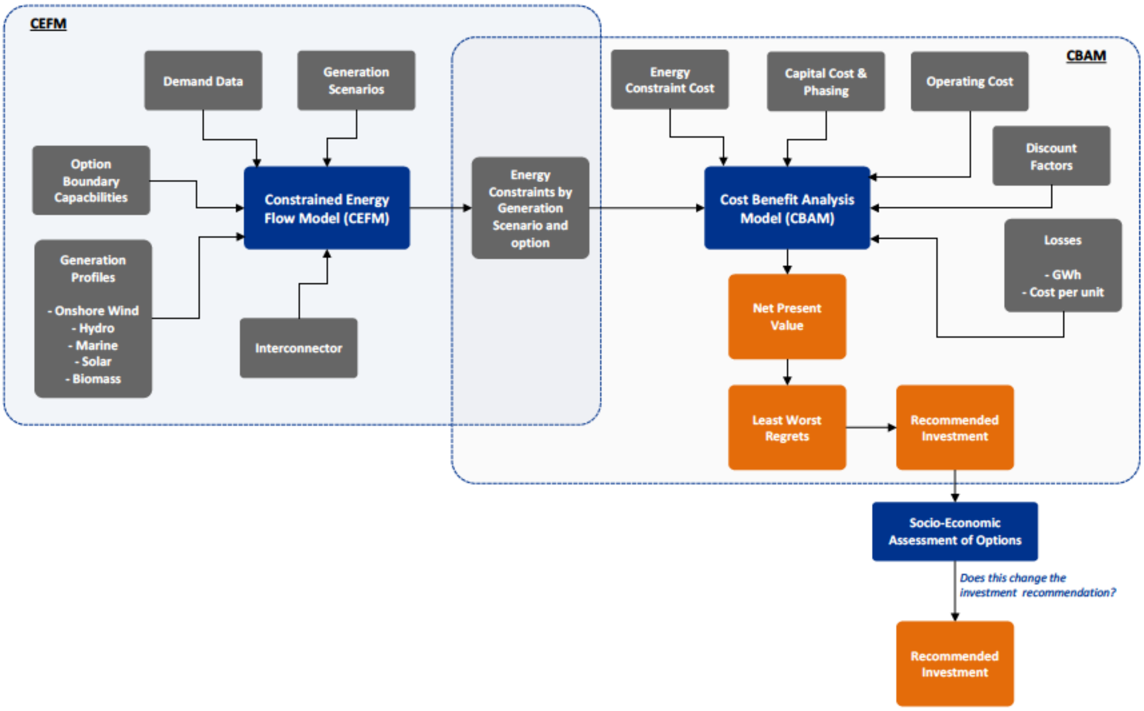
The modelling approach adopted by GHD for assessing the costs and benefits of transmission reinforcement between Shetland and mainland Scotland comprises two independent but linked Microsoft Excel based models:

- The Constrained Energy Flow Model (CEFM), and
- The Cost Benefit Analysis Model (CBAM).

The CEFM model determines the constrained energy (in GWh per annum) under the counterfactual (no reinforcement) and for each investment option considered for alternative generation scenarios and generation profiles. The energy constraints calculated by the CEFM form a critical input into the CBAM. The CBAM is a cash flow model converting energy constraints into a benefit stream for each option and comparing to the capex and opex of the option to determine a project Net Present Value (NPV) for each generation scenario. Option NPVs are compared to identify the reinforcement of Least-Worst Regret (LWR).

Our modelling approach is summarised in Figure 3-1 below.

Figure 3-1: CBA modelling approach



The CEFM and CBAM identify the option of LWR in terms of constraints avoided and this recommendation is supplemented by a socio-economic assessment. The socio-economic assessment explores the impact of each reinforcement option and associated generation investment on Shetland economy in terms of Gross Value Added (GVA). Whilst not specifically part of the SWW analysis, given the importance of potential generation development to the island economies and the duty on relevant public bodies to 'island proof' their relevant functions by identifying consequences to island communities, a socio-economic evaluation is a useful addition to the SWW analysis.

The underlying methodology and inputs used in the CEFM, CBAM and socio-economic modelling is provided in Section 6.

3.2 Conditional needs case submission

The UK Government announced in 2017 that islanded onshore wind will be able to compete in the next 'less established technologies' CfD auction scheduled for 2019. This has recently been reconfirmed, along with further CfD auctions to be held every two years[9]. GHD understands that the largest proposed wind farm on Shetland, Viking Wind Farm, intends to compete in the 2019 CfD Round 3 auction. This project alone currently represents up to 457 MW of consented generation and so its success, or not, in the CfD auction is fundamental to the Needs Case for the proposed transmission reinforcement.

As a result, SHE Transmission is submitting a 'conditional' Needs Case to Ofgem, with the 'need' for reinforcement and the subsequent optimum reinforcement option, conditional on the award of a CfD to the Viking project.

The 'conditional' Needs Case submission has a number of implications on the CBA study:

- **Generation scenarios.** The generation scenarios outlined in this report are designed to reflect the 'conditional' approach with a common assumption that the Viking project does secure a CfD contract. The scenarios are supplemented by varying levels of underlying development of private/commercial or community onshore wind development identified that would be facilitated by a transmission cable.

  GHD's generation scenarios are presented and discussed in Section 4 and Appendix A of this report.

- **Reinforcement options.** The proposed transmission reinforcement options considered by SHE Transmission for use in this CBA study reflect those technically and environmentally viable options that can (i) transmit the expected level of energy arising from the generation scenarios and (ii) be delivered in time should the Viking project be awarded a CfD in 2019.

SHE Transmission's approach to determining the options considered within this CBA and the subsequent options considered is outlined in Section 5.

[9] https://www.gov.uk/government/news/a-boost-for-north-east-innovation-to-promote-high-quality-jobs-and-growth

4. Generation scenarios

To explore the long term 'need' for and assess the uncertainties surrounding the potential need for a transmission connection to Shetland in the longer term, scenarios are required to explore alternative paths of future network use. The scenarios developed must explore differing and credible paths of growth for SHE Transmission to fully 'stress test' the requirement for transmission reinforcement in its Needs Case.

Determining the prospects for future onshore wind generation – location and certainty of progression – on Shetland (and the Scottish islands in general) is complex. The existing electricity network on Shetland has reached capacity and therefore new generation is unable to connect to the grid without tangible plans and commitment to reinforce the network. This results in a 'Catch-22' situation.

> **Scottish Islands Catch 22:**
>
> **The 'need' for the transmission reinforcement is dependent on the development of generation on the islands, but generation development on the islands cannot occur without the transmission reinforcement. The case for either transmission or generation development is entirely predicated on the other.**

The situation is further complicated by the position of the Shetland outside the GB transmission charging zones. Because of Shetlands' position outside the main interconnected transmission system (MITS), potential transmission connected generators on the islands will be allocated a 'wider' TNUoS charge to the nearest transmission charging zone, plus a 'local spur' charge for transmission to the islands. Given the relatively high cost of the local spur (a subsea link) then the resulting TNUoS charge for island generators is high.

The UK Government has recently announced that islanded onshore wind will be able to compete in the next 'less established technologies' CfD auction scheduled in 2019, with further CfD auctions to be held every two years thereafter.

GHD understands that the largest proposed wind farm on Shetland, Viking Wind Farm will compete in the 2019 CfD auction. Viking Wind Farm is a joint venture between SSE and the Shetland community; it has a grid connection contract for 412 MW of capacity and is contracted to connect in March 2024. The wind farm is currently consented at 457 MW. Viking has also applied for an additional 45 MW of contracted capacity.

As this project alone currently represents up to 457 MW of consented generation and potentially contracted capacity, SHE Transmission wishes to submit a '**Conditional Needs Case**' to Ofgem, with the need conditional on the award of CfDs.

The generation scenarios outlined in this report reflect SHE Transmissions 'conditional' approach and therefore assume ***Viking Wind Farm secures a CfD, either at its current contracted capacity of 412 MW or its consented capacity of 457 MW***. For the other known transmission projects, various capacities emerge across the scenarios based on a range of contracted, consented and notified capacities. The scenarios are supplemented by varying appetite for private or community development should a new, high capacity transmission cable be constructed, taking into consideration the applicability of TNUoS charges to the prospective projects (i.e. transmission vs distribution connected projects).

In total, nearly 875 MW of known projects at various stages of development have been identified in producing the scenarios. These include the projects identified in Table 4-1 below.

Table 4-1: Known generation projects in Shetland

Wind Farm	Capacities Considered	Status
V king	412 - 457 MW	Consented at 457 MW, contracted at 412 MW, [redacted]
Beaw Field	57.8 - 82 MW	Consented at 57.8 MW, contracted at 72 MW, [redacted]
Energy Isles	120.3 [redacted]	Contracted at 120.3 MW. [redacted] Consented
Mossy Hill	50 MW	Planning application for 50 MW. [redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
Culterfield	2.7 MW	Consented at 2.7 MW, [redacted]
Hillhead	0.1 MW	Consented at 0.1 MW
East of Brae	0.1 MW	Consented at 0.1 MW
Swinster	0.5 MW	Pre-application planning enquiry made at 0.5 MW
Total	767.5 - 875.1 MW	

In addition, the generation scenarios assume a modest amount of background growth in small scale wind generation, consistent with the Shetland Islands Council's Supplementary Guidance for Onshore Wind Energy, as well as some growth in small scale solar PV and tidal energy.

Having considered some of the features of these projects and the factors that could affect them going forward the following chart (Figure 4-1) shows the resulting GHD generation scenarios developed (GHD S1 – S4). The generation scenarios outlined in this report intend to explore a range of potential generation development on Shetland, initiated by the 2019 CfD auction. Detail of the technologies underpinning the scenarios is shown in Table 4-2. It must be noted that the potential maximum capacity of the three contracted projects could total some 719 MW alone and therefore is most closely represented by GHD's generation scenario S4.

Figure 4-1: GHD generation scenarios for Shetland

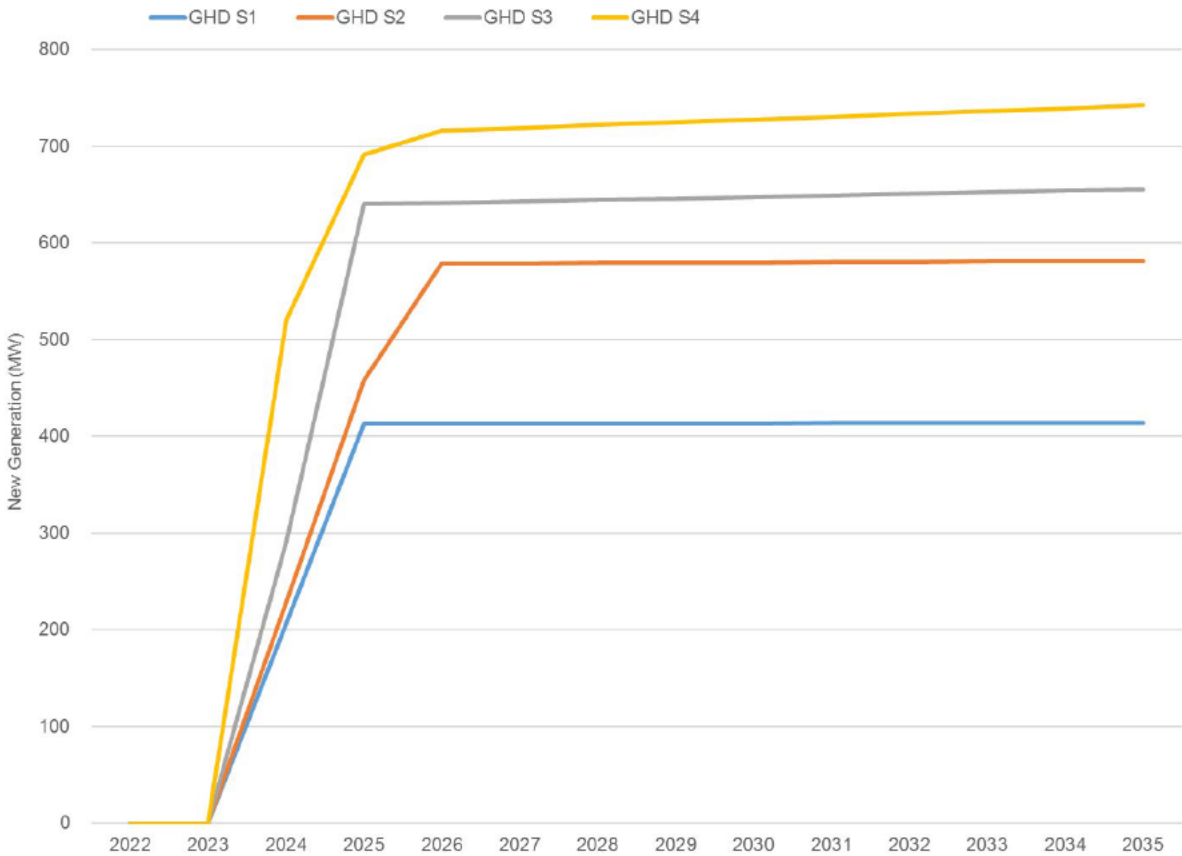


Table 4-2: New generation capacity (MW)

Scenario	Large Onshore Wind	Embedded Wind	Embedded Solar	Tidal	Total
S1	412.0	1.0	1.0	0.1	414.1
S2	577.3	2.0	2.0	0.1	581.4
S3	645.1	5.9	3.0	1.5	655.5
S4	729.1	7.4	4.0	1.5	742.0

Appendix A provides a detailed description of the prospects for further generation on Shetland and how the GHD scenarios presented above have been derived and how they compare with the 2018 FES. Although there are some similarities between the GHD scenarios and the FES these are limited due to the more binary nature of the FES and their inclusion of only contracted, transmission level generation projects[10].

[10] In the case of Shetland, only the Viking and Beaw Field projects are considered in the FES and only at their contracted capacities, which are some 55 MW below the capacities that they are seeking to connect in total.

5. Reinforcement options

As there is no existing transmission system connection between Shetland and the Scottish mainland SHE Transmission has performed an option development and screening process to identify potential transmission connection options. Through this process SHE Transmission has identified five potential transmission options that could support renewable generation developments on Shetland, these are:

1. 450 MW High Voltage Direct Current (HVDC) subsea cable connection to Noss Head, in Caithness, circa 257 km in length
2. 600 MW HVDC subsea cable connection to Noss Head, circa 257 km in length
3. 800 MW HVDC subsea cable connection to Noss Head, circa 257 km in length
4. 800 MW HVDC subsea cable connection to Rothienorman in Aberdeenshire, circa 320 km in length
5. 1000 MW HVDC subsea cable connection to Rothienorman, circa 320 km in length

The island termination point for all options will be in the vicinity of Kergord on Shetland. For Options 1 to 3 the mainland Scotland termination point for the Shetland HVDC cable will be in the vicinity of Noss Head, where it will connect to a new three terminal HVDC switching station that also connects the Caithness-Moray HVDC transmission cable. For Options 4 & 5 the mainland Scotland termination point will be at the existing Rothienorman SHE Transmission substation in Aberdeenshire where it will connect to the existing 275 kV transmission system via a new HVDC converter station.

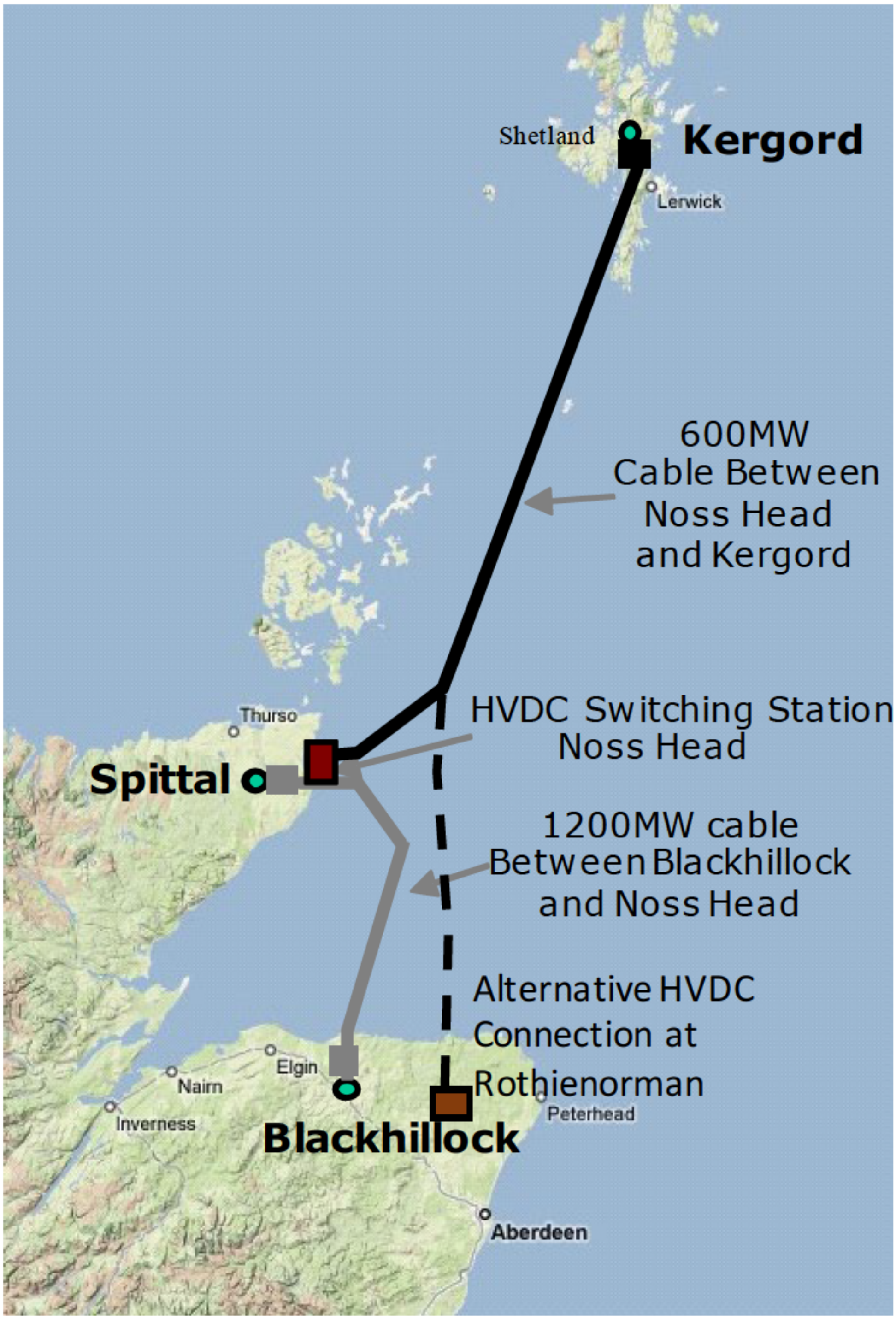
The SHE Transmission Needs Case for Shetland is submitted as a ‘conditional’ need contingent on success of the Viking Wind Farm in the 2019 CfD auction. For the initial CBA results we assume Options 1 and 2 will be delivered by the end of Quarter 1 in 2024 and so enable renewable project developers to compete in the 2019 CfD auction. Options 3 to 5 will incur additional work associated with the revised HVDC project design and additional onshore SHE Transmission system works. Therefore these options cannot be delivered before the end of Quarter 4 2025. The later earliest-in-service-date (EISD) may not be compatible with participation in the 2019 CfD auction and, although it may enable renewable project developers to enter a subsequent auction, there is increased risk over future auctions and island participation in them.

Note that if the Viking project does not achieve success in the forthcoming CfD auction then a wider pool of transmission connections options, including lower capacity links, could be considered as part of a future re-submission.

5.1 Technical details of considered options

For the three Options (1 to 3) that run from Noss Head in Caithness the approximate distance to Shetland is around 257 km with the approximate subsea cable route shown in Figure 5-1. With these options a new HVDC switching station will be constructed at Noss Head in the vicinity of Wick to connect the Shetland subsea cable to the existing Caithness – Moray HVDC cable that originates at Spittal.

