SHE - Transmission

Transmission Reinforcement between the Western Isles and the Scottish Mainland

Cost Benefit Analysis Study

Final Rev 1
August 2018

Executive Summary

This report details the Cost Benefit Analysis undertaken by GHD to support SHE-T's Needs Case assessment as part of the Strategic Wider Works (SWW) submission to Ofgem for the Western Isles transmission connection project. As part of this process we have performed a rigorous cost benefit analysis of a range of proposed transmission connection options from the Western Isles to mainland Scotland across a credible range of potential generation development scenarios.

The principal transmission link options considered are:

- Option 1: 450 MW High Voltage Direct Current (HVDC) subsea and underground cable connection
- Option 2: 600 MW HVDC subsea and onshore underground cable connection
- Option 3: 237 MW AC subsea and underground cable connection

The specific generation scenarios considered the following maximum capacity:

- Scenario 1: 333 MW
- Scenario 2: 422 MW
- Scenario 3: 525 MW
- Scenario 4: 638 MW

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). This conclusion is influenced to some extent by the highest capacity generation scenario (S4) as the performance of both HVDC connection options (Option 1 and 2) are actually very similar across the mid-scenarios (S2 and S3). Both options also perform commensurately worse under the lowest capacity S1 scenario where the lowest capacity AC connection (Option 3) is the preferred option. Option 3 does however incur a significant regret cost under the mid and high generation scenarios and would offer insufficient overall transmission capacity for those projects wishing to compete in the forthcoming CfD auction.

Further supporting the GHD recommendation that Option 2 represents the preferred connection option we have examined the break-even point of generation capacity required to economically support Option 2 and also further investigated the tipping point of generation capacity required to result in Option 2 being the preferred connection design. Our analysis suggests that the 'break-even' point of generation for Option 2 is less than 174 MW – below the capacity of generation even in our lowest scenario. Furthermore the 'tipping point' of renewable generation capacity that results in Option 2 having the superior overall NPV is around 520-530 MW. The generation required to meet the 'tipping point' between Option 1 and 2 could come from a wide range of potential combinations of generation projects as currently there are over 800 MW of potential project capacity known, with potentially more that could be developed over the longer term.

GHD has also reviewed the CBA and regret costings provided by the SO for the same range of generation scenarios and transmission connection options. We note that the SO analysis has identified that Option 1 (450 MW HVDC link) is the option of LWR when examining the wider range of scenarios, including the four FES generation scenarios and the four SHE-T derived scenarios. However, the SO also confirms that this outcome is based on the inclusion of the

FES Steady State (SS) scenario which in their own words is something of “an outlier in this analysis as exports never exceed 200 MW”. They further indicate that this scenario is essentially incompatible with the basis of SHE-T’s Needs Case submission which is conditional on the two larger wind farm projects on Lewis achieving success in the forthcoming CfD auction. When they remove the Steady State scenario from their regret analysis, Option 1 has a worst regret of £90 m and Option 2 has a worst regret of £44 m. Option 2 thus presents the least worst regret option. Thus, the SO conclusion effectively matches with the recommendation from GHD’s own analysis that Option 2 represents the most appropriate transmission connection option for the Western Isles.

Some further final considerations relating to the identification of Option 2 as the preferred transmission connection option for the Western Isles are the socio-economic benefits facilitated by the connection and the impact on prospective renewable generation developers of TNUoS charges. In the case of Option 2, the total identified socio-economic benefit has been calculated as £229 m, around £55 m higher than Option 1. In relation to prospective TNUoS charges that could be incurred by renewable generation developers on the Western Isles we have identified that this would be around 20% higher (on a £ per kW or £ per MWh basis) under Option 1. On this basis Option 1, due to the increased expected TNUoS costs to Western Isles renewable developers, runs the risk of resulting in no transmission connected generation on the Western Isles if such developers are uncompetitive during the forthcoming CfD auction. This would also jeopardise the prospective socio-economic benefits for the Western Isles already outlined and would therefore appear to be inconsistent with the aims of the recent 2017 ‘Islands (Scotland) Bill’ which places a duty on relevant public bodies to have regard to island communities in exercising their functions.