Figure 5-1: Subsea cable routes



The alternative Shetland HVDC cable termination point is at Rothienorman in Aberdeenshire (as shown in Figure 5-1), with a total subsea cable length around 60 km longer than the Caithness options. The principal advantage of these Options (4 & 5) is that establishing a HVDC terminal substation at Rothienorman will effectively bypass the existing B0 and B1 onshore transmission system boundaries. These boundaries[11], and the potential power flow constraints that are expected to arise due to the development of significant further renewable generation in the north of Scotland and on other Scottish islands i.e. the Western Isles and Orkney, were the principal driver underpinning the development of the Caithness – Moray HVDC cable

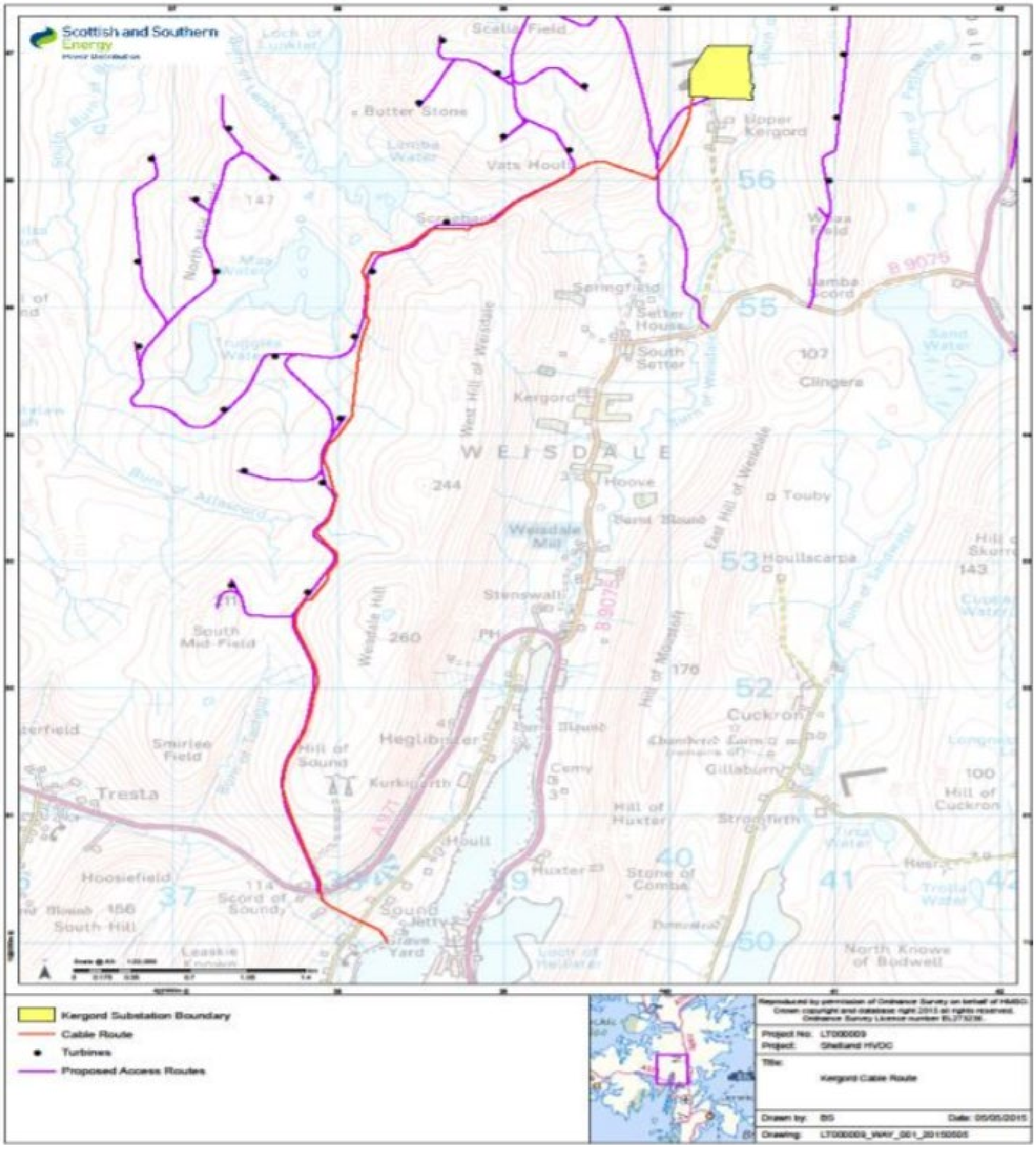
[11] Transmission boundary B0 separates the area north of Beauly from the wider transmission system including Caithness, Sutherland and Orkney. Boundary B1 effectively runs diagonally from the Moray coast near Macduff to the west coast near Oban.

connection. However, whilst this project does provide a significant increase in the B0 and B1 transmission boundary capacity, adding in the potential additional generation export from Shetland under higher development scenarios i.e. +600 MW, is likely to see further constraints materialise across these boundaries. By connecting the Shetland HVDC cable to Rothienorman these potential additional onshore transmission boundary constraints can be significantly reduced.

On-island reinforcement works

In addition to the HVDC subsea cable, short underground cable sections around 7.4 km (from the landing point on Shetland to the proposed converter station at Kergord) and 2.4 km (from the Caithness landing point to Noss Head) will also be required under Options 1 to 3. The proposed onshore cable route from the Shetland landing point to Kergord is shown in Figure 5-2.

Figure 5-2: Onshore cable route to Kergord



For Options 4 & 5 the onshore cable works to Rothienorman are more extensive requiring around 29 km from the landing point on the Moray coast. The onshore cabling works on Shetland under Options 4 & 5 are however identical to Options 1 to 3.

In addition to the works outlined above, there is further capital investment associated with connecting the Kergord HVDC converter station with the existing SHEPD distribution system. This will require the construction of a new SHE Transmission Grid Supply Point (GSP) substation at Gremista with two 90 MVA 132 / 33 kV transformers supplied via two circa 22 km 132 kV wooden pole overhead lines.

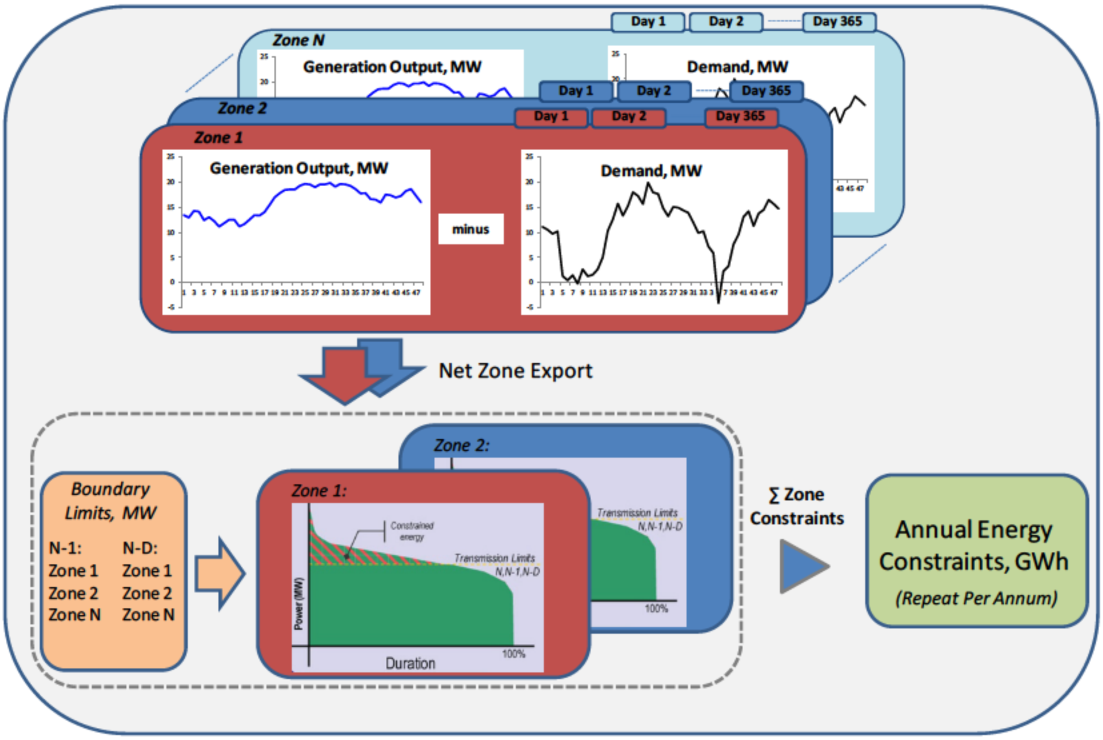
Onshore network costs are not included in the Strategic Wider Works (SWW) submission to Ofgem (e.g.), however we have included the construction of the Grid Supply Point to connect with SHEPD's network (some £30m) in our analysis.

6. CBA modelling

6.1 Constrained Energy Flow Model (CEFM)

A key aspect of the CBA modelling is to determine the notional benefit that reinforcement will provide. The benefit of a transmission reinforcement is determined by calculating the constrained energy that would arise under the counterfactual (no reinforcement case) and the reduction in energy constraints (on a per annum basis) resulting from the reinforcement. The GHD modelling tool (CEFM) calculates energy constraints on a given transmission network area (or zones) under a range of potential future generation scenarios and can consider a range of potential reinforcement options. The CEFM is outlined in Figure 6-1.

Figure 6-1: The CEFM process



The CEFM allows the representation of generation and demand within a boundary area or zone and calculates the subsequent flows across the network boundary (generation output – demand). These boundary power flows are compared to the seasonal boundary ratings resulting from the most onerous contingency complying with planning standard requirements, typically N-1, although in the case of reinforcements associated with generation power flows only generally the N boundary rating. A constraint is identified if the power flow on a half hour basis exceeds the capacity rating of the zone boundary. The process is repeated for each half hour within a year, with demand and generation changing to align with future growth scenarios. Total energy constraints are calculated for each year.

GHD's CEFM generic modelling process outlined above can be adapted for a specific area and this allows 'micro' local conditions to be taken into account to give a more accurate localised flow modelling and impacts. Fundamental to the model is the generation and demand data inputs used for the area under consideration. Below we outline the generation and demand inputs used for Shetland version of the CEFM.

6.1.1 Wind generation

Onshore wind

As outlined in Section 2.2, Shetland is an area of high wind resource with existing operational wind farms routinely demonstrating annual capacity factors in excess of 50%. To support the CBA analysis historic time series power output data has been provided by SHE Transmission for the Burradale wind farm on Shetland for the period 2013 to 2017. A summary of the annual capacity factors achieved by this wind farm is shown in Table 6-1.

Note that these are slightly different from capacity factors in Table 2-1 on account of the former based on a financial year rather than a calendar year as shown in Table 6-1. The average capacity factor achieved by Burradale over these five years was 52.9% - this compares with the average capacity factor achieved since construction of 52%.[12]

Table 6-1: Burradale wind farm annual capacity factors (%)

Year	Capacity Factor
2013	49.31%
2014	52.14%
2015	55.2%
2016	47.99%
2017	56.81%

In addition to the times series power output data provided for Burradale wind farm, SHE Transmission also provided a synthesized power output profile for Garth, Luggies Knowe and North Hoo wind farms in 2017 developed from wind speed measurements at these sites. The resulting annual capacity factor during 2017 at these sites, which was generated using a typical wind turbine power curve, are shown in Table 2-1 and range from 48% to 53%. These values are broadly in line with the results for the Burradale wind farm and further support the claimed high power output from Shetland based wind generation.

Offshore wind

We are not aware of any offshore wind developments coming forward in the Shetland area. Therefore, we have not considered it further in this study.

6.1.2 Marine generation

There is potential for tidal and wave generation around the coast of Shetland, with one active tidal generator. Nova Innovation was the first company to secure financial close on a commercial tidal array. It has installed three 100 kW turbines in Bluemull Sound (Shetland) with the first turbine installed in March 2016. The project has been generating up to full power and across all tidal conditions.

Nova Innovation has recently won a major new European tidal energy project (Enabling Future Arrays in Tidal (EnFAIT) project), heading a consortium of nine leading industrial, academic and research organisations. The project began in July 2017 and will run until June 2022, extending the Bluemull Sound array to six turbines and demonstrate that high array reliability and availability can be achieved using best practice maintenance regimes. The layout of the

[12] https://www.burradale.co.uk/

turbines will be adjusted to enable array interactions and optimisation to be studied for the very first time at an operational tidal energy site.

However, at present there are no larger scale plans for tidal development on Shetland, as a result we have not considered significant growth.

Wave technology is not as close to commercial viability as tidal generation and we have not considered wave generation.

6.1.3 Solar

Although it is not expected to represent a significant renewable resource the CBA power flow modelling has also considered a modest capacity of photo-voltaic generation, expected to be comprised a mix of some roof-top installation across residential dwellings plus some larger commercial developments.

In terms of the power output profile adopted in the power flow modelling for PV generation, as no historic data is currently available a generic output profile for installations in England[13] has been adopted to obtain a representative daily output profile for each calendar month.

Note that it is recognised that the actual output profile for more northerly located PV generation on Shetland is likely to be slightly different from the profile expected for such installations in England, given the lower irradiance data and the slightly longer / shorter seasonal daylight hours, however this is not expected to have a significant impact on the CBA results.

6.1.4 Hydro

We are not aware of any existing or proposed hydro-electric generation in Shetland and have therefore not considered it further in this study.

6.1.5 Demand

As outlined in Section 2.3, the existing maximum electrical distribution demand on Shetland is around 44 MW, relatively low in the context of the potential future generation growth. However, in order to provide a realistic export power flow from the islands for the power flow modelling, we have utilised half-hourly time series profiles for Shetland for the years 2014 to 2017 and scaled this based on the expected demand growth to obtain an estimated current demand profile for years 2018. Going forwards it is not expected that there will be a significant change in Shetland peak electrical demand hence the developed time series profile for 2018 will be adopted for all future study years.

6.1.6 Treatment of SHEPD distribution network

The principal focus of GHD's modelling and analysis is evaluating the need for a future transmission connection from Shetland to the Scottish mainland. A key assumption when developing the future generation scenarios is that all new renewable generation will ultimately export to the SHE Transmission network, even if physically connected at a lower voltage i.e. 11 kV or 33 kV.

The proposed SHE Transmission subsea cable will also provide enhanced security for the SHEPD distribution network. The existing Lerwick power station was commissioned in the mid-1950s to supply power to Shetland. The current generation installation comprises a mixture of diesel generator sets (6, 8 and 12 MW), a combined cycle heat recovery generator (2.1 MW) and standby gas turbines (5 MW each). Lerwick currently provides around half of the Shetland's electrical demand, with the remainder supplied by Sullom Voe (around 20 MW) as

[13] http://solar-panels-review.321web.co.uk/monthly-pv-solar-panel-generation.php

well as from embedded renewable generation. SHEPD is currently considering alternatives to the aged Lerwick power station and these have been included as a sensitivity in our analysis.

6.2 Cost Benefit Analysis Model (CBAM)

The CBAM is a net present value (NPV) investment appraisal tool used to assess and compare the economic costs and benefits of each reinforcement option.

We adopt the Spackman approach in our CBA, as proposed by National Grid and supported by Ofgem. The Spackman approach was promoted by the Joint Regulators Group, and addresses situations where a firm finances an investment, but the benefits of the investment accrue mainly to consumers or the wider public, such as transmission investments. Ofgem 'considers the Spackman approach appropriate for evaluating the NPV of a transmission project as the benefits (in terms of avoided constraint costs and potentially more macro considerations) accrue to consumers more widely'. Under the Spackman approach a firm's financing costs are taken into account by converting the firm's investment cost (capex) into annual payments (an annuity akin to a corporate bond) using the firm's weighted average cost of capital (WACC). The resulting costs and benefit flows are then discounted at the social time preference rate (STPR).

In accordance with Ofgem's RIIO T1 final decision, we use an economic asset life of 45 years and a post-tax WACC of 3.97% based on SHE Transmission's RIIO-T1 price control. Therefore, capex incurred in any year is annualised over a 45-year period at WACC.

The resulting net benefits are discounted to 2018 by multiplying the stream of net benefits with the STPR of 3.5% in years 0 to 30 and 3.0% in years 31 to 75 as outlined by the HM Treasury Green Book.

In this CBA, the cost of each reinforcement option comprises annualised capital expenditure and operating expenditure. The benefit of a reinforcement option is assessed by determining the volumes of generation that would be constrained if no network reinforcement is undertaken under each generation scenario (the counterfactual) and determining the volumes of generation constrained under each reinforcement option. The net reduction in constrained generation from the counterfactual is the benefit determined for each reinforcement option. The value of the benefit for each reinforcement option is best understood through a simple example:

- Imagine each GWh of constrained energy is valued at £100/MWh.
- If the energy constrained under the counterfactual were 400 GWh/annum, the value of constrained energy under the counterfactual would be £40m/annum.
- If the energy constrained under one of the reinforcement options is 100 GWh/annum, so the reinforcement removes 300 GWh/annum of constraints relative to the counterfactual, the value of remaining constrained energy under this reinforcement option is £10m/annum. The benefit of the reinforcement is the value of the constrained energy relieved from undertaking the reinforcement, 300GWh/annum, providing a benefit of £30m/annum.
- If the energy remaining constrained under another reinforcement option totalled 300 GWh/annum so the reinforcement removes 100 GWh/annum of constraints, then the value of constrained energy is £30m/annum. The benefit of this option is therefore only £10m/annum.
- The value of the constrained energy relieved is considered against the counterfactual for each reinforcement option.

The cost and benefit streams are discounted at the STPR to provide a NPV for each reinforcement option under alternative generation scenarios and other sensitivities such as capex increases.

Investment appraisal theory indicates that only those projects with a positive NPV should be considered for investment, with the highest positive NPV considered the most beneficial reinforcement investment option. However, relying on NPV analysis alone will not result in a robust investment decision, as the most 'beneficial' reinforcement option is likely to change depending on key uncertainties modelled in particular the generation scenario. To accommodate these uncertainties the CBAM incorporates a Least Worst Regret (LWR) analysis - also known as minimax regret theory. The LWR approach provides a recommended investment option based on minimising the worst-case regret. The aim of this approach is to perform as closely as possible to the optimal course. Since the least-worst criterion applied is to the regret rather than to the payoff, it is not as pessimistic as an ordinary least-worst approach.

Key inputs into the model include:

- Project capex
- Project opex
- Constraints (GWh resulting from the CEFM and constraint costs (£/MWh))

6.2.1 Project costs

SHE Transmission has provided capital expenditure (CAPEX) and operational expenditure (OPEX) estimates for the five transmission connection options, as shown below in Table 6-2.

Table 6-2: Transmission reinforcement options & costs (2018 prices)[14]

Option	Description	Capex £m	Opex £m p.a.
1	450 MW HVDC Kergord to Noss Head (EISD End Q1 2024)	[redacted]	[redacted]
2	600 MW HVDC Kergord to Noss Head (EISD End Q1 2024)	[redacted]	[redacted]
3	800 MW HVDC Kergord to Noss Head (EISD End Q4 2025)	[redacted]	[redacted]
4	800 MW HVDC P2P (EISD End Q4 2025)	[redacted]	[redacted]
5	1000 MW HVDC P2P (EISD End Q4 2025)	[redacted]	[redacted]

The phasing of capital expenditure for the reinforcement options is shown in Figure 6-2 – Options 3, 4 and 5 commission 21 months behind Options 1 and 2. The costs for the inter-island onshore works (GSP) have also been estimated by SHE Transmission at an additional £[redacted]m. We have combined the CAPEX profiles of the options and the GSP into combined profiles, which are shown in Figure 6-2 for each option. The amounts in 2018 mainly represent costs which have already been incurred.

[redacted]

Figure 6-2: Capital cost phasing of reinforcement options

[redacted]

6.2.2 Energy constraints

The benefit stream of each reinforcement option is derived from the amount of constrained energy relieved and the assumed cost of constrained energy. Whilst the constrained energy of the counterfactual and each reinforcement options comes directly from the CEFM, the cost of each GWh of constrained energy has been developed by GHD. Conservatively we have assessed the average cost of constraints over the regulatory life of the transmission asset at £55/MWh with an upper value of £70/MWh.

Our approach to determining constraint costs is based on a number of parameters:

- The bid price of reducing relevant wind output in the balancing mechanism
- The offer price of replacement energy in the balancing mechanism to replace wind constrained off
- The cost of replacing reserves used in the balancing actions

The bid price of reducing wind in the BM is set against the offer price of replacement energy to arrive at a net 'direct' constraint cost. Added to this net direct cost is the cost of replacement reserve – with the net cost of replacement energy determined as the replacement reserve price net of the average energy reference price (the wholesale price).

We consider £55/MWh a cautious lower value given the results of the strike price of wind in the 2nd CfD round for less established technologies and longer term lower electricity wholesale price projections made by both National Grid for the FES and the Department of Business, Energy and Industrial Strategy (DBEIS). We consider £70/MWh represents a reasonable higher level based on higher wholesale price and balancing mechanism action assumptions – although remains conservative – the average constraint cost for Scotland (predominantly onshore wind) was £98/MWh in 2017/18[15].

6.3 Socio-economic analysis

There is a clear interdependency between grid reinforcement and the realisation of potential economic benefit arising from renewable development on Shetland. The Shetland Islands Council considers renewable energy an important development opportunity for the local economy. In June 2017 the Scottish government introduced what it has described as an

[15] National Grid MBSS DATA

'historic bill' to create a sustainable future for Scotland's islands. The 'Islands (Scotland) Bill' was subsequently unanimously backed by MSPs in May 2018 and includes:

- A duty on Scottish Ministers to publish a National Islands Plan – setting out the main objectives and strategy of the Scottish Ministers in relation to improving outcomes for island communities
- A duty on Scottish Ministers and other relevant public bodies to have regard to island communities in exercising their functions – including an island communities impact assessment ('island proofing') of any new/revised policy likely to have a significantly different effect on islands communities from its effect on other communities. This 'islands proofing' is considered a cornerstone of the Bill

Under the Scotland Act 2016 Ofgem is required to provide its annual report to Scottish Ministers. Ofgem should therefore consider the impact on Shetland of its SWW decisions given that the impact on Shetland will differ substantially from that on other communities. Part of this impact assessment is a socio-economic impact evaluation. GHD has developed an approach to evaluating the socio-economic benefits of grid reinforcement and renewable development on Shetland.

Our approach, explained in detail in our Socio-economic report in Appendix B is outlined below:

- Project expenditure (generation and transmission) is categorised into three key groupings – development costs, capital costs and operating costs (including decommissioning).
- These costs are further deconstructed into relevant Office of National Statistics (ONS) Standard Industry Classifications (SIC)
- A local content for each SIC is determined based on similar studies for Scottish regions, Orkney and Shetland
- Input output multipliers are used to measure the change in total output following the increase in final demand for the relevant SIC sector's output. Change is the sum of the stimuli direct effect and indirect effects on other sectors.
- In addition we have assessed the potential gross value added (GVA) effects that will arise from retained 'economic rent' from community ownership/benefit payments. Not all 'rent' stays within Shetland – some 'leaks.' The retained rent has an additional GVA impact.
- Total benefits are assessed over the 45 year life of the link and discounted using the social time preference rate of 3.5%
- For a comparative evaluation of the socio-economic benefits of each reinforcement option, the generation related benefit under each generation scenario is capped at the capacity of the reinforcement.

While socio-economic benefit alone cannot justify the transmission link, we believe Ofgem should consider the evident benefit to Shetland. Securing additional economic benefit is fundamentally dependent on reinforcement of the network.

7. CBA results – central case

We have developed a 'central case' for our flow modelling and CBA analysis for each reinforcement option and generation scenario. Our central case includes the following common assumptions:

- SHE Transmission's central capital cost and operating cost assumptions,
- SHE Transmission's delivery date assumptions,
- An asset life of 45 years,
- Constraint costs of £55/MWh and £70/MWh,
- A wind farm long term average capacity factor of 52%,
- Existing Shetland demand is netted off the total generation export, and
- Other CEFM and CBA modelling assumptions as outlined in Section 6.

The results of our central case CBA analysis for each reinforcement option and generation scenario are outlined below.

7.1 Net present value

Table 7-1 and Table 7-2 show the net present value (NPV) for each reinforcement option and each generation scenario based on a long term average constraint cost of £55/MWh (Table 7-1) and £70/MWh (Table 7-2).

Table 7-1: Central case NPV with £55/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1020	1501	1624	1749
2	600 MW HVDC	983	1717	2031	2231
3	800 MW HVDC	882	1612	1932	2308
4	800 MW HVDC P2P	515	1245	1565	1941
5	1000 MW HVDC P2P	470	1200	1520	1896

Table 7-2: Central case NPV with £70/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1503	2115	2271	2431
2	600 MW HVDC	1466	2400	2800	3054
3	800MW HVDC	1343	2272	2680	3159
4	800 MW HVDC P2P	976	1905	2313	2792
5	1000 MW HVDC P2P	931	1860	2268	2747

The results show that all reinforcement options under all generation scenarios return a positive NPV. NPVs are lower under the £55/MWh constraint cost – where the 450 MW HVDC cable (Option 1) returns the highest positive NPV under scenario S1. Under scenarios S2 and S3 the 600 MW HVDC cable (Option 2) returns the highest NPV, whilst under S4 the 800 MW HVDC link (Option 3) returns the highest NPV. At a higher constraint cost of £70/MWh all NPVs are higher and there is no change to the most favourable option in each scenario.

The results suggest that Shetland transmission reinforcement is strongly economically viable under the four generation scenarios considered, demonstrating a clear economic case for reinforcement.

7.2 Least worst regret

While the NPV analysis shows that the economic viability of reinforcement is robust, the results also show that the optimum reinforcement option differs depending on generation scenario analysed. In order to determine which reinforcement option represents the option of Least Worst Regret (LWR) across all scenarios, we have undertaken regrets analysis.

Least worst regrets explained:

- For each generation scenario considered, the NPV of each reinforcement option is compared to that of the reinforcement option with the highest NPV. The result is the regret (disbenefit) of selecting one particular reinforcement option over that with the highest NPV. For example, if Option A has an NPV of £500 m and Option B an NPV of £450 m, the regret of choosing Option B over Option A is £50 m. The regret of choosing Option A is zero. The approach provides a series of regrets for each transmission option under each generation scenario.
- The maximum (worst) regret across all generation scenarios is then determined for each reinforcement option.
- The option of least worst regret is the one that minimises the worst regret across scenarios

Table 7-3 shows the individual regrets as well as the maximum (worst) regret for each option in the central case with a £55/MWh constraint cost. The results show that Option 2, the 600 MW link, is the overall option of LWR. The worst regret of adopting Option 2 is £78m under scenario S4 compared to £138m for the 800 MW Link (Option 3) under scenario S1. The increase in regret of investing in Option 3 over Option 2 is £60m.

Table 7-3: Central case LWR with £55/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	216	408	560	560
2	600 MW HVDC	37	0	0	78	78
3	800 MW HVDC	138	105	99	0	138
4	800 MW HVDC P2P	505	472	466	367	505
5	1000 MW HVDC P2P	550	518	511	412	550

The lower capacity Option 1 is optimal under the lowest generation scenario, when more generation emerges the regret of this reinforcement rapidly increases due to the heavy constraints incurred. In scenario S4, the regret associated with Option 1 increases to £560 m, the highest regret of all those calculated for this constraint cost.

Options 4 and 5 suffer from high regrets in each scenario due to their relatively high capex costs, however the effect of mainland constraints is not considered in our central case but is explored as a sensitivity in 8.2.

Table 7-4 shows the LWR analysis with a higher constraint cost of £70/MWh. Option 2 remains the option of LWR.

Table 7-4: Central case LWR with £70/MWh constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	285	529	728	728
2	600 MW HVDC	37	0	0	105	105
3	800 MW HVDC	160	128	120	0	160
4	800MW HVDC P2P	527	495	487	367	527
5	1000 MW HVDC P2P	572	540	532	412	572

Overall we can conclude that Option 2, the 600 MW HVDC link, is the reinforcement option of LWR under both constraint cost assumptions in the central case.

7.3 The impact of uncertainty

Our analysis under central case assumptions shows that Option 2, the 600 MW HVDC link, is the option of LWR and the optimum reinforcement for scenarios S2 and S3. Clearly, over the life of the transmission asset variations on the generation scenarios developed and constraints costs assumed are likely to emerge, with no specific generation scenario or constraint cost assumption prevailing for the entire life of the asset.

To further explore the impact of variations in the key assumptions of generation and constraint costs, we have analysed the results across a range of outcomes to highlight the impact on the preferred reinforcement option. Figure 7-1 shows the results of this exercise for variations in constraint costs and ranges of generation capacity.

Figure 7-1: Impact of generation capacity and constraint costs on NPVs

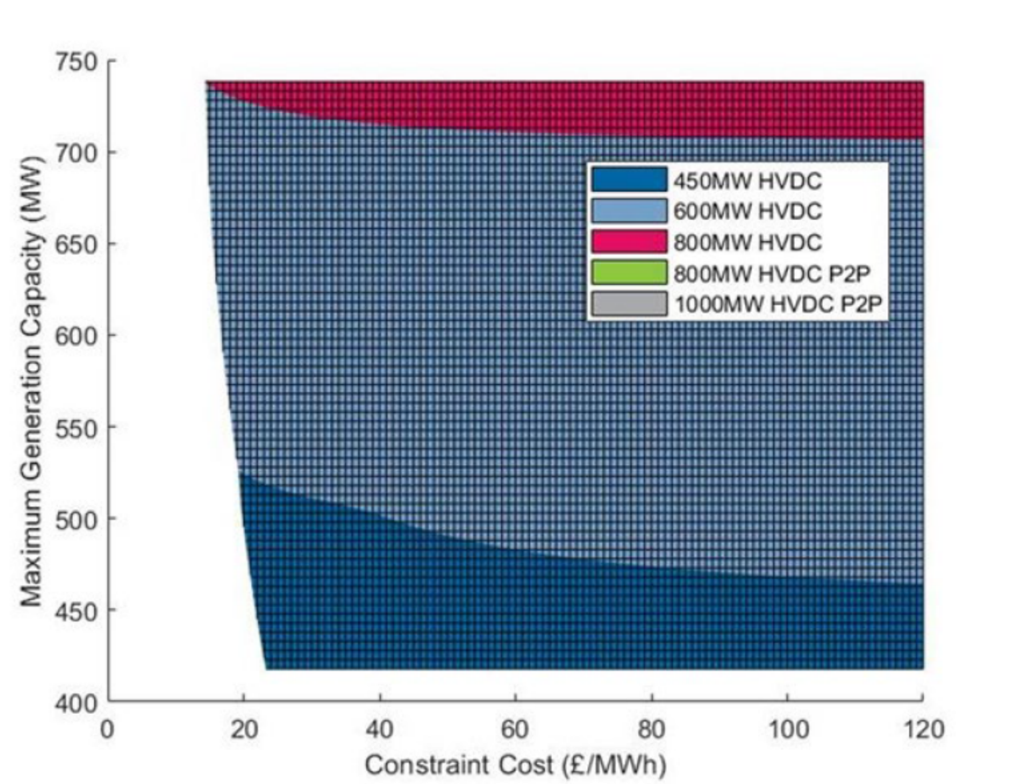


Figure 7-1 shows the 'tipping point' between each of the reinforcement options – between Option 1 and 2 (450 MW and 600 MW HVDC) this is around 470 MW based on a £55-70/MWh constraint cost. Based on the same range of constraint costs, the 600 MW HVDC option is optimal up to approximately 700 MW, at which point the 800 MW HVDC option 'tips' to become optimal.

7.4 Socio-economic impact

There is a clear interdependency between grid reinforcement and the realisation of potential economic benefit arising from renewable development on Shetland. In order to determine the materiality of the potential socio-economic benefit to Shetland we have assessed the gross value added (GVA) benefit to the economy of Shetland associated with the transmission link and the subsequent generation realised. Appendix B of this report provides a detailed description of the methodology and assumptions underpinning GHD's analysis.

Table 7-5 shows the total present value (PV) GVA (economic) benefit for each generation scenario and transmission option considered in GHD's Central Case analysis. The economic impact includes all wind developments (large and small) and the transmission link, but excludes on-island transmission works.

Table 7-5: Present value GVA impact for each scenario (£m 2018 prices)

Transmission Options	Transmission (£m)	Generation (£m)				Total
		S1 - 414MW	S2 - 582MW	S3 - 655MW	S4 - 742MW	
Option 1 - 450MW HVDC	11	132	141	143	144	143 - 156
Option 2 - 600MW HVDC	12	132	183	191	193	143 - 204
Option 3 - 800MW HVDC	12	132	183	208	238	144 - 251
Option 4 - 800MW HVDC P2P	17	132	183	208	238	149 - 256
Option 5 - 1000MW HVDC P2P	18	132	183	208	238	150 - 257

The overall economic benefit to Shetland is substantial, ranging from £143 m to £256 m depending on the generation scenario and the reinforcement option considered. In terms of GVA impact, the benefit of the transmission link is small due to the relatively minor local content assumed. Conversely, the impact of wind generation is much larger.

In assessing the GVA impact of each transmission option on generation – for simplicity we have capped the MW generation at the size of the reinforcement, i.e. the socioeconomic benefit from generation connection associated with transmission Option 1 is capped at 450 MW. Clearly additional generation may economically connect without incurring significant constraint costs, therefore our analysis is conservative.

The larger the capacity of the transmission option, the greater the amount of generation can be developed on the Islands and thus leads to economic benefits during wind farm construction and operation as well as the establishment of further community funds directly related to the successful operation of renewable projects which directly benefit island residents and communities.

7.4.1 Socio-economic benefit in context

Whilst the identified economic benefit is significant it is worth putting the benefit into context. Table 7-6 shows the minimum and maximum lifetime economic benefit of the reinforcement as derived from our analysis. The average lifetime economic benefit per annum has also been derived (based on the assumed life of 45 years). The economic benefit per annum ranges between £3.6 m and £6.4 m per annum. The minimum and maximum economic benefit per annum has been compared to a number of Shetland-specific demographic and economic parameters including: population; number of households; regional GVA; average gross household income and average GDHI (gross disposable household income)[16].

Table 7-6: GVA benefit in relation to Shetland demographic and economic data (2018 prices)

Lifetime Economic Benefit (£m)	Economic Benefit Per Annum (£m)	Economic Benefit Per Capita Per Annum (£)	Economic Benefit Per Household Per Annum (£)	Economic Benefit Per Annum as a Proportion of Total GVA (%)	Economic Benefit Per Household Per Annum as a Proportion of Average Household Income (%)	Economic Benefit Per Household Per Annum as a Proportion of Average GDHI (%)
£143	£3.6	£154	£347	0.5%	1.4%	1.7%
£257	£6.4	£277	£624	0.9%	2.5%	3.1%
		...based on Population of Shetland in 2016	...based on No. of Households in Shetland in 2016	...based on Shetland GVA (£m, 2016)	...based on Shetland Average Gross Household Income (£)	...based on Shetland Average GDHI (£)
		23,200	10,283	£680	£24,600	£20,124

Our analysis indicates that **the reinforcement options can be expected to create an annual economic benefit of between £154 and £277 per person per annum or around £347 to £623 of economic benefit per household per annum**. The total economic benefit is likely to form between 21% and 38% of the total regional GVA (as of 2016) whilst on an annual basis the economic benefit would range between 0.5% and 0.9% of the total regional GVA. The economic benefit per annum is equivalent to between 1.4% to 2.5% of gross household income, whilst the economic benefit in relation to GDHI is higher at between 1.7% and to 3.1%. Clearly the impact on a per capita, per household and overall economic perspective is substantial and has the potential to improve the economic welfare and social well-being of residents in the Shetland Islands.

Table 7-7 presents the Shetland demographic and economic ratios relative to the equivalent ratios derived for the Highlands (a large geographic area with a relatively sparse population) and the City of Edinburgh (a small geographic area with a compact population). The analysis is presented based on the same amount of economic benefit (in £m terms) as that derived for the Shetland reinforcement.

Table 7-7: Comparison of GVA ratios

Region	GVA Benefit	GVA benefit per capita per annum (£)	GVA benefit per household per annum (£)	GVA benefit per annum as a proportion of total GVA	GVA benefit per household per annum as a proportion of Average Household Income (£)
Shetland	Minimum	154	347	0.5%	1.4%
	Maximum	276	623	0.9%	2.5%
Highlands	Minimum	14	30	0.0%	0.1%
	Maximum	46	101	0.1%	0.5%
Edinburgh City	Minimum	6	14	0.0%	0.1%
	Maximum	21	47	0.1%	0.2%

The same amount of economic benefit arising in the Highlands or the City of Edinburgh would have a much smaller relative impact on the regional economy and on households. Considered another way, to derive the same economic benefit on a household-to-household basis would require a project that created 6 times more economic benefit in the Highlands and over 13 times more economic benefit in the City of Edinburgh.

[16] Refer to Appendix C for details of source data and assumptions.

Whilst local multipliers and leakage rates will differ by region (meaning the ratio between capital investment and resulting economic benefit may be higher in many regions), there are also other factors that could result in lower economic benefits or a lack of 'Need' for investment in the first place. SHE Transmission are required to connect customers where they want to be connected and the generation scenarios developed in our CBA are a reasonable reflection of the known (not speculative) demand and appetite for building wind generation on the islands if a link were available. This demand/appetite is driven by the high capacity factors not available elsewhere on the mainland, a lack of opposition from residents and local councils from building onshore wind farms and the Council and community's desire to tap into the economic benefit that investment would bring.

8. CBA results - sensitivities

Following our assessment of the central case we have explored a number of further sensitivities, including:

- Project capex – increase 20%; and
- Lower wind load factor – 48%;
- The timing of the reinforcement option delivery dates;
- Impact of onshore constraints;
- The costs associated with SHEPD network investment.

All sensitivity analysis uses central case assumptions as outlined in Section 7. The results of our CBA sensitivity analysis are outlined below.

8.1 Project capex (+20%)

We have also explored the impact of increasing project capex by 20%. Table 8-1 shows the results in £m (2018 prices) – NPVs remain positive for all options under all generation scenarios.

Table 8-1: High project capex NPV with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	870	1351	1474	1599
2	600 MW HVDC	826	1560	1874	2073
3	800MW HVDC	720	1450	1770	2147
4	800 MW HVDC P2P	280	1010	1330	1706
5	1000 MW HVDC P2P	225	955	1276	1652

Table 8-2 shows the impact on the regret analysis of this increased capex sensitivity study.

Table 8-2: High project capex regret analysis with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	209	400	548	548
2	600 MW HVDC	44	0	0	73	73
3	800 MW HVDC	150	110	104	0	150
4	800MW HVDC P2P	590	550	544	440	590
5	1000 MW HVDC P2P	645	604	598	495	645

With higher capex the 600 MW HVDC link remains the option of LWR. Although not presented, at a constraint cost of £70/MWh the 600 MW HVDC link is the option of LWR.

We can conclude that a 20% increase in project capex, while clearly reducing project NPVs, has no material impact on the viability of the project or the option of LWR.

8.2 Lower wind farm load factor

The central case uses the 2014 Burradale wind profile with a mean load factor of 52.14%. While this load factor is also the long run average of Burradale since its construction in

2000/2003, we have also analysed the impact of a lower wind farm capacity factor based on the Barradale wind farm for year 2017 with a mean capacity factor of 47.99%.

Table 8-3 shows the results in £m (2018 prices) – NPVs remain positive for all options under all generation scenarios, but are lower than the central case.

Table 8-3: Low wind capacity factor NPV with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	859	1347	1486	1621
2	600 MW HVDC	822	1496	1795	2023
3	800MW HVDC	726	1396	1691	2037
4	800 MW HVDC P2P	359	1029	1324	1670
5	1000 MW HVDC P2P	314	984	1278	1625

Table 8-4 shows the impact on the regret analysis of utilising the wind farm profile with the lower annual capacity factor.

Table 8-4: Low wind capacity factor regret with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	149	310	415	415
2	600 MW HVDC	37	0	0	14	37
3	800 MW HVDC	133	100	105	0	133
4	800 MW HVDC P2P	500	467	472	367	500
5	1000 MW HVDC P2P	545	512	517	412	545

With a lower capacity factor the 600 MW HVDC link remains the option of LWR at a constraint cost of £55/MWh, with its position reinforced relative to the 800 MW Link.

At a constraint cost of £70/MWh, the 600 MW HVDC Link also remains the option of LWR, as shown in Table 8-5 and Table 8-6.

Table 8-5: Low wind capacity factor NPV with £70/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1298	1919	2096	2268
2	600 MW HVDC	1261	2119	2500	2789
3	800 MW HVDC	1145	1998	2373	2813
4	800 MW HVDC P2P	778	1631	2006	2446
5	1000 MW HVDC P2P	733	1586	1960	2401

Table 8-6: Low wind capacity factor NPV with £70/MWh constraint cost

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	200	404	545	545
2	600 MW HVDC	37	0	0	24	37
3	800 MW HVDC	153	121	127	0	153
4	800 MW HVDC P2P	520	488	494	367	520
5	1000 MW HVDC P2P	565	533	540	412	565

At a lower wind capacity factors, the sensitivity of the results to the constraint cost is increased, but the 600 MW link remains the option of LWR.

8.3 Variation in delivery dates

In this section we explore two aspects surrounding the delivery date of the reinforcement options:

1. The impact of a deferring delivery date for all options. Deferrals of one and two years are considered.
2. We also explore the impact of delivering all options with identical earliest in service date (EISD) of 31st March 2024.

8.3.1 Impact of delayed delivery

Table 8-7 and Table 8-8 show the resulting NPVs (£ m, 2018 prices) for all options under the central case assumptions with a one year deferral for both a £55/MWh constraint cost and a £70/MWh constraint cost.

Table 8-7: Option NPV with one year deferral with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1015	1495	1606	1703
2	600 MW HVDC	979	1715	2013	2181
3	800 MW HVDC	854	1561	1872	2238
4	800 MW HVDC P2P	499	1205	1517	1883
5	1000 MW HVDC P2P	455	1162	1473	1839

Table 8-8: Option NPV with one year deferral with £70/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1490	2101	2242	2366
2	600 MW HVDC	1454	2391	2769	2984
3	800 MW HVDC	1301	2200	2596	3062
4	800 MW HVDC P2P	946	1845	2241	2707
5	1000 MW HVDC P2P	902	1801	2198	2663

The results show that NPVs reduce compared to the central case. Therefore we can conclude that there is no benefit to deferring reinforcement.

Table 8-9 and Table 8-10 show the impact on NPV regret of deferral for two years in the central case under a £55/MWh and £70/MWh constraint cost.

Table 8-9: Option NPV with two year deferral with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	983	1456	1555	1650
2	600 MW HVDC	949	1676	1949	2114
3	800 MW HVDC	828	1511	1814	2170
4	800 MW HVDC P2P	484	1167	1471	1826
5	1000 MW HVDC P2P	442	1125	1428	1784

Table 8-10: Option NPV with two year deferral with £70/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1443	2045	2171	2292
2	600 MW HVDC	1408	2334	2681	2892
3	800 MW HVDC	1260	2130	2516	2968
4	800 MW HVDC P2P	917	1786	2172	2625
5	1000 MW HVDC P2P	874	1744	2130	2583

The impact of a two year deferral further reduces NPVs below the central case.

As a result we can conclude there is no benefit in deferring the investment under any scenario. The higher the constraint cost, the higher the regret of deferral, and therefore there is no benefit of deferring the delivery of any option.

8.3.2 Identical earliest in service date (EISD)

Options 1 and 2 (the 450 MW HVDC and 600 MW HVDC options) have EISD of 31st March 2024. The higher capacity options all have later EISD of 31st December 2025. These differing dates represent a delay of 20 months during which constraints cannot be mitigated. To understand the implications of the impact of these timings we have assessed all options assuming they are all delivered in March 2024.

Table 8-11 and Table 8-12 show the resulting NPVs (£ m, 2018 prices) for both a £55/MWh constraint cost and a £70/MWh constraint cost.

Table 8-11: NPV with EISD of 31st March 2024 with £55/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1020	1501	1624	1749
2	600 MW HVDC	983	1717	2031	2231
3	800 MW HVDC	958	1692	2053	2467
4	800 MW HVDC P2P	589	1323	1685	2098
5	1000 MW HVDC P2P	544	1278	1639	2053

Table 8-12: NPV with EISD of 31st March 2024 with £70/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	1503	2115	2271	2431
2	600 MW HVDC	1466	2400	2800	3054
3	800 MW HVDC	1440	2375	2835	3361
4	800 MW HVDC P2P	1072	2006	2466	2993
5	1000 MW HVDC P2P	1026	1961	2421	2947

The NPVs of Options 1 and 2 do not change from the central case, however the NPVs of Options 3, 4 and 5 increase. These results suggest there is benefit of delivering the higher capacity options earlier.

Table 8-13 and Table 8-14 show the regrets (£ m, 2018 prices) for both a £55/MWh constraint cost and a £70/MWh constraint cost.

Table 8-13: Regrets with EISD of 31st March 2024, £55/MWh constraint cost

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	216	429	718	718
2	600 MW HVDC	37	0	22	236	236
3	800 MW HVDC	62	25	0	0	62
4	800 MW HVDC P2P	431	394	368	368	431
5	1000 MW HVDC P2P	476	439	414	414	476

Table 8-14: Regrets with EISD of 31st March 2024, £70/MWh constraint cost

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	285	563	930	930
2	600 MW HVDC	37	0	34	307	307
3	800 MW HVDC	62	25	0	0	62
4	800 MW HVDC P2P	431	394	368	368	431
5	1000 MW HVDC P2P	476	439	414	414	476

The results show a change from the central case – if all options are delivered in March 2024, then Option 3, the 800 MW option, is the option of LWR and is elevated to the optimum reinforcement in both S3 and S4. Given the results of this analysis we have also explored the 'timing tipping point' impact of Option 3 – in short how great a delay to the Option 3, relative to 31st March 2024, will still result in it being the option of LWR?