Taking due account of all of these supplementary considerations GHD believes that this further supports the principal recommendation, that ***overall Option 2 (the 600 MW HVDC link) is the preferred transmission connection option for Western Isles***. This recommendation is fully aligned with the SHE-T Needs Case submission.

SUMMARY REPORT:
KEY FINDINGS AND RECOMMENDATIONS

Background

The Western Isles is an archipelago rich in renewable energy sources – in particular onshore wind. Wind speeds on the Western Isles are high and one developer (Lewis Wind Power) has contracted with SHE-T to develop two significant wind farms. However, the existing distribution network on the islands is operating at full capacity. New transmission system infrastructure is therefore needed to ensure the Western Isles can exploit and benefit from its valuable renewable resource.

The purpose of this report

Any planned transmission reinforcement project falling within the RIIO-T1 Strategic Wider Works (SWW) funding arrangements requires SHE-T to submit to Ofgem a 'Needs Case' 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-T has commissioned GHD to undertake a CBA for the Western Isles.

The basis of the CBA is a discounted cash-flow analysis of benefits versus annualised project costs to give net present values (NPVs) for:

- A range of alternative options for a transmission link; ("options");
  under
- A range of different potential scenarios for development of generation capacity on the islands ("scenarios")

The NPVs under different scenarios are then reviewed to identify the "regrets" that would result under each option for a given scenario out-turn.

For sensitivity purposes, a number of alternative cases for different input assumptions are also considered ("cases").

Overview of potential transmission requirement

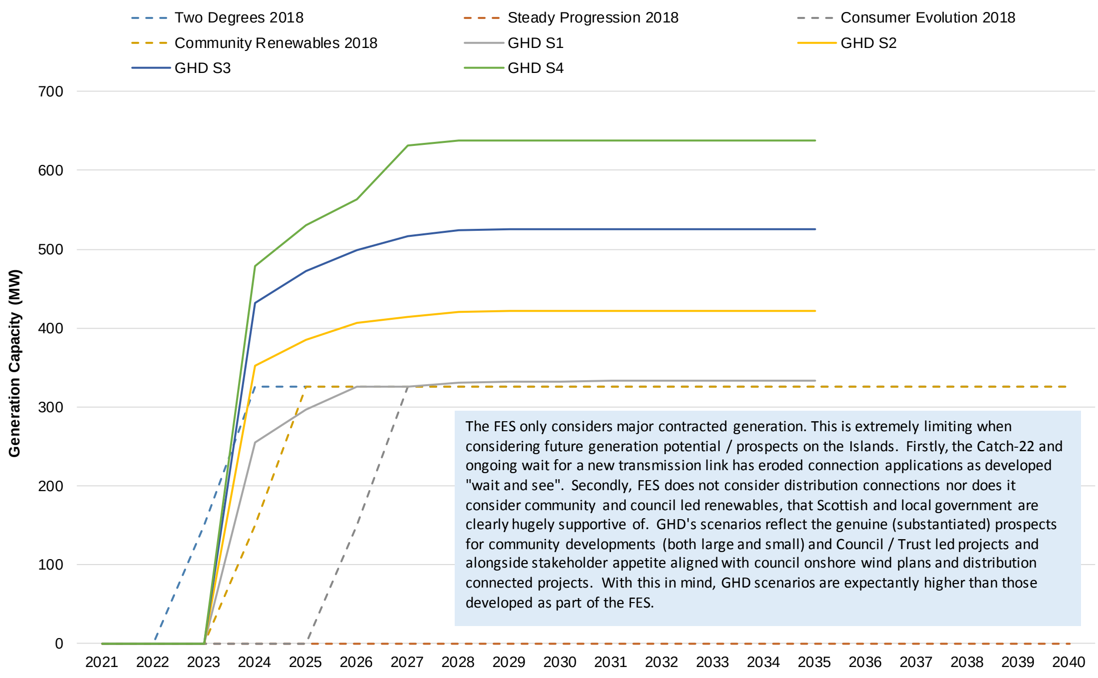
GHD understands the two largest proposed wind farms on the Western Isles (Stornoway, and Uisenis) intend to compete in the 2019 CfD Round 3 auction[1]. As these projects alone currently represent between approximately 340-430 MW of generation capacity, SHE-T wishes to submit a 'conditional' Needs Case to Ofgem, with the need being conditional on the award of CfDs to those generators. GHD has developed four generation scenarios to reflect this approach that assume varying alternative degrees of success in the 2019 CfD auction for these large transmission-connected wind farms. The scenarios are supplemented by varying levels of underlying local appetite for additional community and Council development should a new, high capacity transmission connection to the Scottish Mainland be constructed.