Figure 8-1 and Figure 8-2 show the LWR impact (£ m, 2018 prices) on Options 2 and 3 of delaying the EISD of Option 3. The LWRs of the options cross at around 16-18 months delay – suggesting that if Option 3 can be brought forward by four to six months it will become the option of LWR.

Figure 8-1: Option 3 (800 MW HVDC) LWR impact, £55 MWh / constraint cost

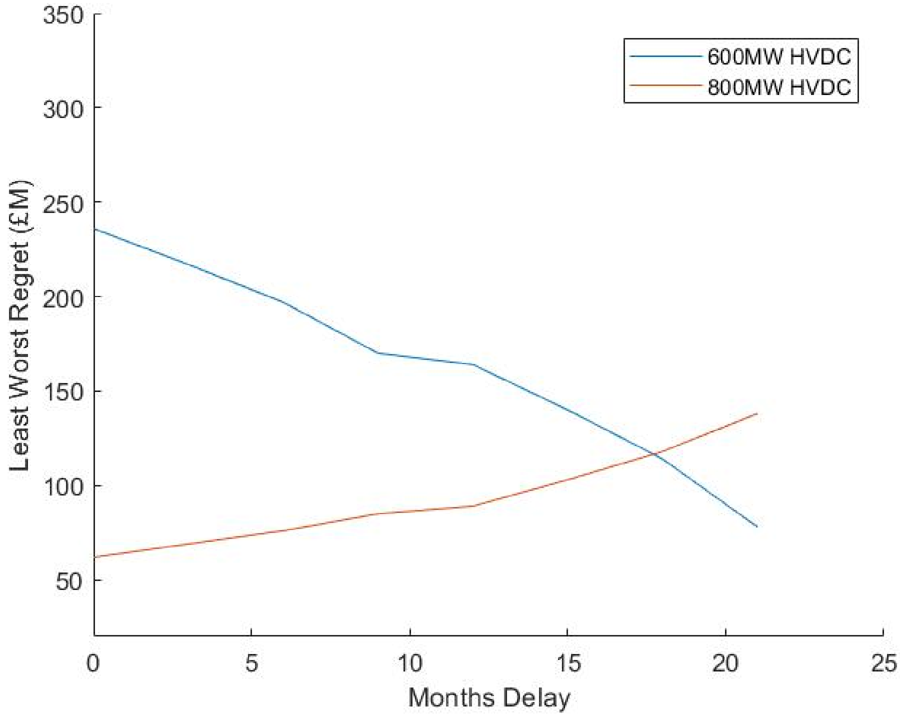
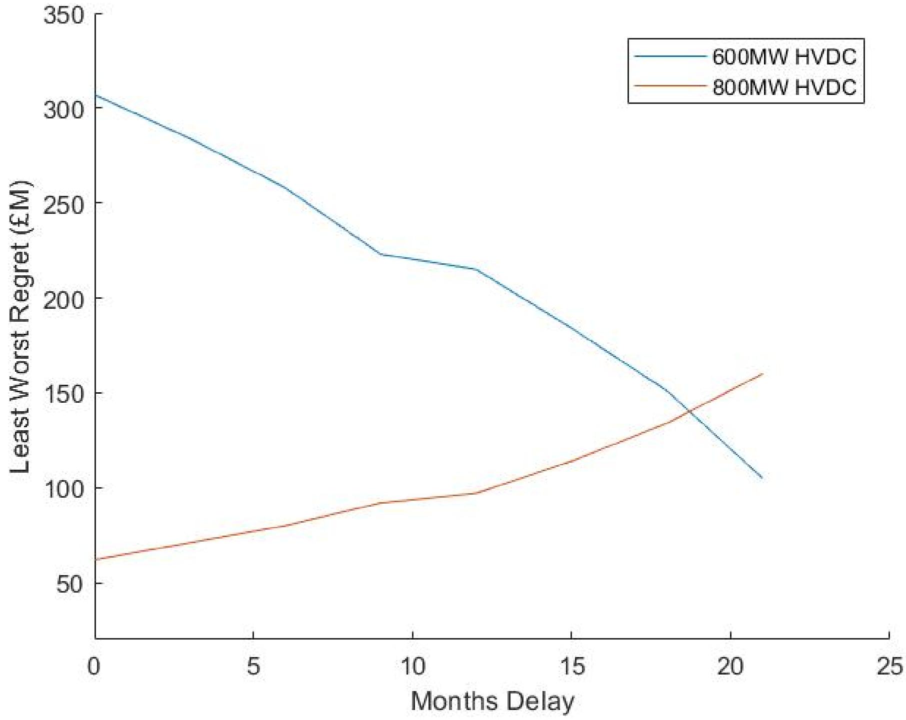


Figure 8-2: Option 3 (800 MW HVDC) LWR impact, £70 MWh / constraint cost



Following the results of our analysis SHE Transmission explored in depth the potential to accelerate delivery of option 3. After a detailed evaluation SHE Transmission concluded that the 800 MW link could not be significantly accelerated and the earliest delivery represents a 20 month delay to Option 2.

8.4 Onshore constraints

The CEFM assess flows across the reinforcement from Shetland to the Scottish mainland. However, it is possible that some constraints may occur on the onshore network, particularly boundary B1. Therefore, we have modified the CEFM to include the impact, if any, of onshore constraints across boundaries B0 and B1. Constraints on the B1 boundary will typically be higher for a larger capacity Shetland-mainland link and therefore the impact of including onshore constraints may disadvantage the larger capacity options. Point-to-point (P2P) Options 4 and 5, connecting south of B1 at Rothienorman, avoid the constraints on the B1 boundary and so would perform better in this sensitivity. The NOA has identified considerable reinforcement required to B1 and we assume this is completed for Boundary B1 in the CEFM.

Table 8-15 shows the impact on project NPVs (£55/MWh constraint cost, 2018 prices). NPVs continue to remain positive for all options under all generation scenarios.

Table 8-15: NPV with onshore constraints, £55/MWh constraint cost

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	908	1342	1458	1578
2	600 MW HVDC	871	1518	1791	1972
3	800 MW HVDC	768	1409	1680	1989
4	800 MW HVDC P2P	515	1245	1565	1941
5	1000 MW HVDC P2P	470	1200	1520	1896

Table 8-16 shows the impact on regret analysis of inclusion of onshore constraints (£55 / MWh constraint cost).

Table 8-16: Regret analysis with onshore constraints

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	0	176	333	411	411
2	600 MW HVDC	37	0	0	17	37
3	800 MW HVDC	140	109	112	0	140
4	800 MW HVDC P2P	393	273	226	48	393
5	1000 MW HVDC P2P	438	318	271	93	438

The 600 MW HVDC link remains the option of LWR with a highest regret of £37 m, compared to £140 m for the next best option. Although not presented, at a constraint cost of £70/MWh the 600 MW HVDC link remains the option of LWR. We can conclude that the inclusion of mainland constraints in the North of Scotland has no material impact on the results of our central case.

8.5 SHEPD

SHEPD is currently undertaking analysis aimed at evaluating a 'New Energy Solution' (NES) for Shetland. As part of its assessment SHEPD is considering a number of ways in which Shetland's future security of supply can be secured and potentially new generation enabled. Ofgem has asked SHEPD to undertake a CBA of the viable energy solutions for Shetland – and the options SHEPD is considering include a transmission link, a distribution link and a replacement power station. As SHE Transmission's proposed transmission link could form part of the NES for Shetland, we have adapted our CBA to consider the costs and benefits of it doing so. This 'all island' sensitivity is aligned with the analysis SHEPD is undertaking and based on the same cost assumptions. However, our analysis does not replicate that of SHEPD – given the generation scenarios developed our high level conclusion is that a high capacity transmission link is a more effective method of exporting generation than a low capacity distribution link. Therefore our CBA sensitivity is not comparing the costs and benefits of a transmission link with the security of supply alternatives for Shetland. Instead this sensitivity takes into consideration the costs and benefits of a transmission link forming part of the NES for Shetland.

Cost assumptions

In order for a transmission link to form part of the NES additional costs must be taken into consideration, these include:

- The establishment of a new grid supply point on Shetland (GSP) – capex approximately. £[redacted]m[17]
- A new 54 MW standby generator operating on gas oil running at around 1.6% load factor based on the following cost assumptions:
  - Capex of £[redacted]m
  - Fixed operating cost of £[redacted] p.a.
  - Variable O&M of £[redacted]/MWh
  - Fuel price of £[redacted]/tonne, thereafter increasing at the same annual percentage rate as BEIS reference case gas oil fuel price assumptions
  - Carbon price based on BEIS reference scenario electricity supply sector carbon price assumptions
  - 20 year life, with a refurbishment cost 80% of original capex
- Plus the cost of importing electricity across the transmission link to Shetland in order to meet demand – assumed to be imported at GB wholesale prices based on BEIS' reference price scenario

These costs are included in our CBA model and result in a PV cost of £[redacted] million. This cost is common to all the transmission reinforcement options considered in our analysis.

Benefit assumptions

The benefit of using transmission reinforcement as part of the NES for Shetland is based on the costs avoided compared to:

- A 60 MW distribution link combined with the standby generation
- A standalone 60 MW 'on island' generator with no associated link to mainland Scotland

Our analysis ***excludes*** the potential benefit of connecting additional renewable generation enabled by the transmission link. There are two key benefits associated with this generation. The first is the socio-economic benefit to Shetland of the Viking Wind Farm, our evaluation has calculated the PV of this socio-economic benefit (GVA) to be around £132 m (see Appendix B).

The other benefit is the potential reduction in wholesale prices, combined with carbon and fuel savings if renewable generation displaces higher cost fossil fuel generation.

The distribution link

The benefit of the transmission link compared to the distribution link is assessed simply as the avoided capex and opex of a 60 MW distribution link. SHEPD provided a capex assumption for the distribution link of £[redacted] m with an annual opex of £[redacted]m. Based on these cost assumptions

[17] This GSP cost is included across our analysis – including central case and all sensitivities

and a 45 year life over which capex is annualised, the present value cost of the distribution link is £[redacted]m. As a distribution link must also employ a standby generator in the same way a transmission link would, the PV cost of standby generation is netted off the cost of the distribution link to lead to an overall PV benefit impact of a transmission link with standby generator of £[redacted]

The on island generating station

The benefit of the transmission link compared to a replacement standalone on island generator on Shetland is assessed as the avoided capex and opex of a 60 MW gas oil fired power station. SHEPD provided a capex assumption for the power station of £[redacted]m and an annual opex of £[redacted]m. The power station is assumed to be refurbished at a cost of 50% of original capex after 20 years. SHEPD also provided the annual marginal cost of operating the power station, marginal costs are based on fuel and carbon price assumptions and a station efficiency of 42%. Based on these cost assumptions and a 45 year life over which capex is annualised, the present value cost of the on island generator is £[redacted] m. This PV cost of on island generation is the cost avoided by building a transmission link with standby generation, therefore, when compared to an on island generator, the benefit of the transmission link with standby is £[redacted]m [redacted]

Based on potentially lower costs for a 60 MW on island generator of £[redacted]m, a fixed operating cost of £[redacted]m p.a. and a 44% efficiency, then the PV cost of on island generation is £[redacted]m. The subsequent benefit of the transmission link with standby compared to an on island generator falls to £[redacted]m [redacted]

In summary, the results suggest that a distribution link with standby generation is a more cost effective option than the on island generator, even when adopting arguably more competitive cost assumptions for the on island generator. The result is largely based on the ability to import lower cost electricity than that generated by the on island generator. We can also conclude that the additional costs associated with using the transmission link as part of the NES security of supply solution for Shetland is outweighed by the benefit of costs avoided by SHEPD – leading to a positive NPV impact of between £129 m – £618 m.

8.6 Summary

The NPVs returned in our central case are strong and therefore sensitivity analysis of a 20% increase in project capex, while reducing project NPVs, does not change our conclusions and the project remains strongly economically viable. A similar outcome arises if the cost of mainland constraints is included or if the long term wind farm capacity factor is below 50%. Under all these sensitivities Option 2, the 600 MW link, is the option of LWR.

Only when all options are delivered at the identical, earliest date of March 2024 does the option of LWR change from Option 2, and Option 3, the 800 MW link, becomes the LWR reinforcement. However, SHE Transmission cannot deliver the 800 MW link before the end of Q4 2025 and therefore we can conclude that the 600 MW link remains the option of LWR

The transmission link to Shetland can also form part of the New Energy Solution (NES) for Shetland. We have assessed the costs and benefits of a transmission link as part of the NES and conclude that overall NPVs will improve – while additional standby generation investment will be required on Shetland, this is mitigated by the expenditure avoided by SHEPD on either a distribution link or an on island power station.

9. Analysis and conclusions

This report details the Cost Benefit Analysis undertaken by GHD to support SHE Transmission's Needs Case submission for Shetland transmission connection project. As part of this process we have performed a rigorous assessment of the proposed transmission connection to mainland Scotland across a credible range of potential generation development scenarios.

Our analysis shows that when assessed as part of a 'conditional' Needs Case across a range of cost and output assumptions Option 2, the 600 MW HVDC link, is the reinforcement option of LWR. The NPVs returned in our central case are strong and therefore sensitivity analysis of a 20% increase in project capex, while reducing project NPVs, does not change our conclusions and the project remains strongly economically viable. A similar outcome arises if the cost of mainland constraints is included or if the long term wind farm capacity factor is below 50%. Under all these sensitivities Option 2, the 600 MW link, is the option of LWR. Deferring the delivery of the SHE Transmission proposed Option 2 beyond the planned delivery date of 2024 provides no benefit.

Only when all options are delivered at the identical, earliest date of March 2024 does the option of LWR change from Option 2 to Option 3, the 800 MW link, which then becomes the LWR reinforcement. However, SHE Transmission cannot deliver the 800 MW link before the end of Q4 2025 and therefore we can conclude that the 600 MW link remains the option of LWR

The transmission link to Shetland can also form part of the New Energy Solution (NES) for Shetland. We have assessed the costs and benefits of a transmission link as part of the NES and conclude that overall NPVs will improve – while additional standby generation investment will be required on Shetland, this is mitigated by the expenditure avoided by SHEPD on either a distribution link or an on island power station.

An additional consideration relevant to Shetland Needs Case submission is the 2017 'Islands (Scotland) Bill' that places a duty on relevant public bodies to have regard to island communities in exercising their functions – including an island communities impact assessment ('island proofing') of any new/revised policy likely to have a significantly different effect on islands communities from its effect on other communities. While not a specifically defined 'relevant' public body, Ofgem should be mindful of the socio-economic impact of transmission reinforcement on Shetland.

Our analysis indicates that the reinforcement options can be expected to create an annual economic benefit of between £154 and £276 per person per annum or around £347 to £623 of economic benefit per household per annum. The impact on a per capita, per household and overall economic perspective is substantial and has the potential to vastly improve the economic welfare and social well-being of the Shetland Islands.

The same amount of economic benefit arising in the Highlands or the City of Edinburgh would have a much smaller relative impact on the regional economy and on households in those locations. Considered another way, to derive the same economic benefit on a household-to-household basis would require a project that created 6 times more economic benefit in the highlands and over 13 times more economic benefit in the City of Edinburgh

Taking due account of these additional considerations GHD believes that this further supports the principal recommendation arising from this work that ***Option 2 (600 MW HVDC link) is the preferred transmission connection option for Shetland***. This recommendation is fully aligned with the SHE Transmission Needs Case submission.

Appendices

Appendix A – Generation scenarios

A.1 Complexity of generation development on Shetland

The anticipated level of new generation connections will be the key determinant to the feasibility of transmission reinforcement. Essential to the development of a SWW Needs Case is a plausible view of new generation development in the study area over the 45-year regulatory life of the transmission asset. Given the relatively long life of the asset, the generation scenarios developed must explore differing and credible paths of growth in order for SHE Transmission to fully 'stress test' the requirement for transmission reinforcement in its Needs Case.

For Shetland, where no transmission link exists, a key uncertainty is whether any new generation projects will emerge over the next 5 years – the development period required for a transmission link. Shetland's geographical location provides the islands with significant wind energy resource potential - but limits the potential for other large-scale renewable generation technologies such as biomass and large scale solar[18]. Whilst there is clearly potential for marine energy resources, and some tidal flow development in the Bluemull Sound between Unst and Yell, uncertainty over future development is high, including achieving commercial viability without a significant shift in UK Government subsidy policy. As such, wind power will form the basis of near term generation growth on Shetland.

However, determining the prospects for future onshore wind generation – location and certainty of progression – on Shetland (and the Scottish islands in general) is complex. The existing electricity network on Shetland has reached capacity and therefore new generation is unable to connect to the grid without tangible plans and commitment to reinforce the network. This results in a 'Catch-22' situation.

Scottish Islands Catch 22:

The 'need' for the transmission reinforcement is dependent on the development of generation on the islands, but generation development on the islands cannot occur without the transmission reinforcement. The case for either transmission or generation development is entirely predicated on the other.

To understand the prospects for generation development on Shetland requires an understanding of the local (micro) conditions and drivers for investment that may not be visible when making an assessment at a national (macro) level.

A.1.1 GB subsidy support

The case for transmission or generation development is entirely predicated on the other. The situation is further complicated by the position of the Shetland outside the GB main interconnected transmission system (MITS) – any new transmission reinforcement will lead to transmission connected generators incurring a 'local spur' charge for transmission to the islands together with a 'wider' TNUoS charge to the nearest transmission charging zone. Given the relatively high cost of the local spur (a subsea link) then the resulting TNUoS charge for island generators is high.

In October 2012, The Rt Hon. Edward Davey and the Scottish Government set up a joint independent study to address concerns that renewable projects on the Scottish Islands were '*not coming forward quickly enough, in part because of the cost of the links required to connect the islands to the mainland transmission network*' . Further analysis outlined the increased cost of generation for renewable projects on the islands arising mainly from the increased TNUoS

[18] Although rooftop solar PV can be found throughout the islands.

charges. The report also outlined the potential of the islands to generate significant renewable energy, including the further development of marine generation, and the subsequent positive economic impact on island communities.

The higher cost of island generation, coupled with the potential benefit to the islands and their role in the development of embryonic marine generation, led to DECC's[19] consultation proposal for an 'islands' CfD. The 2013 consultation on additional support for islands renewables concluded that:

> **"The projects are physically and electrically remote from the high voltage transmission system needed for the export of their generation output and would require long new connections to the Main Interconnected Transmission system based on subsea High Voltage DC cables. Under the transmission charging regimes, they are forecast to be subject to transmission charges (TNUOS) of several times the average for comparable generators located elsewhere in the UK. We consider that the characteristics described above mean that the development of onshore wind on the Scottish islands constitutes a separate class of renewable generation that warrants separate treatment and potentially a different level of support to other onshore projects."**

The 2017 Conservative party's manifesto made a commitment to "support the development of wind projects in the remote islands of Scotland, where they will directly benefit local communities". The Conservative commitment was more recently reiterated by Richard Harrington, Parliamentary Under Secretary of State at the Department for Business, Energy and Industrial Strategy who stated in a House of Commons debate in July 2017:

> **"I hope that my response today....provides some reassurance... that the Government will support the development of onshore wind projects in the remote islands of Scotland, where they will directly benefit local communities."**

In October 2017 the Government finally announced its intention to allow islands wind projects to compete in the 'less established technologies' CfD auction to be held in spring 2019:

> **"We want to go further creating thousands of good jobs and attracting billions of pounds worth of investment. That's why we are ensuring that remote island wind projects in Scotland, which have the potential to benefit the island communities directly, have access to the same funding opportunities as offshore wind in the next renewables auction round."**
>
> UK Government Press release, Boost for island wind projects as UK government announces new funding for renewable generation, 11 October 2017[20]

Key to the decision was the potential for renewable projects to benefit local communities.

A.1.2 Scotland

In January 2017, the Scottish Government published its draft Scottish Energy Strategy - The Future of Energy in Scotland[21]. The strategy highlights the need for secure, reliable and affordable energy supplies as being central to the continued inclusive growth of the Scottish economy. A separate Onshore Wind Policy Statement[22] was issued alongside the Draft Energy Strategy. The strategy makes clear Scottish Government support for further onshore wind development in Scotland, and in particular on the Islands:

[19] DECC has since been replaced by the Department for Business, Energy & Industrial Strategy (BEIS).
[20] https://www.gov.uk/government/news/boost-for-island-wind-projects-as-uk-government-announces-new-funding-for-renewable-generation
[21] http://www.gov.scot/Publications/2017/01/3414
[22] http://www.gov.scot/Publications/2017/01/7344

> **"Onshore wind development is essential to Scotland's transformation to a fully decarbonised energy system by 2050 and brings opportunities which underpin our vision to grow a low carbon economy and build a fairer society. This statement reaffirms the Scottish Government's existing onshore wind policy set out in previous publications...**
>
> **...Although electricity generation energy policy is largely reserved to the UK Government, the Scottish Government wishes to make full use of its devolved powers to promote investment in appropriately sited onshore wind...**
>
> **...A number of recent changes at both a UK and Scottish level have highlighted the need to reassess the role of onshore wind to ensure it continues to deliver maximum value for Scotland in terms of economic, social and environmental benefits...**
>
> **...The Scottish Government will continue to support further development of onshore wind in order to achieve the targets set by the Climate Change (Scotland) Act at the lowest cost. Onshore wind offers low carbon renewable electricity at scale and sustains growth and employment in the Scottish supply chain....**
>
> **...Island wind represents an exciting opportunity for sustainable economic development that would provide tangible benefits for the communities on the islands...**
>
> **...The Scottish Government is of the firm view that the unique characteristics of island wind, specifically the technical challenges and variation in costs and revenues, sets the technology apart from onshore mainland wind. We remain committed to realising the potential of the island projects and capturing the wider renewable resource potential of all of Scotland's islands. We continue to press UK Ministers to recognise the strong case for a distinct approach to support for island wind projects."[23]**

In terms of planning, Scotland's National Planning Framework recognises the country's significant renewable energy resource and the key role of coastal and island locations in realising the potential of renewable energy. A letter from the Chief Planner to all local authorities on 11 November 2015 confirmed that despite changes to UK policy on the development of onshore wind, the Scottish Government's policy remains unchanged. This includes support for new onshore renewable energy developments, including onshore wind and particularly community-owned and shared ownership schemes. This policy support continues even if national renewable energy targets are met – in large part due to the economic and social benefits.

Onshore wind development, particularly on the islands is an important part of the Scottish Government's energy strategy.

A.1.3 Local government

In June 2017, the Scottish government introduced what it has described as an 'historic bill' to create a sustainable future for Scotland's islands. The proposed legislation aims to offer greater powers to local authorities on the islands, including Shetland, Orkney and the Western Isles. The Bill will give island councils powers over activities on and around their coastlines. As part of their 'Our Islands Our Future' campaign, local authorities were seeking additional powers and resources to shape the destinies of Orkney, Shetland and the Western Isles, including:

- Control of the seabed around the islands, allowing revenues currently paid to the Crown Estate to be channelled into local needs.
- New grid connections to the Scottish mainland to allow world class wave, tidal and wind energy resources to generate maximum benefits for the islands.

[23] The consultation process for the draft energy strategy is now closed but the final strategy is not yet available.

- New fiscal arrangements to allow the islands to benefit more directly from the harvesting of local resources, including renewable energy and fisheries.

The Bill was unanimously backed by MSPs at Holyrood and passed Stage 3 on 30 May 2018. The Bills passing gives island councils extra powers over activities on and around their coastlines and requires ministers to have a long-term plan for improvement.

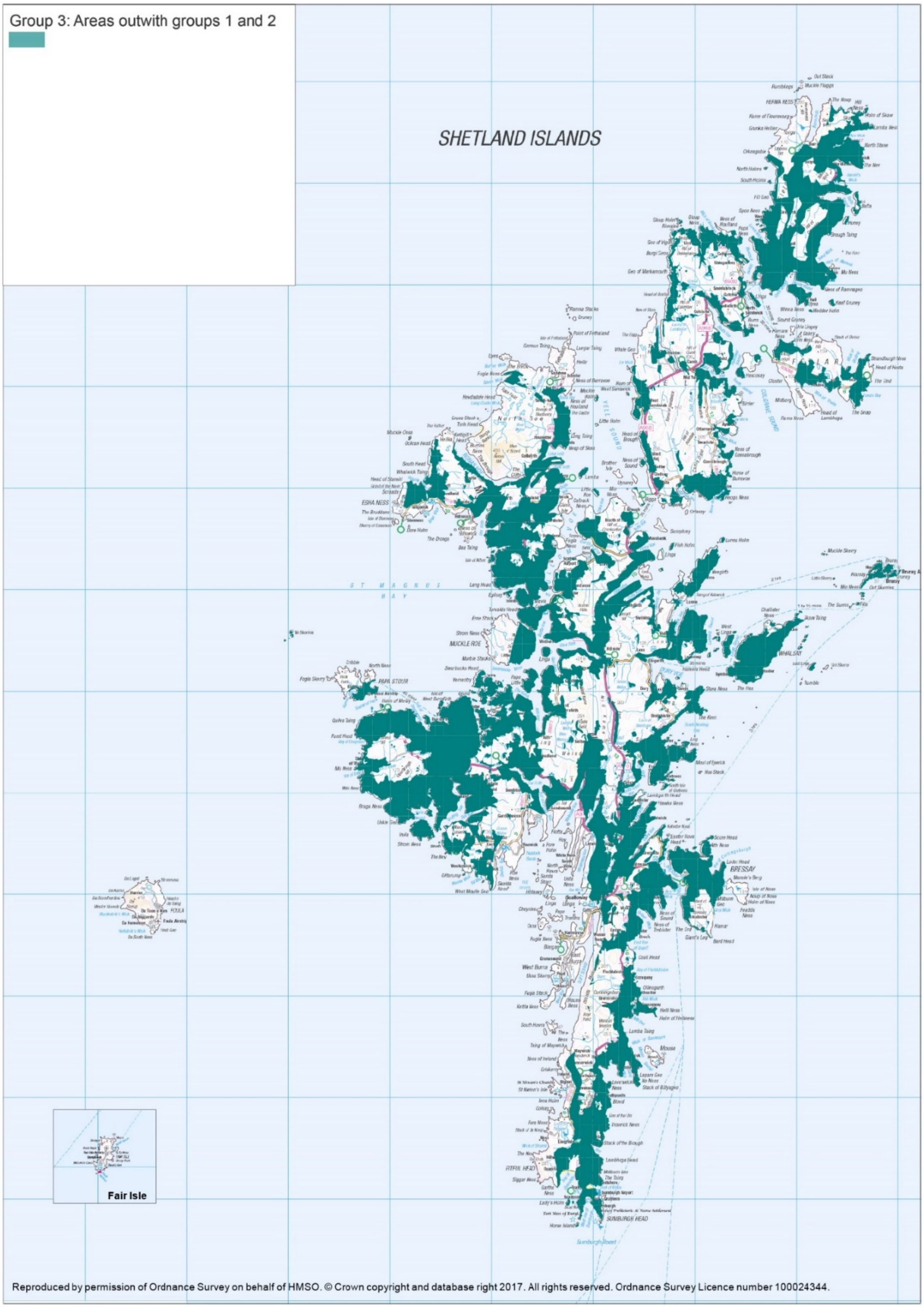
In September 2014, Shetland Islands Council adopted the Shetland Local Development Plan (LDP). The purpose of the plan was to assist with the delivery of sustainable economic growth and preserve the natural and built environment of Shetland. With regard to energy production, the Plan stated:

> **"The Council is committed to delivery renewable energy developments that contribute to the sustainable development of Shetland.**
>
> **...Renewable energy developments can provide a sustainable opportunity for diversification within the Shetland economy. There is potential for communities and small businesses to invest in the ownership of renewable energy projects or develop their own projects for the benefit of local communities.**
>
> **...Shetland demonstrates a number of strengths that support the development of renewable technologies and the Plan seeks to support these opportunities ensuring that Shetland's renewable energy potential is optimised."**[24]

In February 2018, the Council adopted detailed Supplementary Guidance for Onshore Wind Energy[25]. The Supplementary Guidance provides developers with information and guidance on where, in principle, large-scale onshore wind energy developments are likely to be acceptable. It provides the planning policy framework for the Council to use as a basis when assessing applications for wind energy developments of all sizes. The map below identifies all areas "considered to be capable, in principle of supporting large scale wind energy developments". These areas appear to cover of the order of half of the entirety of the Shetland Islands, indicating significant potential for future onshore wind farm developments to come forward.

[24] The Shetland Local Development Plan, Shetland Islands Council, Page 49, September 2014
[25] Supplementary Guidance – Onshore Wind Energy, Shetland Islands Council, Adopted February 2018

Figure A-1: Shetland Islands Council areas considered capable of supporting large scale wind energy developments



:

A.1.4 Summary

The UK Government has recently announced that island onshore wind will be able to compete in the next ‘less established technologies’ CfD auction scheduled in 2019. This announcement represents a turnaround in fortunes for islanded onshore wind after the Government’s ‘minded to’ position following the 2016 general election. The announcement represents an opportunity for island onshore wind to secure a CfD without which transmission connected projects in particular will be disadvantaged by high TNUoS charges resulting from the cost of the transmission spur.

The Scottish Government and Local Island Authorities are keen to support the Islands to make use of their natural resource and in doing so help develop the island economies and combat fuel poverty. As a result, the Scottish Government and Shetland Islands Council are strongly in favour of more onshore wind on Shetland.

A.2 Generation prospects

As outlined above, onshore wind will form the basis of generation growth in Shetland. In the subsections below, we discuss the prospects for onshore wind generation. We also consider offshore wind and marine generation.

A.2.1 Onshore wind generation

The potential for onshore wind in Shetland is significant. A number of wind farms have secured contracts with SHE Transmission and interest in securing grid connection capacity at both transmission and distribution level has been shown by a number of parties.

Transmission level generation

There is currently 604 MW of transmission-contracted generation comprising two projects, shown in Table A-1.

Table A-1: Transmission contracted generation

Wind Farm	Owner	Contracted Capacity	Consented Capacity	Potential Capacity Increase (Total)
V king	SSE & Community	412.0 MW	457.0 MW	45.0 MW (457.0 MW)
Beaw Field	Peel Energy	72.0 MW	57.8 MW	[redacted]
Energy Isles	Energy Isles Ltd	120.3 MW	Not consented	[redacted]
Total	-	604.3 MW	514.8 MW	[redacted]

Viking Wind Farm is a joint venture between SSE and the Shetland community; it has a grid connection contract for 412 MW of capacity and is contracted to connect in March 2024. The wind farm is currently consented at 457 MW. Viking has applied for an additional 45 MW of contracted capacity that, following the conclusion of an interactivity process, has been offered on a non-firm basis. The project will compete in the 2019 CfD auction.

Peel Energy’s Beaw Field development has planning consent for 17 turbines, each up to 145 m to blade tip. It is consented with a nominal capacity of 57.8 MW. However, it is contracted at 72 MW [redacted] The project is contracted to connect in March 2024 but will not compete in the 2019 CfD auction.

Energy Isles Ltd is a company established by local businesses in Shetland to take forward the proposed Yell Wind Farm. An initial scoping exercise for a potential 200 MW, 63-turbine wind farm has been modified to 50 turbines and an application submitted to SHE Transmission for a 120.3 MW connection. The project was successful and has a contracted capacity of 120 MW to connect in March 2024. [redacted]

These three projects could result in the connection of between 604 MW and 719 MW of onshore wind generation, depending on commercial and planning considerations. In addition a further three transmission level projects are known to SHE Transmission at the time of preparing this CBA, shown in Table A-2.

Table A-2: Transmission potential generation

Wind Farm	Owner	Capacity Applied For / Expected
Mossy Hill	Peel Energy	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]		[redacted]

[redacted] Peel has submitted a planning application for the most advanced of its three projects, Mossy Hill 50 MW wind farm. Planning determination is expected in late 2018 [redacted]

[redacted]

Distribution level generation

[redacted] In addition, a further three projects of 100 kW or above have applied for planning.

Table A-3: Distribution level known potential generation

Wind Farm	Owner	Capacity Applied For / Expected
[redacted]	[redacted]	24.0 MW
Culterfield Wind Farm	Freelight (Shetland)	2.7 MW
Hillhead Wind Turbine	Drew Ratter	0.1 MW
East of Brae Wind Turbine	VG Energy	0.1 MW
Swinster Wind Farm	Erlend Tait	0.5 MW
Total	-	27.4 MW

The [redacted] had not entered the planning system at the time of writing. The Culterfield Wind Farm (three 900 kW turbines) was awarded planning permission in

2016. Both the Hillhead Wind Turbine and East of Brae Wind Turbine are consented, [redacted] It is not known to what extent these are currently constrained but any constraint will be removed following installation of the transmission link. For the purposes of modelling we have adopted a conservative assumption that the constraints are negligible.

The Shetland Islands Council onshore wind spatial plan

The Shetland Islands Council has adopted Supplementary Guidance for onshore wind energy[26] shown in Figure A-1, identifies around half the geographic area of Shetland the Council considers could be suitable for wind farm developments.

A number of the known projects identified above will fall within the areas identified in the Supplementary Guidance. However, it is reasonable to conclude that when uncertainty over transmission capacity is removed and a business case can be made, a number of further developments will begin to come forward. For the purposes of our CBA, we have made a conservative assumption that this would total no greater than 30 MW in any of the scenarios modelled, although the potential may be significantly larger.

Small scale generation

To promote the uptake of small-scale renewable and low-carbon electricity generation technologies, the UK government introduced the Feed in Tariff (FIT) scheme - a scheme that pays people for creating their own "green electricity". The FIT is based on the electricity generated by a renewable energy system and there is an additional bonus for any energy produced exported to the electricity grid. As a result, FiT generation has received three separate financial benefits:

- A generation tariff payment, which is based on the total electricity generated and the energy type
- An export tariff payment, which is for any energy exports made when generating more than you use
- Lower charges for the electricity imported to the owner of the FiT project

Most domestic renewable and low carbon electricity-generating technologies have qualified for the scheme, including:

- Solar photovoltaic (PV) with a total installed capacity (TIC) of 5 MW or less (roof mounted or standalone)
- Wind turbines with a TIC of 5 MW or less (building mounted or free standing)

Table A-4 shows FIT installations and capacity in Shetland, Orkney, the Western Isles, the Highlands and Scotland for 2017/18. The table also includes an estimate of the total number of households in each location. Shetland has a higher concentration of FIT qualifying onshore wind turbines (2% of all households) compared to Scotland as a whole (0.13%). Solar PV penetration is lower than the overall Scottish uptake, at 0.49% compared to a national 2.16%.

FIT tariffs have declined in recent years and in November 2017 the UK Treasury "*there will be no new low-carbon electricity levies until 2025*". The current FIT legislation ends in March 2019 and it appears at present there will be no replacement.

[26] http://www.shetland.gov.uk/developmentplans

However, the removal of the FIT scheme is counterbalanced by the falling cost of wind and solar generation. Small-scale onshore wind generation is likely to remain relatively attractive on Shetland due to the excellent wind speeds. Those interested in small-scale wind turbines will likely be able to benefit, as, over time, the cost of generating electricity for their own consumption is likely to be lower than the retail price of electricity from national suppliers on a p/kWh basis.

Table A-4: FIT generation statistics (2017)

Technology	Region	Households (estimated)	No. of Installations	Proportion of Households with Installations	Installed Capacity (MW)	Average Capacity (kW)
Onshore Wind	Western Isles	13,048	171	1.31%	8.1	47.46
	Orkney	10,374	758	7.31%	17.7	23.41
	Shetland	10,419	208	2.00%	2.2	10.58
	Highlands	108,643	207	0.19%	9.3	44.74
	Scotland	2,486,766	3147	0.13%	281.3	89.38
Solar PV	Western Isles	13,048	287	2.20%	1.2	4.18
	Orkney	10,374	372	3.59%	1.4	3.74
	Shetland	10,419	51	0.49%	0.2	4.09
	Highlands	108,643	4249	3.91%	16.7	3.94
	Scotland	2,486,766	53793	2.16%	258.7	4.81
Hydro	Western Isles	13,048	10	0.08%	4.0	395.88
	Orkney	10,374	1	0.01%	0.0	11.00
	Shetland	10,419	2	0.02%	0.0	9.25
	Highlands	108,643	177	0.16%	80.6	455.60
	Scotland	2,486,766	509	0.02%	160.7	315.81
Micro CHP	Western Isles	13,048	0	0.00%	0.0	0.00
	Orkney	10,374	0	0.00%	0.0	0.00
	Shetland	10,419	0	0.00%	0.0	0.00
	Highlands	108,643	4	0.00%	0.0	0.99
	Scotland	2,486,766	28	0.00%	0.0	1.03
Anaerobic Digestion	Western Isles	13,048	0	0.00%	0.0	0.00
	Orkney	10,374	0	0.00%	0.0	0.00
	Shetland	10,419	0	0.00%	0.0	0.00
	Highlands	108,643	2	0.00%	1.0	499.00
	Scotland	2,486,766	37	0.00%	15.0	404.95

Source: https://www.ofgem.gov.uk/environmental-programmes/fit/contacts-guidance-and-resources/public-reports-and-data-fit/installation-reports; https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/households/household-projections/2014-based-household-projections/list-of-tables

A.2.2 Marine generation

There is potential for tidal and wave generation around the coast of Shetland. However, to date, the take up has been limited compared to other Scottish islands, such as Orkney.

There is currently one Crown Estate lease granted for tidal generation around Shetland, the Shetland Tidal Array. At present, this comprises an operational demonstration project, with planning permission for up to 2 MW. Nova Innovation was the first company to secure financial close on a commercial tidal array. It has installed three 100 kW turbines in Bluemull Sound, the first turbine in March 2016. The project has been generating up to full power and across all tidal conditions.

Nova Innovation recently won a major new European tidal energy project (Enabling Future Arrays in Tidal (EnFAIT) project), heading a consortium of nine leading industrial, academic and research organisations. The project began in July 2017 and runs to June 2022, extending the Bluemull Sound array to six turbines and aims to demonstrate that high array reliability and availability can be achieved using best practice maintenance regimes.

While tidal development on Shetland has potential, we have conservatively not included significant growth in our generation scenarios given its current small scale compared to other islands, in particular Orkney. Wave technology is not as close to commercial viability as tidal and therefore we have not considered wave generation in this study.

A change in the UK subsidy support for marine technologies subsidies and/or a step change in technology could change this picture significantly.

A.3 Generation scenarios

A.3.1 A conditional needs case submission

The UK Government has announced that islanded onshore wind will be able to compete in the next 'less established technologies' CfD auction scheduled in 2019, with further CfD auctions to be held every two years thereafter[27]. This announcement represents a turnaround in fortunes for islanded onshore wind after the Government's 'minded to' position following the 2016 general election.

Whilst the announcement is good news for islanded onshore wind, the appetite for significant amounts of additional onshore wind to be subsidised by the UK Government is waning and does not align with the appetite within Scottish Government and Local Authorities to support the Islands in making use of their natural resource and developing the island economies.

GHD understands that the largest proposed wind farm on Shetland, Viking, intends to compete in the 2019 CfD auction. As this project alone currently represents up to 457 MW of consented generation and potentially contracted capacity, SHE Transmission wishes to submit a '**Conditional Needs Case**' to Ofgem, with the need conditional on the award of CfDs.

The generation scenarios outlined in this report reflect the 'conditional' s approach and therefore assume ***Viking Wind Farm secures a CfD, either at its current contracted capacity of 412 MW or its consented capacity of 457 MW***. For the other known transmission projects, various capacities emerge across the scenarios based on a range of contracted, consented and notified capacities. The scenarios are supplemented by varying appetite for private or community development should a new, high capacity transmission cable be constructed, taking into consideration the applicability of TNUoS charges to the prospective projects (i.e. transmission vs distribution connected projects).

A.3.2 Top down and bottom up approach

To assess the 'conditional need' for transmission reinforcement we have developed a range of generation scenarios. Our approach to developing the scenarios combines both bottom up and top down assessments.

Our bottom up assessment uses a detailed generation database identifying all proposed projects in the public domain, providing a clear assessment of projects that could come forward in a relatively short period. Clearly, there is potential for other projects to come forward not currently in the public domain. In order to reflect this we have examined the Council's

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/documents/01bWebOnshoreWindEnergySG20160803.pdf

[27] https://www.gov.uk/government/news/a-boost-for-north-east-innovation-to-promote-high-quality-jobs-and-growth

Supplementary Guidance for onshore wind that identifies potential areas of wind farm development supported by the Council through the planning system.

Our top down approach considers the economic, political, environmental and social drivers that are likely to influence potential levels of future generation growth. We apply these drivers to the projects identified in the generation database to develop scenarios of future generation development.

A.3.3 Scenario drivers

Using top down development drivers and specific project based information from the bottom up assessment; we have developed four generation scenarios, each with varying amounts of onshore wind. We split onshore wind into five categories of generation, shown in Figure A-2.

Figure A-2: Onshore wind generation categories

Transmission Level Contracted Projects	**Transmission Level Known Projects**	**Distribution Level Known Projects**
Projects contracted to SHE Transmission, including major wind farm developments Viking, Beaw Field and Yell.	Projects known to SHE Transmission but not yet contracted, including the three Peel Energy projects.	Projects known to have expressed an interest in connecting at distribution level.
Future Growth in Large Scale Projects	**Other, Small-scale Projects**	
Projects known to SHE Transmission but not yet contracted,	Either known small-scale projects or a prediction of future growth	

Table A-5 provides a summary of the generation growth assumptions for our generation scenarios broken down by each of the onshore wind categories as well as other types of generation including embedded solar and tidal.

A.3.4 Small-scale generation

In each scenario, we assume a reasonable appetite for small-scale onshore wind generation and solar projects will continue. We assume a further 1 to 5 MW of wind turbine projects will emerge by 2030 with a further 1-5 MW of solar projects over the same period. We have not assumed any growth in small-scale hydro due to apparently little interest/potential on the islands.

Table A-5: Generation growth assumptions

Scenario	Onshore Wind								Other		
	T-Contracted		T-Known			D-Known		Future growth in large scale	Small Scale wind (<5MW)	Tidal	Solar
	Viking	Beaw	Energy Isles	Mossy Hill	Other	Sellafirth REP	Culterfield				
S1	Wins CfD and is developed but at contracted capacity not planning capacity 412 MW	Fails to win a CfD either due to strike price or empty pot 0 MW	Either fails at planning or fails to win a CfD 0 MW	Either fails at planning or fails to win a CfD 0 MW	Both projects either fail at planning or fail to win a CfD 0 MW	Either fails at planning or fails to win a CfD 0 MW	Fails to win a CfD 0 MW	Seeing others fail to go ahead, none come forward 0 MW	Limited developments, mostly domestic. 1 MW	Consented extension to existing array proceeds 0.1 MW	Limited developments, mostly domestic. 1 MW
S2	Wins CfD and is developed 457 MW	Fails to win a CfD either due to strike price or empty pot. Loses to Energy Isles due to economies of scale and lack of community 0 MW	Granted permission, wins a CfD at grid application capacity. Beats Beaw due to economies of scale and community ownership 120.3 MW	Either fails at planning or fails to win a CfD 0 MW	Both projects either fail at planning or fail to win a CfD 0 MW	Either fails at planning or fails to win a CfD 0 MW	Fails to win a CfD 0 MW	Seeing others fail to go ahead, none come forward 0 MW	Stronger growth in small scale developments 2 MW	Consented extension to existing array proceeds 0.1 MW	Stronger growth in small scale developments 2 MW
S3	Wins CfD and is developed 457 MW	Wins CfD but fails to get planning permission for larger capacity notified to SHET 57.8 MW	Granted permission, wins a CfD at grid application capacity 120.3 MW	Either fails at planning or fails to win a CfD 0 MW	Both projects either fail at planning or fail to win a CfD 0 MW	Either fails at planning or fails to win a CfD 0 MW	Already consented, wins a CfD at stated capacity 2.7 MW	Some distribution connected projects come forward having seen other D-Known projects 10 MW	Stronger growth in small scale developments 3.2 MW	Full Crown Estate lease allowance used at existing array site 1.5 MW	Stronger growth in small scale developments 3 MW
S4	Wins CfD and is developed 457 MW	Wins CfD but fails to get planning permission for larger capacity notified to SHET 57.8 MW	Granted permission, wins a CfD at grid application capacity 120.3 MW	Granted permission, wins a CfD at stated capacity 50 MW	Both projects either fail at planning or fail to win a CfD 0 MW	Granted permission, wins a CfD at stated capacity 24 MW	Already consented, wins a CfD at stated capacity 2.7 MW	Further distribution connected projects come forward 20 MW	Stronger growth in small scale developments 4.7 MW	Full Crown Estate lease allowance used at existing array site 1.5 MW	Stronger growth in small scale developments 4 MW

A.3.5 Generation scenarios

The generation scenarios developed within this report are not 'forecasts' of generation growth per se, but rather represent possible longer-term outcomes for differing types of generation that may be realised given a set of reasonable underlying economic, political, environmental and social assumptions and drivers. In doing so, the merits of each transmission reinforcement option proposed for the area can be assessed.