The following chart (Figure 1) shows the resulting GHD generation scenarios developed (S1 – S4). The chart also shows the Future Energy Scenarios (FES) developed by National Grid for

[1] Which will be held in 2019 and thereafter every two years see, https://www.gov.uk/government/news/a-boost-for-north-east-innovation-to-promote-high-quality-jobs-and-growth

the Western Isles. We conservatively assume there is no additional generation growth beyond 2030 – in common with the FES.

Figure 1: Generation scenarios for the Western Isles



Reinforcement options

SHE-T has performed option development and screening to identify potential transmission reinforcements that could support renewable generation development on the Western Isles. It has identified six reinforcement options that could connect the Western Isles to mainland Scotland:

1. 450 MW High Voltage Direct Current (HVDC) subsea and onshore underground cable connection
2. 600 MW HVDC subsea and underground cable connection
3. 237 MW AC subsea and underground cable connection
4. 237 MW AC subsea and overhead line connection
5. 138 MW AC subsea and underground cable connection
6. 138 MW AC subsea and overhead line connection

The SHE-T Needs Case submission for the Western Isles transmission connection is being submitted on a 'conditional' Needs Case basis, that is contingent on renewable projects on the Western Isles having success in the forthcoming CfD auction. Consequently, our analysis has considered those transmission options that can be delivered by the end of 2023 and have sufficient transmission capacity to accommodate renewable projects that presently intend to complete in the future CfD Round 3 auction. This is principally the two HVDC options, both of which have sufficient capacity to cater for the main renewable projects seeking CfDs and can also be delivered in time to enable the project developers to meet CfD obligations. This also notionally rules out most of the AC transmission options, the two lowest capacity options (5 and 6) providing insufficient capacity to cater for prospective CfD submission projects whilst options involving overhead line (4 and 6) are not considered to be deliverable before 2026 at the earliest due to the potential consenting and deliverability issues. We have however included the remaining AC Option 3 (237 MW with subsea / underground cable) for consideration in our analysis, albeit with a delivery date of end 2024, one year behind the two HVDC options, in order to provide a lower capacity transmission option for the analysis. However, implicit under this option is that only one of the two larger renewable generation projects[2] on the Western Isles would achieve CfD success in the forthcoming auction in 2019.

Note that if none of the larger renewable generation projects considered for the Western Isles achieve success in the forthcoming CfD auction then the wider pool of transmission connection options, including those currently excluded from our analysis, could be reconsidered as part of any future re-submission.

SHE-T has provided capital expenditure (capex) and operational expenditure (opex) estimates for the considered transmission connection options, as shown below in Table 1.

Table 1: Transmission Reinforcement Options & Costs (2018 prices)

Option	Description	Capex £m	Opex £m p.a.
1	Arnish-Dundonnell 450 MW HVDC subsea (single circuit) & Dundonnell-Beauly HVDC cable (single circuit)	[redacted]	[redacted]
2	Arnish-Dundonnell 600 MW HVDC subsea (single circuit) & Dundonnell-Beauly HVDC cable (single circuit)	[redacted]	[redacted]
3	Arnish - Dundonnell 220 kV HVAC subsea (single circuit) & Dundonnell to Beauly HVAC Cable (single circuit) – 237 MW	[redacted]	[redacted]

Cost Benefit Analysis

The GHD study has evaluated the cost and benefits of the three reinforcement options shown in Table 1 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 Western Isles transmission connection is forthcoming.

The results of our analysis show that a transmission connection to the Western Isles is strongly economically viable. All reinforcement options return significantly positive NPVs in our Central Case at both a £55/MWh and £70/MWh constraint cost across all four scenarios, as shown in Table 2 and Table 3.

Table 2: Central Case NPV with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	432	792	1,161	1,371
2	600 MW HVDC	382	742	1,155	1,584
3	220 kV AC Cable	482	589	679	751

[2] Either LWP Uisenis or LWP Stornoway wind farm projects

Table 3: Central Case NPV with £70/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	731	1,189	1,658	1,926
2	600 MW HVDC	681	1,139	1,664	2,211
3	220 kV AC Cable	741	878	992	1,084

CBA for high capex sensitivity cases

Sensitivity analysis of a 20% increase in project capex, while reducing project NPVs, does not change our conclusions and a proposed transmission connection to the Western Isles remains strongly economically viable. A similar outcome arises if the cost of enabling onshore works is included in total project costs – again the proposed transmission connection remains strongly economically viable.

CBA for revised connection date sensitivity cases

We have also investigated delaying the delivery date of the preferred Option 2 (600 MW HVDC link) beyond SHE-T's planned delivery date of 2023 as well as a further case examining all options (including Option 3) delivery dates being the end of 2023 i.e. the first full year of benefit starting in 2024. For the former this was found to provide no benefit to the resultant NPV as any effective savings in relation to deferred capex are outweighed by the cost of increased constraint costs. In the case of the latter sensitivity this improved the NPV of Option 3 by up to £21 m (£31 m under the higher constraint cost) under the highest S4 scenario with a concomitant reduction in maximum (worst) regret. The overall observations from the Central Case remain unchanged though, that is Option 2 remains the option of least worst regret across the scenarios.

Breakeven point of generation

Further demonstration of the value provided by the proposed Western Isles transmission connection options can be seen from an assessment of the installed capacity of generation (in MW) necessary to return a positive NPV for each reinforcement option. This is the so-called 'breakeven' point of generation, the results of which are shown in the following table (Table 4).

Table 4: The Breakeven Point of Generation

Option	Description	£55/MWh constraint cost	£70/MWh constraint cost
1	450 MW HVDC	163	128
2	600 MW HVDC	174	136
3	220 kV AC Cable	118	93

From review of the above Table 4 it is evident that the AC Option 3 has the lowest breakeven point of generation at between 93-118 MW due to its lower overall capex. The breakeven point of generation for the 450 MW and 600 MW HVDC options is similar and ranges from 128-163 MW for the 450 MW link, and 136-174 MW for the 600 MW link. Note that all of these breakeven points are significantly below the generation capacity outlined in any of GHD's generation scenarios as shown in Figure 1.

Least worst regrets analysis

While the NPV analysis shows that the economic viability of a transmission connection to the Western Isles is robust, the results also show that the optimum reinforcement option differs depending on the generation scenario analysed. To determine which reinforcement option represents the option of Least Worst Regret (LWR) across all scenarios, a regrets analysis has been undertaken as shown in the following Table 5 and Table 6. The basis of this analysis is as follows:

- For each potential generation out-turn scenario, the highest NPV option is identified;
- For each alternative transmission option, the regret under that scenario is calculated as the difference between (i) the NPV for that option and scenario; and (ii) the NPV identified above;
- For each option, the "worst regret" is the highest regret across all generation scenarios for that option;
- The worst regrets for each option are then compared to identify the option of LWR;

Table 5: Central Case LWR with £55/MWh Constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	49	0	0	213	213
2	600 MW HVDC	99	50	6	0	99
3	220 kV AC Cable	0	203	482	833	833

Table 6: Central Case LWR with £70/MWh Constraint cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	10	0	6	284	284
2	600 MW HVDC	60	50	0	0	60
3	220 kV AC Cable	0	311	672	1,127	1,127

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 with a maximum regret value significantly lower than the 450 MW HVDC option.

Comparison with SO study results

For completeness GHD has also performed a comparison of our CBA results with those provided by the System Operator (SO) in their analysis of the Needs Case for Western Isles. The SO has considered the four national generation scenarios (Two Degrees, Slow Progression, Steady State and Consumer Power[3]) included in their Future Energy Scenarios (FES) as well as the four island-specific generation scenarios provided by SHE-T and included in the GHD analysis. The SO has also modelled all six transmission connection options presented earlier even though Options 4, 5 and 6 have been ruled out due to their timing or capacity and hence could not facilitate a successful outcome for the large, transmission-contracted projects wishing to enter the CfD auction process. A summary of the SO results for the four SHE-T orientated generation scenarios for Options 1 to 3 (to align with the GHD analysis) is shown in Table 7.