Figure A-3 shows the resulting total installed capacity for the four generation scenarios developed (S1 - S4).

Figure A-3: Total new generation by scenario

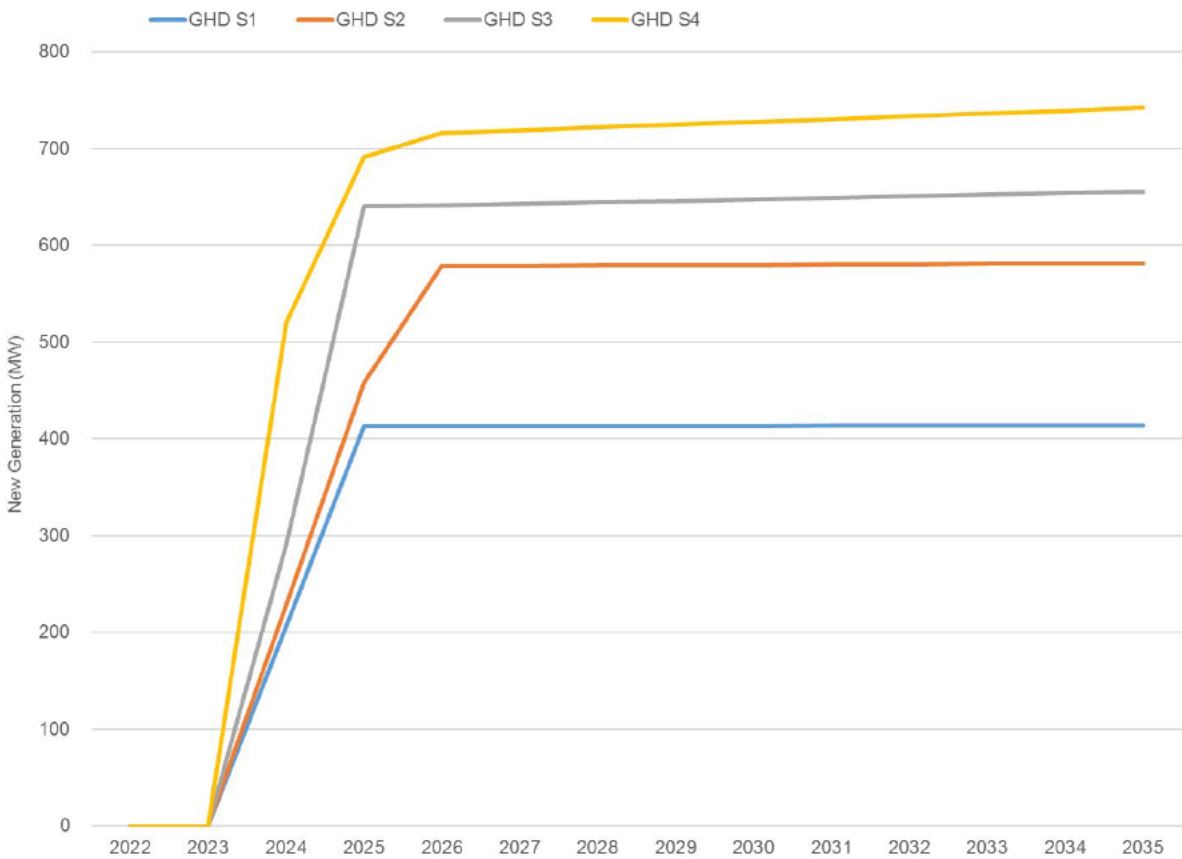


Table A-6 shows generation assumed in each scenario.

Table A-6: Total new generation by scenario 2035 (MW)[28]

Scenario	Large Onshore Wind	Embedded Wind	Embedded Solar	Tidal	Total
S1	412.0	1.0	1.0	0.1	414.1
S2	577.3	2.0	2.0	0.1	581.4
S3	645.1	5.9	3.0	1.5	655.5
S4	729.1	7.4	4.0	1.5	742.0

[28] GHD's scenarios have been provided to the SO and included in their analysis. When interpreting GHD's scenarios the SO did not fully remove all existing generation, and therefore a small amount of small scale existing solar and wind amounting to 18 MW included in the SO's GHD scenarios. This inclusion will have no material impact on results

A.3.6 Summary

The generation scenarios outlined in this report reflect alternative outlooks of future generation development on Shetland based on varying levels of success in future CfD auctions for the largest proposed transmission-connected wind farms, alongside other, distribution level developments. The scenarios intend to explore a range of potential generation development on Shetland, initiated by the 2019 CfD auction. It must be noted that the potential maximum capacity of the three contracted projects could total some 719 MW alone and therefore is most closely represented by S4.

A failure for the anchor Viking Wind Farm to secure a CfD in the 2019 auction will result in significantly lower generation development. However, as SHE Transmission wishes to submit a 'Conditional Needs Case', conditional on the success of the Viking project, we have not modelled this outcome at this stage.

A.4 Comparison to National Grid's FES

GHD's generation scenarios are detailed and localised, taking into account identifiable generation developments that are both close to market and those further away from development but driven by local factors including Council policy and community ownership.

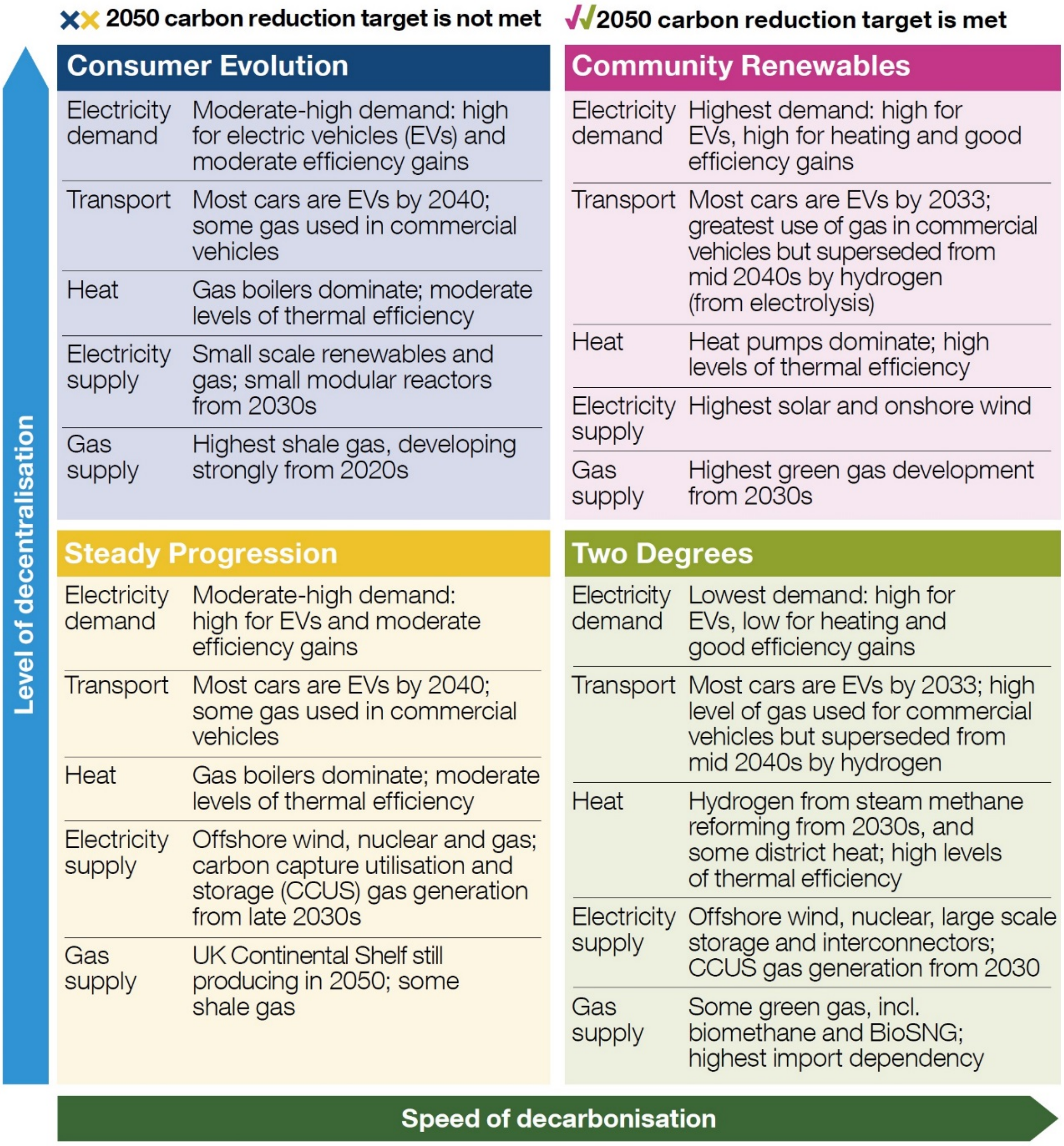
The Future Energy Scenarios (FES) scenarios developed by National Grid for GB include the Shetland study area. We compare the FES against our scenarios and explore any resulting differences below.

A.4.1 What are the FES?

Each year, National Grid develop GB scenarios of energy growth and development over a long-term timeframe – the FES. The FES are developed using a 'top down' scenario planning approach that is intended to reflect the impact of differing principal drivers of energy progress in the GB economy in the long term. As a result the FES are not intended to accurately represent 'bottom up' details of generation and demand growth in specific areas - but provide a useful background against which to assess differing drivers of energy development. Like GHD's generation scenarios, the FES are not forecasts, they are predictions of the future that seek to discover plausible and credible conclusions for the future of energy.

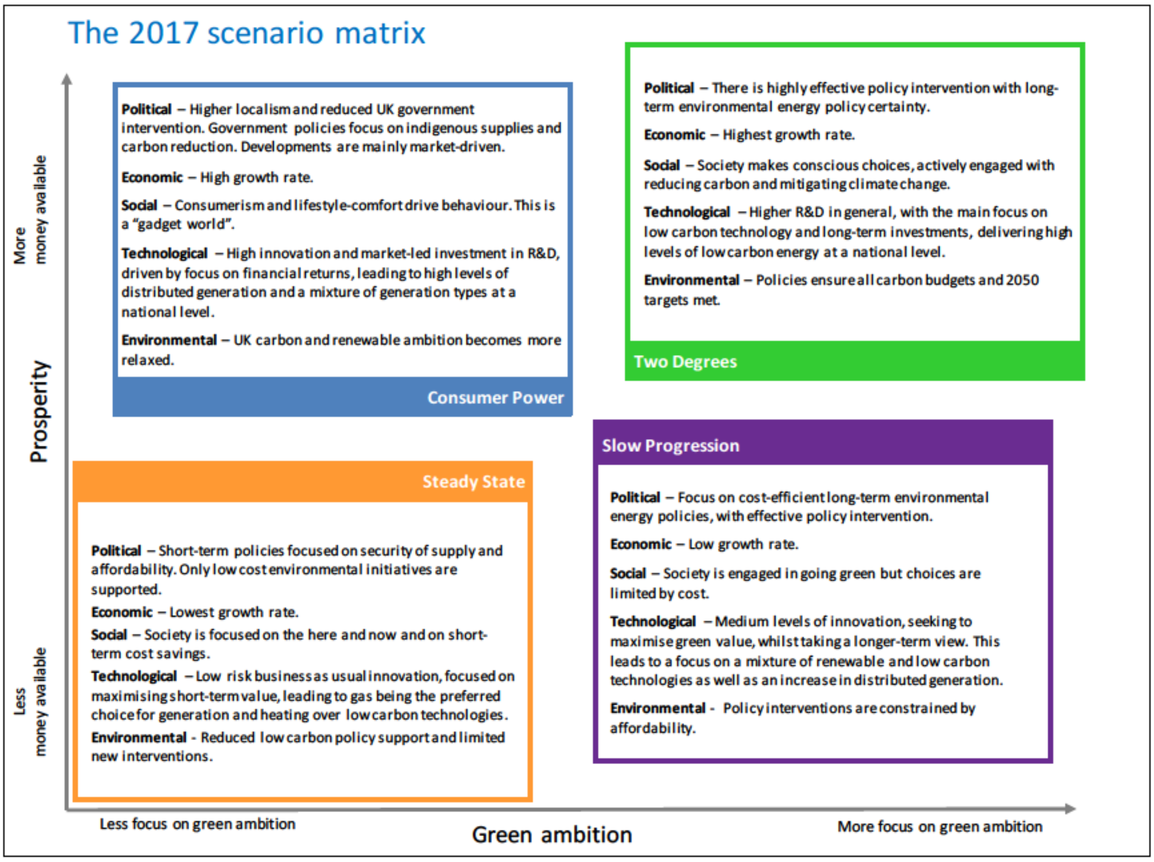
The most recent, fully published FES developed by National Grid was released in July 2018 (FES 2018) and comprises four scenarios. These scenarios, outlined in Figure A-4, are aligned to two axes: 'speed of decarbonisation' and 'level of decentralisation'. Each scenario considers the broad themes of power demand, transport, heat and energy supply.

Figure A-4: FES 2018 scenarios / assumptions



Although published, GHD understands that the SO will not use the FES 2018 in their modelling of the Shetland network as part of this CBA. As such, we have considered the 2017 FES for comparative purposes. Figure A-5 summarises the underpinning political, economic, social, environmental and technological assumptions supporting the 2017 FES.

Figure A-5: FES scenario assumptions (2017)



National Grid's approach to Needs Case development adopts a model of the UK electricity system to conduct the analysis for input into the CBA. The model is an optimising tool that uses three broad inputs:

- Boundary capabilities provided by each TO
- Generation data (including MW and pricing information)
- Demand data

As part of National Grid's FES process, the generation and demand data aims to create a range of credible futures out to 2050 that form the basis of transmission network and investment planning.

A.4.2 FES 2017 results

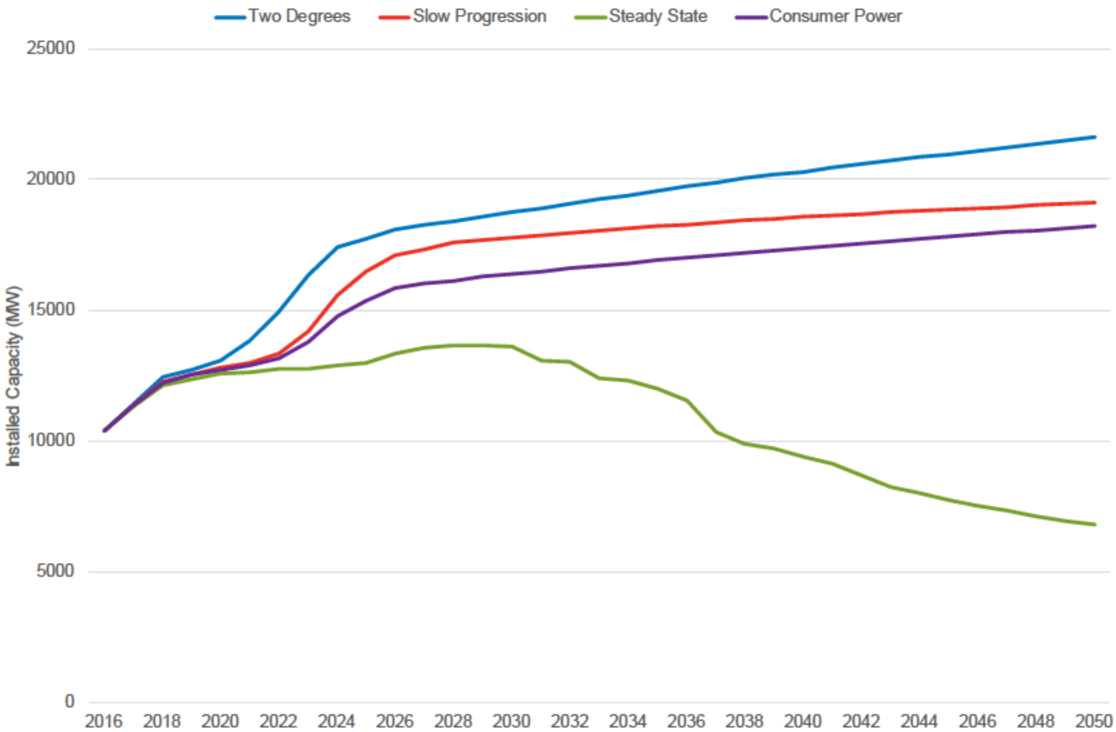
National Grid publishes FES scenario data for the whole of the GB online[29]. Differing outcomes for GB renewable growth are presented over the period to 2050. Figure A-6 shows the growth in GB renewable generation particularly relevant to the Shetland Islands (onshore wind) in the 2017 FES scenarios.

Up to 2020, the scenarios show similar rates of onshore wind growth – this is expected given the relative short-term development pipeline to 2020. In the medium term, over the period to 2020-2030, the scenarios show significant divergence as the scenario drivers and local factors exert greater influence.

[29] http://fes.nationalgrid.com/fes-document/

In the longer term (beyond 2030) the divergence continues, with wind growth continuing at varying paces in all but one of the scenarios. Under the Steady State scenario, onshore wind capacity declines significantly from 2030.

Figure A-6: 2017 FES onshore wind growth (GB)



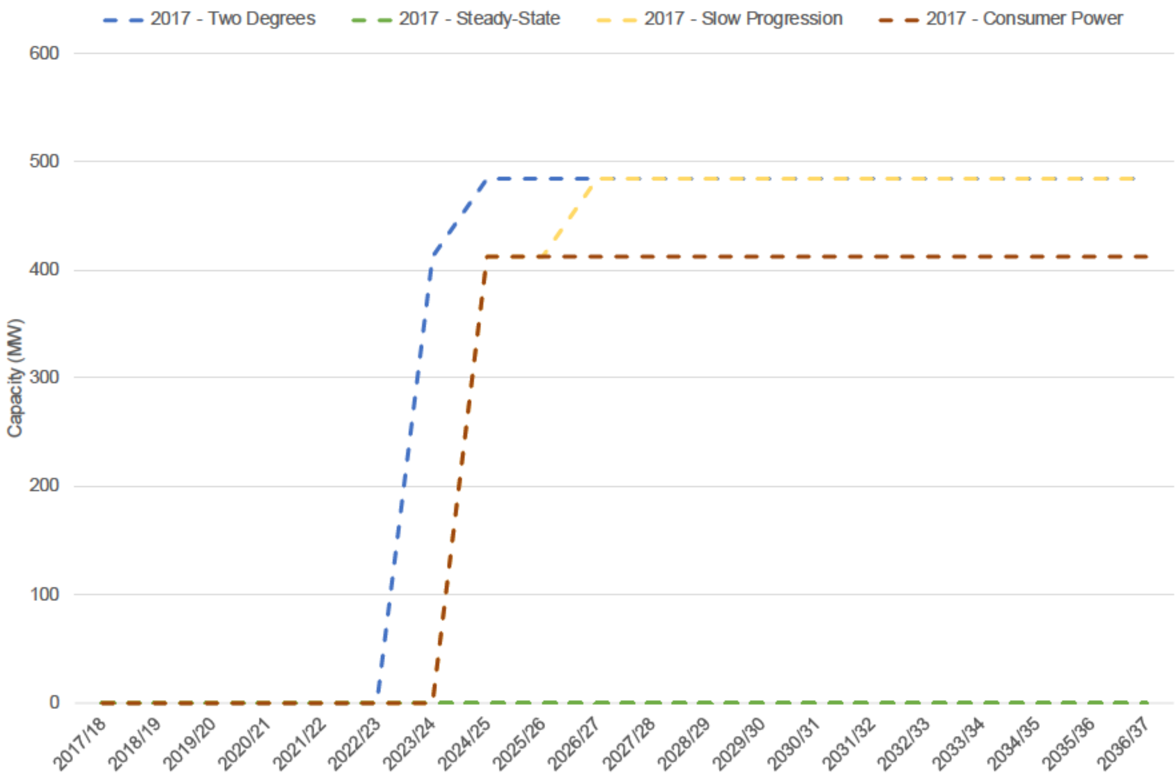
Whilst the FES are formed at the GB (macro) level, they are made up from a detailed list of individual contracted, transmission connected generating plant. SHE Transmission has provided GHD with the FES generation assumptions for the Shetland Islands area[30].

The information was provided for each of the scenarios and includes a list of generation projects in the Shetland Islands area and their assumed operational capacity from 2017 to 2040. The detailed breakdown of generation assumptions on a plant by plant basis for each FES is not included in this report. We have taken the FES data and determined which plants are located in the study area and for each of the four FES, summated the total generation capacity on an annual basis. The results of this analysis is summarised in Figure A-7.

Under the SS scenario, zero generation is developed on Shetland. Under the CP scenario, 412 MW of onshore wind generation is developed by 2024/25 (Viking) whilst under the SP and TD scenario, 484 MW of onshore wind generation is developed (Viking and Beaw Field) by 2026/27 and 2024/25 respectively.

[30] This information is not available publically.