Note that these results from the SO have been determined for constraints against a national generation background and accompanying transmission network reinforcements corresponding to the Slow Progression scenario; i.e. (i) captures the effect of any constraints arising deeper in the GB network; but (ii) does not consider any wider network reinforcement that may occur under the different scenarios for national generation.

[3] Note that the System Operator CBA study results have used the older FES scenarios and definitions as these are presently included along with required associated transmission system boundary reinforcements in their analysis model.

Table 7: SO Results for SHE-T Scenarios (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	3	0	6	90	90
2	600 MW HVDC	44	44	0	0	44
3	220 kV AC Cable	0	157	335	542	542

From review of the SO study results shown in Table 7 it is it is evident that results are similar to those obtained by GHD for the Central Case (£55 / MWh constraint cost) for the two HVDC options. The results for Option 3 are also broadly similar in trend i.e. Option 3 is the option of least regret under scenario S1 for both the GHD and SO analysis and this option also performs poorly in comparison with the two HVDC options over the other scenarios.

Overall, taking the SO results for the same range of scenarios as GHD the same conclusion is reached, that Option 2 (600 MW HVDC link) is the option of least worst regret. However, the SO also includes in their regret analysis the results derived from their four FES scenarios. When these are included, the maximum (worst) regret for Option 1 is £137 m and for Option 2 is £173 m, both achieved under the Steady State scenario. The SO does however recognise that the Steady State scenario is “an outlier in this analysis as its exports (from the Western Isles) never exceed 200 MW hence large regrets are present for all larger capacity options since their capacity is never used despite the high Capex spend”. When they remove the Steady State scenario from their regret analysis Option 2 has a worst regret of £44 m (across the three remaining FES scenarios and four SHE-T scenarios) with Option 1 having a worst regret of £90 m. Thus, the SO conclusion effectively matches with the recommendation from GHD’s own analysis that Option 2 represents the most appropriate transmission connection option for the Western Isles.

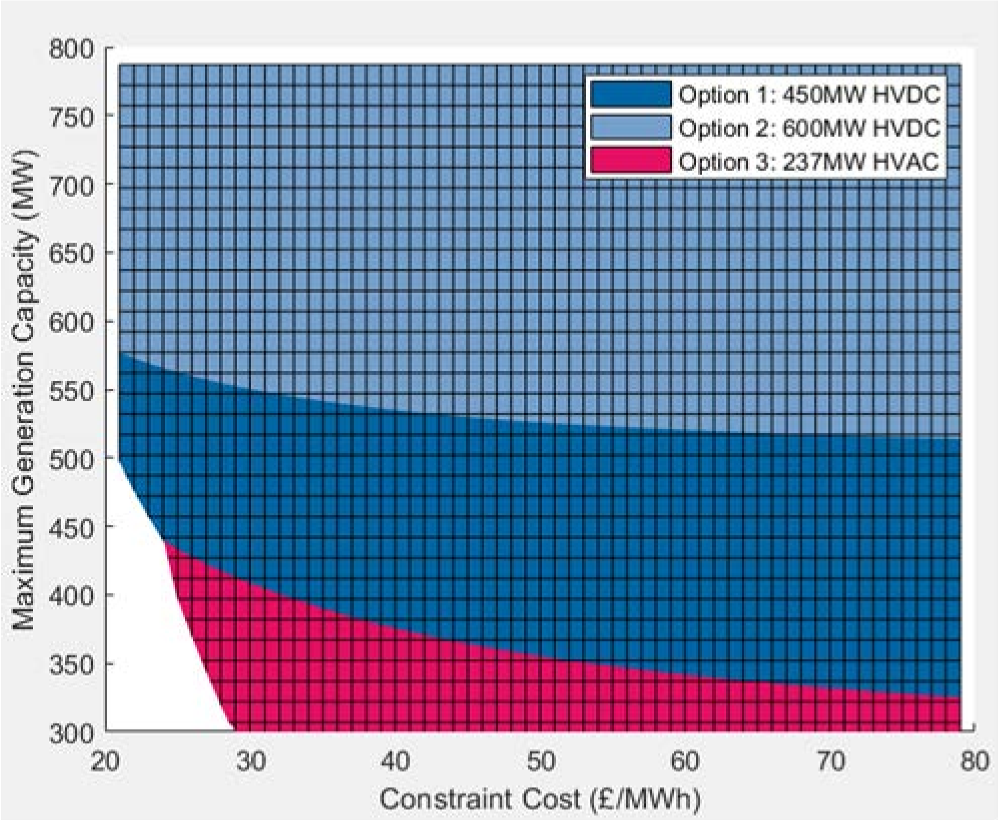
Tipping point analysis

As a further investigation into the sensitivity of different reinforcement options, GHD has carried out analysis to determine the quantity of generation at which each option becomes the option of highest NPV.

The results of the GHD analysis have shown that changes in constraint cost assumptions and generation scenarios can have significant and yet often ‘penny switching’ impacts on the preferred transmission connection option. Clearly, over the life of the transmission assets (generally 40 plus years) variations in the generation scenarios developed and associated system constraints costs assumed are likely to emerge, with no specific generation scenario or constraint cost assumption prevailing for the entire life of the asset.

Hence 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 NPV of each reinforcement option. The following chart (Figure 2) shows the results of this exercise for variations in constraint costs and ranges of generation capacity.

Figure 2: Impact of Generation Capacity and Constraint Costs on NPVs



From review of Figure 2, the white area represents the area of non-viability – for example at a constraint cost of £25/MWh around 440 MW of generation is required for any transmission option to return a positive NPV. The chart also shows the 'tipping point' between each of the reinforcement options – between Option 1 and 2 this is around 520-530 MW based on a £55-70/MWh constraint cost.

With more than 800 MW of known or prospective generation developments that could be developed across the Western Isles there are clearly a number of different combinations of individual projects that could come forward and result in this tipping point (520-530 MW) being reached.

One of the largest potential variations revolves around the eventual installed capacity of LWP's Stornoway and Uisenis projects, with LWP considering a range of combined installed capacities between 340 MW and 430 MW for the two projects. Taking this range into account three potential compositions of the tipping point of generation between Option 1 and 2 are illustrated in the following figure (Figure 3). A composition without LWP's Stornoway project is also considered, i.e. a scenario where LWP loses its ongoing court proceedings with the local crofter community but that the community projects that are proposed to take its place proceed.

Figure 3: Tipping Point Analysis: Potential Composition of Generation Scenarios for Options 1 and 2

Redacted

Each composition identifies generation projects that would be needed for the tipping point to be reached. A number of these are known projects which are consented and being actively pursued and therefore form the basis of all tipping point compositions.

Overall, GHD considers each of these possible compositions to represent a realistic development path for renewable generation projects on the Western Isles that could occur if a transmission connection to the Scottish mainland of sufficient capacity were to be developed. Crucially even under the lower "D" scenario the tipping point still only represents development of around two thirds of the prospective renewable generation plant capacity that is currently known. Further prospects are also likely to develop once the transmission connection link is operational and potential generation developers have more certainty over their ability to connect.

Other considerations – affordability of TNUoS

Stakeholders have suggested to SHE-T that the higher TNUoS associated with Option 1 (450 MW HVDC link) will lead to an unsuccessful outcome for a transmission connected wind farm on the Western Isles in the forthcoming 2019 CfD auction. While clearly a range of inputs and assumptions will influence the lifetime levelised cost of a Western Isles based wind farm and its subsequent bid into the CfD auction, our analysis suggests that Option 2 (600 MW HVDC link) will indeed result in a more competitive bid as shown in the illustrative calculations presented in Table 8. Therefore, CfD auction bids from a wind farm on the Western Isles reliant on the lower capacity transmission connection Option 1 can be expected to carry an additional risk due to their higher costs. Ultimately this could lead to no large-scale renewable generation developments on the Western Isles depending on the CfD auction bids submitted by other prospective developers.