Figure A-7: Shetland generation (FES 2017)



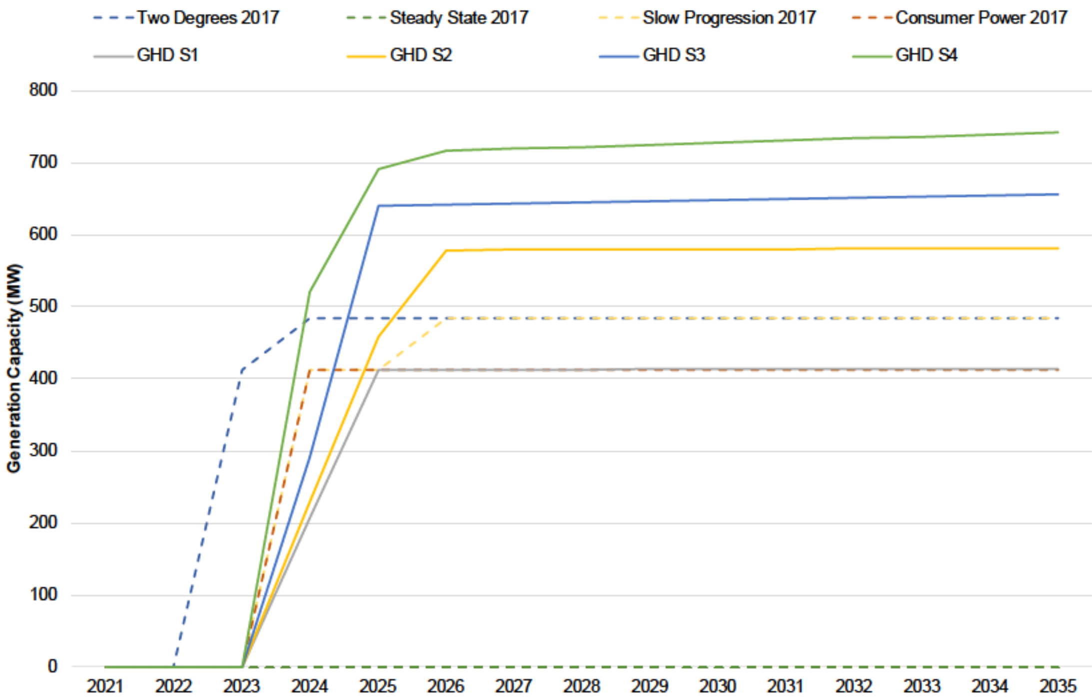
A.4.4 Comparison

Figure A-7 compares GHD's generation scenarios with the FES 2018 scenarios. As the SHE Transmission Needs Case is conditional upon the success of the Viking project in the upcoming CfD auction the GHD scenarios assume that the project comes online as soon as the link commissions in 2024/25 This is consistent with the FES TD scenario. The remaining FES scenarios assume later commissioning of the Viking project and are therefore less consistent with the Conditional Needs Case.

GHD's scenario S1 assumes a similar amount of generation as the 2017 FES CP scenario. While in all other GHD scenarios more generation comes forward than the 2017 FES TD and SP scenarios for the following reasons:

- The FES are based on a macro view of GB drivers (economic, political, environmental etc.) against a short list of transmission-contracted generation at their contracted capacities (484 MW). Understandably, they do not include non-transmission contracted generation or consider localised investment conditions and factors that may encourage renewable generation development (such as Council or community ownership).
- The GHD scenarios include all known projects as well as assuming some degree of development of sites not yet developed but that would be consistent with the Council's Supplementary Guidance for Onshore Wind Energy, which identifies of the order of half of the Shetland Islands as suitable for development. GHD's scenarios also assume some degree of background growth in small-scale projects and consider the micro investment conditions and drivers considered alongside the wider macro environment outlined within the FES.
- In addition, we note that the FES include Viking and Beaw Field wind farms at their contracted capacities, some 31 MW lower than their consented capacities and 55 MW lower than they are known to be seeking to contract for via modification applications.

Figure A-7: Comparison of GHD generation scenarios and FES 2017



In summary, with the FES unaware of/unable to consider a significant amount of known or likely projects that are not currently transmission contracted, it is unlikely that the FES and GHD scenarios will be closely correlated in the long term.

A.5 Summary

Four generation scenarios have been developed by GHD that provide a spectrum of alternative generation growth paths in Shetland – ranging from approximately 414 MW to 742 MW of additional generation. The generation scenarios reflect the Conditional Needs Case approach wherein the Viking project succeeds in the upcoming CfD auction. In our scenarios, Viking is supplemented with generation from other sources, including contracted and emerging transmission and distribution level projects as well as conservative assumptions of background growth in small and large-scale developments.

The scenarios have some similarities with the National Grid FES scenarios, albeit that these similarities are limited due to the more binary nature of the FES scenarios and their inclusion of only contracted, transmission level generation projects.

Appendix B – GHD approach to Socio-economic modelling

B.1 Introduction

Cost benefit analysis (CBA) undertaken as part of the SWW quantifies the costs and benefits of potential transmission reinforcements – with the benefit of a potential reinforcement assessed as the future constraint costs avoided and costs as the cost of the reinforcement. However, for the Scottish islands the logic of the CBA approach adopted to date is thwarted by the lack of existing transmission infrastructure that creates an unusual counterfactual resulting in a 'Catch-22' situation as the 'need' for the transmission reinforcement is dependent on the development of generation on the islands, but generation development cannot occur without the transmission reinforcement. Therefore the case for either transmission or generation development is entirely predicated on the other.

The situation is further complicated by the position of the islands (Shetland, Orkney, and the Western Isles) outside the GB transmission charging zones. Because of the islands' position outside the main interconnected transmission system (MITS), potential transmission connected generators on the islands will be allocated a 'wider' TNUoS charge to the nearest transmission charging zone, plus a 'local spur' charge for transmission to the islands. Given the relatively high cost of the local spur (a subsea link) then the resulting TNUoS charge for island generators is high.

In October 2012, The Rt Hon. Edward Davey and the Scottish Government set up a joint independent study to address concerns that renewable projects on the Scottish islands were '*not coming forward quickly enough, in part because of the cost of the links required to connect the islands to the mainland transmission network*'[31]. Further analysis outlined the increased cost of generation for renewable projects on the islands arising mainly from the increased TNUoS charges. The report also outlined the potential of the islands to generate significant renewable energy, including the further development of marine generation, and the subsequent positive economic impact on island communities.[32]

The higher cost of island generation, coupled with the potential benefit to the islands and their role in the development of embryonic marine generation, led to the then DECC's consultation proposal for an 'islands' CfD. The 2013 consultation on additional support for islands renewables concluded that:

'The projects are physically and electrically remote from the high voltage transmission system needed for the export of their generation output and would require long new connections to the Main Interconnected Transmission system based on subsea High Voltage DC cables. Under the transmission charging regimes, they are forecast to be subject to transmission charges (TNUOS) of several times the average for comparable generators located elsewhere in the UK. We consider that the characteristics described above mean that the development of onshore wind on the Scottish islands constitutes a separate class of renewable generation that warrants separate treatment and potentially a different level of support to other onshore projects.'[33]

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[31] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/245381/scottish_islands_additional_support_consultation.pdf
[32] https://www.gov.uk/government/publications/scottish-islands-renewable-project-final-report
[33] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/245381/scottish_islands_additional_support_consultation.pdf

The 2017 Conservative party's manifesto made a commitment to "*support the development of wind projects in the remote islands of Scotland, where they will directly benefit local communities*[34]". The Conservative Party commitment was more recently reiterated by Richard Harrington, Parliamentary Under Secretary of State at the Department for Business, Energy and Industrial Strategy who stated in a House of Commons debate in July 2017:

'*I hope that my response today….provides some reassurance… that the Government will support the development of onshore wind projects in the remote islands of Scotland, where they will directly benefit local communities".*[35]

In October 2017 the government finally announced its intention to allow islands wind projects to compete in the 'less established technologies' CfD auction to be held in spring 2019[36]. Key to the decision was the potential for renewable projects to benefit local communities.

In June 2017 the Scottish government introduced what it has described as an 'historic bill' to create a sustainable future for Scotland's islands. The 'Islands (Scotland) Bill' was subsequently unanimously backed by MSPs in May 2018 and includes:

- A duty on Scottish Ministers to publish a National Islands Plan – setting out the main objectives and strategy of the Scottish Ministers in relation to improving outcomes for island communities
- A duty on Scottish Ministers and other relevant public bodies to have regard to island communities in exercising their functions – including an island communities impact assessment ('island proofing') of any new/revised policy likely to have a significantly different effect on islands communities from its effect on other communities. This 'islands proofing' is considered a cornerstone of the Bill[37]

Under the Scotland Act 2016 Ofgem is required to provide its annual reports to Scottish Ministers to lay before the Scottish Parliament and is obliged to appear before the Scottish Parliament if requested to do so. **As a relevant public body Ofgem should therefore consider the impact on Shetland of its SWW decisions given that the impact on Shetland will differ substantially from that on other communities. Part of this impact assessment is a socio-economic impact evaluation. GHD has developed an approach to evaluating the socio-economic benefits of grid reinforcement and renewable development on Shetland.**

Shetland does not currently have any grid connections with mainland Scotland, and while some novel active network management technologies have been deployed to maximise the amount of renewables integrated within the islands' grid any further substantial renewables deployment is dependent on a new transmission link to the mainland.

Through micro-generation supported by feed-in tariffs households, communities and businesses can utilise the wind resource to generate their own electricity / heat and thereby reduce energy bills and generate an income at the same time. The reduction in energy bills and access to an income by generating electricity and selling via a feed-in tariff is indirectly a mechanism in combating fuel poverty in the islands – estimated at 40% of households in Shetland. Severe restrictions in grid access within the islands, even at household level, has been a barrier to entry to those wishing to take advantage of feed-in tariffs when they have been at their highest. This

[34] https://www.conservatives.com/manifesto
[35] https://hansard.parliament.uk/Commons/2017-07-04/debates/D202FCC4-4500-4CC9-BED5-0439C39D2ED1/RenewableEnergyGenerationIslandCommunities
[36] https://www.gov.uk/government/news/boost-for-island-wind-projects-as-uk-government-announces-new-funding-for-renewable-generation
[37] https://digitalpublications.parliament.scot/ResearchBriefings/Report/2017/9/4/Islands--Scotland--Bill-1#Part-3---Duties-in-relation-to-Island-Communities

discriminates against consumers on the Scottish Islands and additional grid capacity created by new transmission links would be beneficial in this respect.

Community energy projects are under increasing pressure to deliver their social and economic objectives in the face of rising retail energy costs. In areas where rates of fuel poverty are high such as the Scottish Islands renewable assets can provide the opportunity to help fund measures to alleviate the situation.

This paper outlines the methodology we have adopted to assess the socio-economic benefit of reinforcement and generation development in Shetland and outlines the corresponding results created.

B.2 Methodology

Our analysis focuses on the beneficial economic impact that may arise from further renewable development on Shetland and that of the proposed transmission reinforcement. Impact analyses of local investments typically employ some form of Keynesian multiplier framework to assess the effects of the investment stimulant. These are models that identify the knock on, or 'multiplier,' effects of increased local expenditure. The most sophisticated employ input output (IO) tables that capture linkages between the production sectors of an economy – in simple terms IO tables outline from which sectors another receives its production inputs and to which sectors it sends outputs. However, IO models that can be developed using these databases have drawbacks when used for identifying the economic impact of projects in localised regions, key drawbacks include:

- Limited regional IO data upon which to assess an appropriate multiplier effect for Shetland
- Renewable and transmission projects do not typically have strong backward linkages into a local economy like Shetland – much of the required investment is imported. Such low apparent backward linkages for an onshore windfarm will result in a low IO output multiplier, signifying low indirect and induced impacts on economic activity from the windfarm.
- IO models do not capture the impact of 'economic rent' from renewable generation that might accrue to the local economy, particularly important for projects in partial or total community ownership.

We have adopted an approach that attempts to address the drawbacks of the IO approach and that is similar to those used in a number of studies[38] [39] [40] [41] [42]. Our approach attempts to determine the Gross Value Added (GVA) to the Shetland economy of investment in wind farms based on the following methodology:

- Project expenditure is categorised into three key groupings – development costs, capital costs and operating costs (including decommissioning). Total expenditure and category

[38] The importance of revenue sharing for the local economic impacts of a renewable energy project: A social accounting matrix approach, Allan et al, Regional Studies, Vol 45.9, Oct 2011
Socio economic impacts of community wind power projects in Northern Scotland, Okkonen et al, Renewable Energy 85 (2016)
[39] https://www.thecrownestate.co.uk/media/5468/socio-economic-methodology-and-baseline-for-pfow-wave-tidal-developments.pdf
[40] Socio economic impacts of community wind power projects in Northern Scotland, Okkonen et al, Renewable Energy 85 (2016)
[41] Economic benefits from onshore windfarms, BVG Associates, September 2017
[42] Economic benefits from the development of wind farms in the Western Isles A report for EDF Energy Renewables on behalf of Lewis Wind Power, Feb 2017

breakdown is based on various sources, including BEIS[43], World Energy Council[44], International Renewable Energy Agency[45] and various industry reports[46]

- These costs are then further deconstructed into relevant ONS Standard Industry Classifications (SIC)[47]. A local content for each SIC is determined based on similar studies for Scottish regions, Western Isles, Orkney and Shetland[41 42 48 49].
- We have used Input Output multipliers to determine GVA impact and employment effects based on regional IO data published by the Shetlands Islands Council[50]. Input output multipliers are used to measure the expected change in total output following the increase in final demand for the relevant sector's output. Change is the sum of the stimulus' direct effect on that sector and its indirect effects on other sectors through production interdependencies. Due to the geography of the island economies, output growth results in extra wages and profits for households, who in turn spend more increasing demand for local goods and services – these induced effects are not included in Type 1 multipliers, but are in the Social Accounting Multipliers also developed for the economy[50]. Gross Value Added by SIC for Shetland, published by the ONS[51], show the structure of Shetland economy, in terms of the contribution of each key SIC to GVA.
- In addition we have assessed the potential GVA and employment effects that will arise from retained 'economic rent' from community ownership/benefit payments – these benefits are not part of the IO assessment but are potential important contributors to Shetland economy. Not all renewable 'rent' will stay within Shetland – some is assumed to 'leak' from the economy[52]. The retained rent will have an additional economic impact which we have determined by assessing Shetland sector GVA contribution and assuming retained rent mirrors this. The relevant sector IO multipliers are used to assess GVA.
- Total benefits are assessed over the 45 year life of the link and discounted to 2018 using the social time preference rate of 3.5%.

Our approach allows both the individual nature of Shetland economy to be taken into consideration, along with the impact of retained rent from renewable development depending on

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[43] Review of Renewable Electricity Generation Cost and Technical Assumptions, DECC, June 2016
https://beisgovuk.citizenspace.com/clean-electricity/fit-review-2015/supporting_documents/SmallScale%20Generation%20Costs%20Update.PDF
[44] World Energy Resources, Wind 2016, WEC
[45] Wind Power Technology Brief, IRENA, March 2016
Solar and wind cost reduction potential to 2025, IRENA, June 2016
[46] Market Stabilisation analysis: Enabling Investment in established low carbon electricity generation, An Arup report for Scottish Renewables, July 2017
Review of capital costs for generation technologies, Energy + Environment Economics, Jan 2017
Wind costs heading in the right direction, Wind Power Monthly, Jan 2017
http://www.renewablesfirst.co.uk/windpower/windpower-learning-centre/how-much-does-a-farm-wind-turbine-small-wind-farm-turbine-cost/
https://www.agora-energiewende.de/fileadmin/Projekte/2017/Future_Cost_of_Wind/Agora_Future-Cost-of-Wind_WEB.pdf
https://www.baringa.com/getmedia/99d7aa0f-5333-47ef-b7a8-1ca3b3c10644/Baringa_Scottish-Renewables_UK-Pot-1-CfD-scenario_April-2017_Report_FINA/
Wave and tidal supply chain development plan, February 2015
Wave and tidal energy in the Pentland Firth and Orkney waters:How the projects could be built, Crown Estates, May 2011
Isles Business Plan sub report: Commercially Viable Technology Innovations in the Offshore Renewables Sector, June 2015
Technology Innovation Needs Assessment: Marine Energy summary report, 2012
Maximising the value of Marine Energy to the UK, 2014
Wave and Tidal Energy in the UK: Capitalising on capability, 2015
Marine Energy – Seizing the supply chain opportunity, 2015
[47] https://www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities
[48] Socio economic impacts of community wind power projects in Northern Scotland, Okkonen et al, Renewable Energy 85 (2016)
[49] Clyde Wind Farm Extension – Impact Analysis June 2015
[50] https://www.shetland.gov.uk/coins/submissiondocuments.asp?submissionid=14530
[51] Regional gross value added (income approach) reference tables published on 15 December 2016
[52] In the form of central taxation and spending outside Shetland

the ownership structure adopted. The analysis does not include any carbon reduction benefits (offset against potential CfD subsidy). Furthermore, we note that there is strong support for renewable development and investment in the transmission link in Shetland and our generation scenarios have been developed in cognisance of the Councils onshore spatial plan. We therefore anticipate negligible socioeconomic dis-benefit (such as reduced tourism and amenity) arising locally.

B.2.1 Shetland economy

Table B-1 shows the contribution to Shetland GVA of individual sectors of the economy and compares to that of Orkney, the Western Isles and Scotland as a whole. The relatively large contribution of the public sector and the distribution, transport, accommodation and food sectors in the Shetland economy is apparent, contributing 43% to GVA, generally consistent with the wider Scottish economy. The contribution of construction to the Shetland economy is considerably higher than the Scottish average at 14% as opposed to 6%. Finance and business services contributes a relatively small amount to the local economy at just 1% compared to 7% in Scotland as a whole.

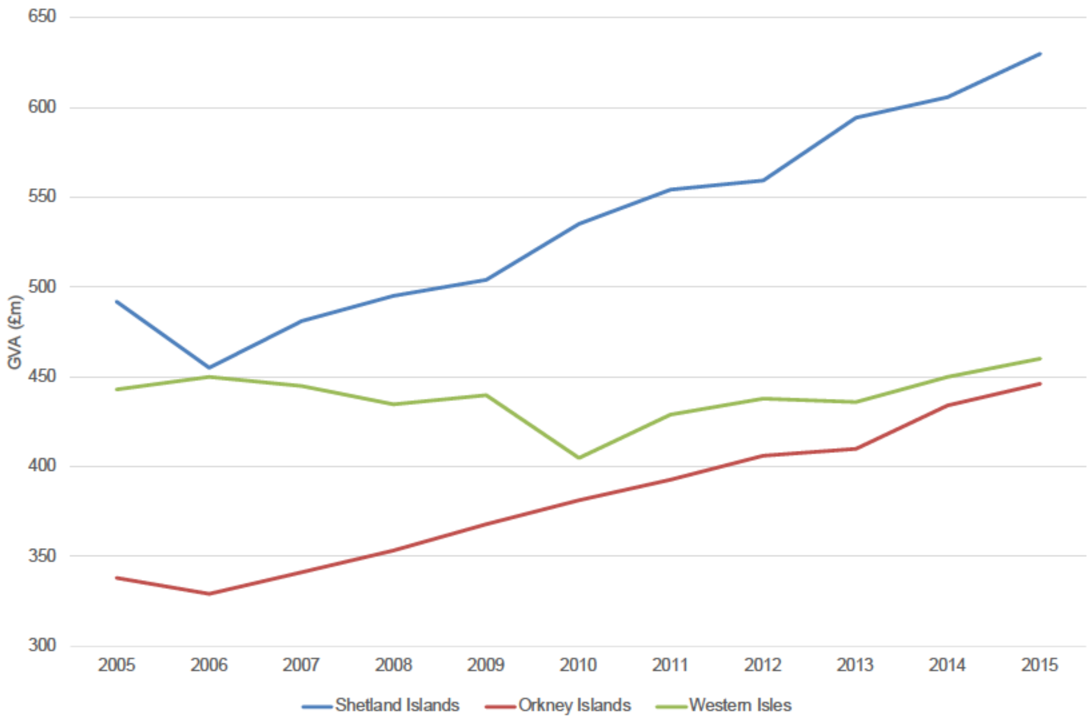
Table B-1: Contribution to 2015 Gross Value Added by Industry (£m)[53]

	Western Isles		Orkney		Shetland		Scotland	
Agriculture, forestry and fishing	15	3%	34	8%	34	5%	1,607	1%
Production	7	2%	16	4%	51	8%	6,943	5%
Manufacturing	31	7%	25	6%	57	9%	14,261	11%
Construction	38	8%	50	11%	88	14%	8,194	6%
Distribution; transport; accommodation and food	92	20%	113	25%	142	23%	23,983	19%
Information and communication	27	6%	7	2%	8	1%	4759	4%
Financial and insurance activities	4	1%	5	1%	4	1%	8,334	7%
Real estate activities	53	12%	45	10%	45	7%	12,756	10%
Business services activities	23	5%	28	6%	41	6%	13,119	10%
Public admin; education; health	154	33%	111	25%	128	20%	28,635	23%
Other services and household activities	14	3%	11	2%	33	5%	4,667	4%
All industries	460	100%	446	100%	630	100%	127,258	100%

Total GVA in Shetland has grown steadily since 2006, as has Orkney, while Western Isles GVA has remained steady – as shown in Figure B-1.

[53] GVA reference tables – Table 6 – GVA (Income Approach) by SICo7 industry at current basic prices

Figure B-1: Islands total GVA growth (205 – 2015, GVA £m, current basic prices)

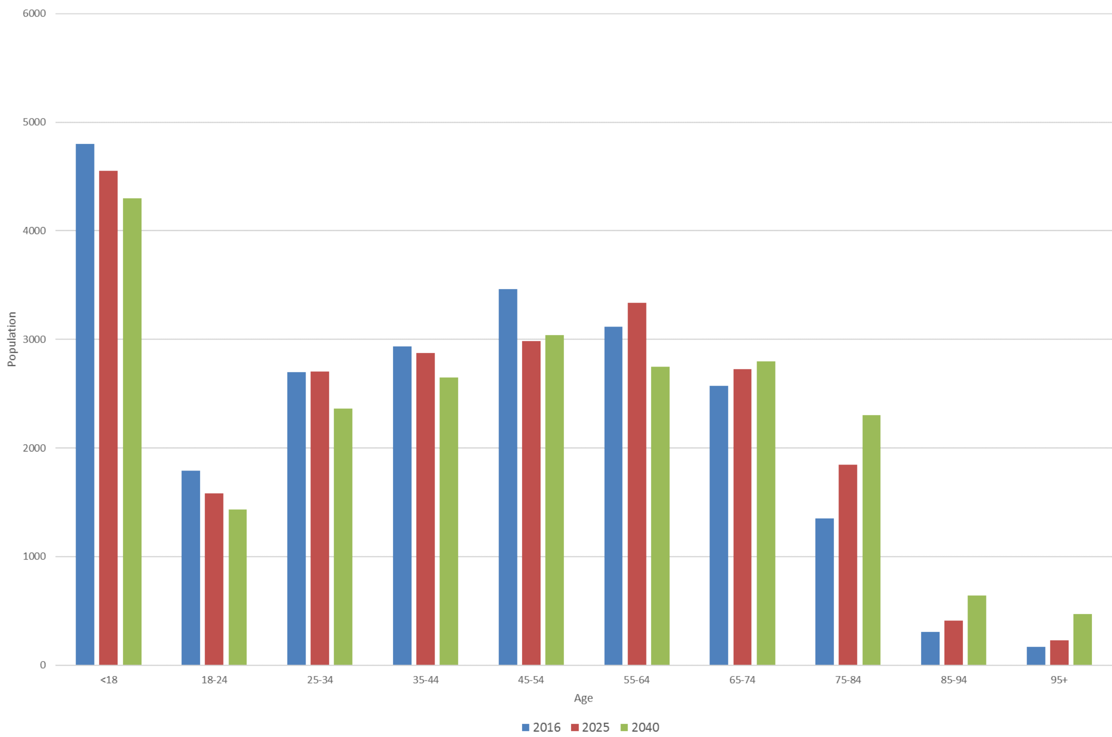


Population

National Records of Scotland publishes population projections by Local Authority in Scotland, with the most recent publication updated for 2016 data[54]. Population projections are produced every two years and are based largely on historic trends, reflecting past policy and economic impacts, but not the impact of future policy initiatives. The projections show a decline in the population of Shetland of 2% over the period to 2040 – with the largest reduction (20%) in the 18-24 age group, with the working age population forecast to reduce by 13%. Conversely, the population of people aged 65 or over is predicted to increase by 41%. Figure B-2 below shows how the population is forecast to change between now, 2025 and 2040.

[54] https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-projections/sub-national-population-projections/2016-based/detailed-tables

Figure B-2: Shetland population projections by age group



Unemployment in the islands has been very low, between 0.7% and 1.6% over the last ten years, less than half of the Scottish average.

Future growth

It is estimated that of the order of 40% of households in Shetland are living in fuel poverty, with over 13% in extreme fuel poverty[55]. The average number of households living in fuel poverty across Scotland is said to be around 26.5% although some estimates make that figure closer to 32%[56]. Average household spending on fuel is some 220% higher than the UK average and electricity consumption per household is over twice the Scottish average[57].

The opportunity to generate energy from community owned assets and also to export it to the Scottish mainland represents an opportunity to make a significant contribution to the future economic prosperity of Shetland.

Scotland's National Planning Framework recognises Scotland's significant renewable energy resources and the key role coastal and island locations will play in realising the potential for renewable energy generation. A letter from the Chief Planner to all local authorities on 11 November 2015 confirmed that, despite changes to UK policy on the development of onshore wind, the Scottish Government's policy remains unchanged. This includes support for new onshore renewable energy developments, including onshore wind farms and particularly community-owned and shared ownership schemes. This policy support continues even if national renewable energy targets have been met.

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55 https://www.shetland.gov.uk/OIOF/IslandsProofing.asp
56 https://www.gov.scot/Topics/Statistics/SHCS/keyanalyses/LAtables2016
57 http://www.cas.org.uk/system/files/Fuel%20Bills%20Survey%20Report.pdf

In practice the potential benefit to the island economies of renewable investment is likely to be important in determining whether the host community supports the development of any renewable energy project, thereby influencing the development of future generation[58].

B.3 Investment scenarios

In order to determine the potential economic impact of generation development on Shetland facilitated by the transmission link we have evaluated the GVA impacts of the generation scenarios and transmission reinforcement options.

B.4 Economic methodology

Input-output model methodology

Input-Output (I-O) modelling was used to evaluate the economic impact of investment in onshore wind in Shetland based on an analysis of the development expenditure, capital expenditure and operational expenditure for onshore wind projects. In addition we have taken into account the 'economic rent' that arises from community income received.

The IO technique used for calculating the direct, indirect and induced impacts of an increase in local economic activity from wind farm development generates the Gross Value Added (GVA) to the economy of Shetland.

Expenditure arising from wind development will impact Shetland economy at levels:

- Direct impact: increased post-tax profit, wages and employment produced directly by project expenditure. To compute the direct GVA impact, sector-matched expenditure is multiplied by the relevant GVA-output ratios for Scotland.
- Indirect impact: increased post-tax profit, wages and employment created from employment of sub-contractors and demand for goods and services from suppliers down the supply-chain.
- Induced impact: increased post-tax profit, wages and employment generated from greater demand and spending on goods and services such as accommodation, food, fuel and retail by employees who are employed as a result of the direct and indirect impacts.

Indirect and induced impacts are assessed using 'Type I' and 'Type II' multipliers. While these are available for Scotland, we have used multipliers calculated for Shetland (Table B-2). Using an I-O model, the GVA and years of employment supported can be calculated that result from wind farm expenditure.

The tables below show the factors considered in our analysis.

58 https://www.academia.edu/20243816/The_Importance_of_Revenue_Sharing_for_the_Local_Economic_Impacts_of_a_Renewable_Energy_Project_A_Social_Accounting_Matrix_Approach

Table B-2: Grid connection elements

Element	Sub-element
Construction	Electrical supply and installation
	Onshore cable supply
	Onshore cable installation
	Offshore cable supply
	Offshore cable installation
Operation and maintenance	Offshore operation and maintenance
	Onshore

Table B-3: Wind/tidal project elements

Element	Sub-element
Development	Project development
Turbine/device	Tower, rotor and nacelle
	Installation
Balance of plant	Civils/moorings
	Electrical
Operation and maintenance	Turbine/device operation and maintenance
	Wind farm/array operation
Decommissioning	Decommissioning

Community benefits

An important benefit to Shetland economy will result from income and benefits arising not fully considered in the IO analysis. This income/benefit arises from three sources:

- Community payments made by the owner/operator of any commercial projects
- Community income received from rent arising from ownership of part of all of a wind farm/turbine
- Reduction in community electricity costs arising from purchasing electricity from locally owned generators rather than grid supplied electricity

Community benefits are already commonplace in the onshore wind industry, with many onshore wind developers providing voluntary contributions in various forms over the lifetime of their projects to the local communities affected by their projects. Even though the provision of benefits is voluntary, community benefit schemes have become a well-established and integral characteristic of onshore wind developments over 5 MW. RenewableUK has produced a protocol committing onshore wind projects above 5 MW to provide a community benefit package to the value of at least £5,000/MW of installed capacity per year, index-linked for the operational lifetime of the project.

Community ownership of an onshore wind project is also increasing. The income arising from community ownership will depend on a number of factors, including the source of funding for a project. It is unlikely that a large proportion of the significant investment required to build the generation projects identified in our scenarios will be sourced locally and so third party borrowing will be required. The rate at which this borrowing is secured will dictate how much of each project's income finds its way into the local economy.

For example, if the IRR of a project is 6% and the community organisation borrows the funds at a 6% rate of interest, there is effectively no net income to the community. However, if a community organisation were to secure funding at a lower rate (e.g. the Local Authority borrowing at 3% from the Public Works Loan Board), then a portion of the annual income would be available to be spent in the local economy.

It is difficult to predict how funds will be sourced for community ownership elements of the generation projects identified. Assuming commercial projects do indeed give a community benefit package worth £5,000/MW/year for each MW not owned by the community it is unlikely that the community would take on any ownership of a project if it was forecast to return less than this amount, having considered borrowing costs versus project IRR. Therefore, for the purposes of modelling the impact on the Shetland economy we have conservatively assumed that income arising from community ownership is equal to £5,000/MW/year.

Self-consumption of electricity generated is both an incentive for a project developer and a benefit to the local economy. For example, if a local business installs a turbine and uses 20% of the electricity generated on-site it will avoid the relatively high cost of a commercial/industrial tariff from its electricity supplier for this portion of its electricity use. Some of this 'avoided cost' will be spent in the local economy.

For the purposes of our model we have assumed that 20% of generation from small-scale projects (any project <5MW) is consumed locally. We have assumed that the benefit to the local economy of each MWh consumed locally is the difference between £126/MWh (the average BEIS forecast industrial tariff from 2023 until forecasts end in 2035) and the levelised cost of generation from these projects. We assume that only 20% of this 'avoided cost' will be available to the local economy, i.e. that 80% of the avoided costs leaks off the islands.

We assume the economic rent identified is distributed in the local economy in line with GVA contribution as outlined in Table B-1. The GVA impact of the distributed economic rent is calculated using the IO methodology. Alternative, more targeted, spending scenarios could be utilised that may provide larger impacts[40], but we have not considered any in our analysis.

All impacts are discounted at the social time preference rate of 3.5% in line with the guidance in HM Treasury's 'Green Book'[59].

B.5 Results

B.5.1 Shetland content

We have assessed the local content of wind projects in Shetland based on output of a number of reports, including Renewable UK's Economic Impacts of onshore wind [41] [42] [49] [60].

Onshore wind farms

For the onshore wind farms we have assessed a 'local' Shetland content of the following areas:

- Development and project management
- Turbines
- Balance of plant (supply and installation)

[59] The Green Book: Appraisal and Evaluation in Central Government, November 2016, HM Treasury. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

[60] http://c.ymcdn.com/sites/www.renewableuk.com/resource/resmgr/Publications/Reports/onshore_economic_benefits_re.pdf

- Operation, maintenance and decommissioning

Development and project management

Development and project management is assumed to include a local content of some 5%, with much development activity taking place outside Shetland.

Turbines

None of the main turbine components will be sourced from Shetland – although we assume a greater local activity in turbine transport to the islands. We calculated 0.5% local content of the turbines and 10% of transport costs Shetland sourced. For small scale wind turbines we assume a higher contribution of Shetland transport of 30%.

Balance of plant

Balance of plant covers the civil and wind farm electrical works. For the civil works, we have assumed a Shetland content of 35%. For small scale wind turbines local content is higher at 65%. For electrical works – almost all components are likely to be imported and the number of local electrical engineers is limited. Therefore local content is limited to 10%.

Operation, maintenance and decommissioning

Shetland has a large number of small scale wind farms. Maintenance of the wind farms will employ a number of local wind farm technicians – although major repairs are likely to require specialist, imported services. Decommissioning is assumed to have a reasonable local content of 30%. Overall we assume a total local content of 24% for large, commercial wind farm opex and decommissioning and a higher local content of 28% for small scale wind turbines.

Table B-4: Shetland content of wind projects

Category	% of TOTEX	Geography	% content of category	
			Commercial wind	Small scale wind
DEVEX	4%	Shetland	5%	25%
		Non Shetland	95%	75%
CAPEX	59%	Shetland	6%	9%
		Non Shetland	94%	91%
OPEX	38%	Shetland	24%	28%
		Non Shetland	76%	72%
TOTEX	100%	Shetland	13%	17%

Table B-5 - shows that the overall Shetland content in larger, commercial wind farms is some 13%, rising to 17% for small scale wind turbines. The local content determined in our analysis broadly similar to that adopted in other studies in Scotland – together with Renewable UK's latest analysis for 'local' content for UK onshore wind.

Table B-5: Local content comparable studies

Local content	Renewable UK[60] (2017)	BVG – Western Isles (2017)	Biggar Economics – Scottish Boarders[61] (2013)	BVG Scotland[62] (2017)	Okkonen et al Shetland/ Orkney (2015)	Baringa Orkney (2016)
Construction	12%	5-11%	5-10%	2%	14%	12%
Operation	42%	22-37%	29-40%	25%	63%	42%
Total	27%	13-24%	25%	16%	37%	25%

We assume the technical life of a wind turbine/farm to be 20 years, after which the turbine/farm is repowered – with subsequent additional capex. Conservatively we do not assume an increase in MW capacity when the wind turbine/farm is repowered

Transmission reinforcement

The breakdown of transmission investment costs is based on information providing by SHE Transmission and GHD's own analysis. Broad expenditure categories include:

- Development costs
- Cable
- Static Var Compensation
- Substations

Local content assumptions for significant components such as substations, cable, SVRs and electrical works are very limited – at around 0.5-1%. However larger local content is assumed for construction elements. Overall we have assumed a local content for transmission investment of some 2%.

B.6 Gross value added

Table B-6 shows the resulting total present value (PV) GVA (economic) benefit for each generation scenario and transmission option considered in GHD's Central Case analysis. The economic impact includes all wind developments (large and small) and the transmission link, but excludes on-island transmission works.

Table B-6: Present value GVA impact for each scenario (£m 2018 prices)

Transmission Options	Transmission (£m)	Generation (£m)				Total
		S1 - 414MW	S2 - 582MW	S3 - 655MW	S4 - 742MW	
Option 1 - 450MW HVDC	11	132	141	143	144	143 - 156
Option 2 - 600MW HVDC	12	132	183	191	193	143 - 204
Option 3 - 800MW HVDC	12	132	183	208	238	144 - 251
Option 4 - 800MW HVDC P2P	17	132	183	208	238	149 - 256
Option 5 - 1000MW HVDC P2P	18	132	183	208	238	150 - 257

The overall economic benefit to Shetland is substantial, ranging from £143m to £257m depending on the generation scenario and the reinforcement option considered. In terms of GVA impact, the benefit of the transmission link is small due to the relatively minor local content assumed. Conversely, the impact of wind generation is much larger.

[61] Economic Impact of Wind Energy in the Scottish Borders, Biggar Economics, Mar 2013
[62] Economic benefits from onshore wind farms - A report for ScottishPower Renewables, BVG, September 2017

We have also assessed the GVA impact of each transmission option – for simplicity we have capped the MW generation at the size of the reinforcement, i.e. the generation associated with Option 1 is capped at 450 MW. Clearly additional generation may economically connect without incurring significant constraint costs, therefore our analysis is conservative.

The larger the capacity of the transmission option, the greater the amount of generation can be developed on the Islands and thus leads to economic benefits during wind farm construction and operation as well as the establishment of further community funds directly related to the successful operation of renewable projects which directly benefit island residents and communities.

B.7 Socio-economic benefit in context

Whilst the identified economic benefit is significant it is worth putting the benefit into context. Table B-7 shows the minimum and maximum lifetime economic benefit of the reinforcement as derived from our analysis. The average lifetime economic benefit per annum has also been derived (based on the assumed life of 40 years). The economic benefit per annum ranges between £3.6m and £6.4m per annum. The minimum and maximum economic benefit per annum has been compared to a number of Shetland-specific demographic and economic parameters including: population[54]; number of households[63]; regional GVA[51]; average gross household income and average GDHI (gross disposable household income)[64].

Table B-7: GVA benefit in relation to Shetland demographic and economic data (2018 prices)

Lifetime Economic Benefit (£m)	Economic Benefit Per Annum (£m)	Economic Benefit Per Capita Per Annum (£)	Economic Benefit Per Household Per Annum (£)	Economic Benefit Per Annum as a Proportion of Total GVA (%)	Economic Benefit Per Household Per Annum as a Proportion of Average Household Income (%)	Economic Benefit Per Household Per Annum as a Proportion of Average GDHI (%)
£143	£3.6	£154	£347	0.5%	1.4%	1.7%
£257	£6.4	£277	£624	0.9%	2.5%	3.1%
		...based on Population of Shetland in 2016	...based on No. of Households in Shetland in 2016	...based on Shetland GVA (£m, 2016)	...based on Shetland Average Gross Household Income (£)	...based on Shetland Average GDHI (£)
		23,200	10,283	£680	£24,600	£20,124

Our analysis indicates that the reinforcement options can be expected to create an annual economic benefit of between £154 and £277 per person or around £347 to £624 of economic benefit per household. The total economic benefit is likely to form between 21% and 38% of the total regional GVA (as of 2016) whilst on an annual basis the economic benefit would range between 0.5% and 0.9% of the total regional GVA. The economic benefit per annum is equivalent to between 1.4% to 2.5% of gross household income, whilst the economic benefit in relation to GDHI is higher at between 1.7% and to 3.1%. Clearly the impact on a per capita, per household and overall economic perspective is substantial and has the potential to improve the economic welfare and social well-being of the Shetland Islands.

Table B-8 presents the Shetland demographic and economic ratios relative to the equivalent ratios derived for the Highlands (a large geographic area with a relatively sparse population) and the City of Edinburgh (a small geographic area with a compact population). The analysis is

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63 https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/households/household-projections/2016-based-household-projections

64 https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/datasets/regionalgrossdisposablehouseholdincomegdhi

presented based on the same amount of economic benefit (in £m terms) as that derived for the Shetland reinforcement[65].

Table B-8: Comparison of GVA ratios

Region	GVA Benefit	GVA benefit per capita per annum (£)	GVA benefit per household per annum (£)	GVA benefit per annum as a proportion of total GVA	GVA benefit per household per annum as a proportion of Average Household Income (£)
Shetland	Minimum	154	347	0.5%	1.4%
	Maximum	276	623	0.9%	2.5%
Highlands	Minimum	14	30	0.0%	0.1%
	Maximum	46	101	0.1%	0.5%
Edinburgh City	Minimum	6	14	0.0%	0.1%
	Maximum	21	47	0.1%	0.2%

The same amount of economic benefit arising in the Highlands or the City of Edinburgh would have a much smaller relative impact on the regional economy and on households. Considered another way, to derive the same economic benefit on a household-to-household basis would require a project that created 6 times more economic benefit in the Highlands and over 13 times more economic benefit in the City of Edinburgh.

Whilst local multipliers and leakage rates will differ by region (meaning the ratio between capital investment and resulting economic benefit may be higher in many regions), there are also other factors that could result in lower economic benefits or a lack of 'Need' for investment in the first place. SHE Transmission are required to connect customers where they want to be connected and the generation scenarios developed in our CBA are a reasonable reflection of the known (not speculative) demand and appetite for building wind generation on the islands if a link were available. This demand/appetite is driven by the high capacity factors not available elsewhere on the mainland, a lack of opposition from residents and local councils from building onshore wind farms and the Council and community's desire to tap into the economic benefit that investment would bring.

B.8 Comparison with other studies

The socio-economic impact of renewable investment has become an increasingly important aspect of project development and is has become relatively widely adopted. In order to validate our socio-economic methodology we have, as far as possible, calibrated our socio-economic model with the assumptions adopted in other studies. Table B-9 shows the results of our model calibration based on five Scotland/islands based socio-economic studies for renewable development. The studies include a number of different authors in order to fully test GHD's approach. In some instances we have not been able to adopt the assumptions used in other studies due to lack of clarity, these instances are outlined.

Table B-9: Socio-economic studies for onshore wind in Scotland – with GHD replication (2017 prices)

Study		Assumptions and comments	£m/MW GVA	GVA
Shetland/Orkney	Okkonen et al	Annual opex not over entire project life, national coefficients with 30% reduction for	0.17	4.8

[65] The population, household and GVA data is derived using the same database sources as those highlighted for Shetland. Household salary data has been approximated by applying an uplift to the Shetland salary based on the ratio of average hourly wages relative to the Shetland average wage (http://www.parliament.scot/ResearchBriefingsAndFactsheets/S5/SB_16-92_Earnings_in_Scotland_2016.pdf)

27.6 MW wind (2014)		Orkney. Multiplier impact only. Revenue reinvestment targeted to maximise GVA impact – corresponding significant result		
	GHD	Annual opex not over project life, Shetland coefficients. Multiplier impact only. Revenue investment not specifically targeted	0.10	2.8
Clyde wind farm extension 173 MW (2015)	PWC	Discounted (2015) capex/opex benefits over 20 year life – Scotland focus, no community benefits	0.27	46
	GHD	Discounted (2017) capex/opex benefits over 20 year life, Shetland focus, no community benefits	0.26	45
Orkney 200 MW wind (2016)	Baringa	Discounted 2015-2040, no community benefits, 23% local content	0.34	68
	GHD	Discounted 2017-2042, no community benefits, 23% local content	0.36	72
Western Isles 520 MW wind (2017)	BVGA	Discounted 2016-2050, 33% community ownership – very large unclarified community benefits (£243m) 53% UK content, unclear local content	0.76	394
	GHD	Discounted 2017-2051, 33% community ownership, £5000/MW community benefits, 15% local content	0.39	203
SW Scotland 474 MW wind (2017)	BVGA	£1.6 bn 'total investment' 16% local content, 25 year life from 2016, discounted to @2015, no community ownership, some community benefit	0.62	297
	GHD	£1.6 bn total, 25 year life from 2023, no community ownership, £5000/MW community benefit, discounted 2017, 16% local content, 30% capacity factor	0.48	228

The results of our calibration indicate that similar results are obtained to other studies when using similar assumptions – while identical assumptions are difficult to ascertain we believe our calibration shows a consistent approach to determining socio-economic benefits.

B.9 Summary

While socio-economic benefit of the transmission link and associated generation should not be used in isolation to justify the transmission link, we believe Ofgem should consider the clear benefit to Shetland resulting, particularly in light of its role as relevant public body obliged under the Islands Bill to consider the impact on the islands. Part of this impact assessment is a socio-economic impact evaluation. With potential benefits of over £255m the impact on the social and economic fabric of Shetland will be significant, with the greatest benefits realised with Option 5 – the 1000 MW HVDC link (due to its higher capital cost and ability to facilitate the most generation).

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Document Status

Rev.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Draft A	L. Foley J. Wearmouth R. Gadsden E. Bennett	L. Foley		P. Espie	Paul Espie	28/09/18
Rev 0	L. Foley	P. Buckworth		P. Espie	Paul Espie	03/10/18