Table 8: Indicative TNUoS Tariffs & Lifetime Levelised Cost for a WI Wind Farm (2018 prices)

	Option 1 (450 MW link)	Option 2 (600 MW link)
Local circuit charge (£/kW)	[redacted]	
Wider TNUoS (£/kW)		
Total TNUoS (£/kW)		
Levelised TNUoS (£/MWh)		
Estimated lifetime levelised cost indicative Western Isles WF (£/MWh)		

Other considerations – local socio-economic benefits

An additional consideration that is relevant to the Western Isles Needs Case submission is that the 2017 ‘Islands (Scotland) Bill’ 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 also consider the socio-economic impact of transmission reinforcement on the Western Isles.

GHD has therefore explored the socio-economic impact on the Western Isles of each of the principal transmission connection options and the associated enabled generation. The results are summarised in Table 9. From review of these results it is clear that Option 2 leads to the highest overall accumulated benefit of £229 m – some £55 m greater than Option 1. This is principally a consequence of the additional renewable generation facilitated by the higher capacity Option 2. This leads to additional 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.

Table 9: Present Value Local Socio-economic Benefit (£m, 2018 prices)

Option	Generation	Transmission	Total Benefit
450 MW HVDC	162.6	11.5	174
600 MW HVDC	216.9	12.4	229
220 kV AC Cable	85.7	8.1	94

Additionally, it should be noted that if the higher TNUoS charges associated with Option 1 (as shown in Table 8) lead to uncompetitive bids in the CfD auction, then the Western Isles may ultimately forgo some or all of the considerable economic benefit resulting from transmission reinforcement as outlined in Table 9.

Conclusion & Recommendation

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

The principal transmission link options considered are:

- Option 1: 450 MW High Voltage Direct Current (HVDC) subsea and underground cable connection
- Option 2: 600 MW HVDC subsea and onshore underground cable connection
- Option 3: 237 MW AC subsea and underground cable connection

The specific generation scenarios considered the following maximum capacity:

- Scenario 1: 333 MW
- Scenario 2: 422 MW
- Scenario 3: 525 MW
- Scenario 4: 638 MW

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. This conclusion has also been confirmed by the SO in their analysis where they agree with SHE-T's proposed approach of submitting a 'conditional' Needs Case for the Western Isles based on a 600 MW HVDC cable connection.

Option 2 also provides a range supplementary benefits over the other options, including more favourable TNUoS charges for prospective renewable projects on the Western Isles plus additional socio-economic benefits for the islands and wider community.

Taking account of these key findings, GHD considers that overall Option 2 (600 MW HVDC link) is the preferred transmission connection option for Western Isles.

Table of contents

1. Introduction

Scottish Hydro Electricity Transmission (SHE-T) as part of Scottish and Southern Energy Networks (SSEN) is considering a potential network reinforcement between mainland Scotland and the Western Isles. The reinforcement will increase the transfer capacity across SHE-T's existing link between mainland Scotland and the Western Isles to allow the export of the Islands considerable renewable energy to the mainland. The Western Isles 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 reinforcement 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 the electricity network as 'wider works outputs'. Under the SWW framework, SHE-T 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 will 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-T has engaged GHD to examine the power flows and resulting economic justification of a new subsea transmission cable between the Western Isles and mainland Scotland. This study evaluates the cost and benefits of the reinforcement options proposed by SHE-T 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 their 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-T. 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-T's and GHD's approach to the Western Isles Needs Case submission
4	Generation Scenarios	A summary of the generation scenarios developed by GHD
5	Reinforcement Options	Outlines the transmission reinforcement options identified by SHE-T

Section	Title	Content
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	Other considerations	Discusses and presents the results of other factors that may influence the CBA
10	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	Wind Data	Outlines how GHD has derived the wind profile used in the CEFM model.
Appendix C	Socio-economic Modelling	Provides a detailed description of GHD's approach to the socio-economic modelling of the Western Isles 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

The Western Isles (also known as the Outer Hebrides) is an archipelago of over 70 islands, situated on the extreme North West coast of Scotland. The main islands are Barra, North and South Uist, Benbecula, Harris and Lewis.

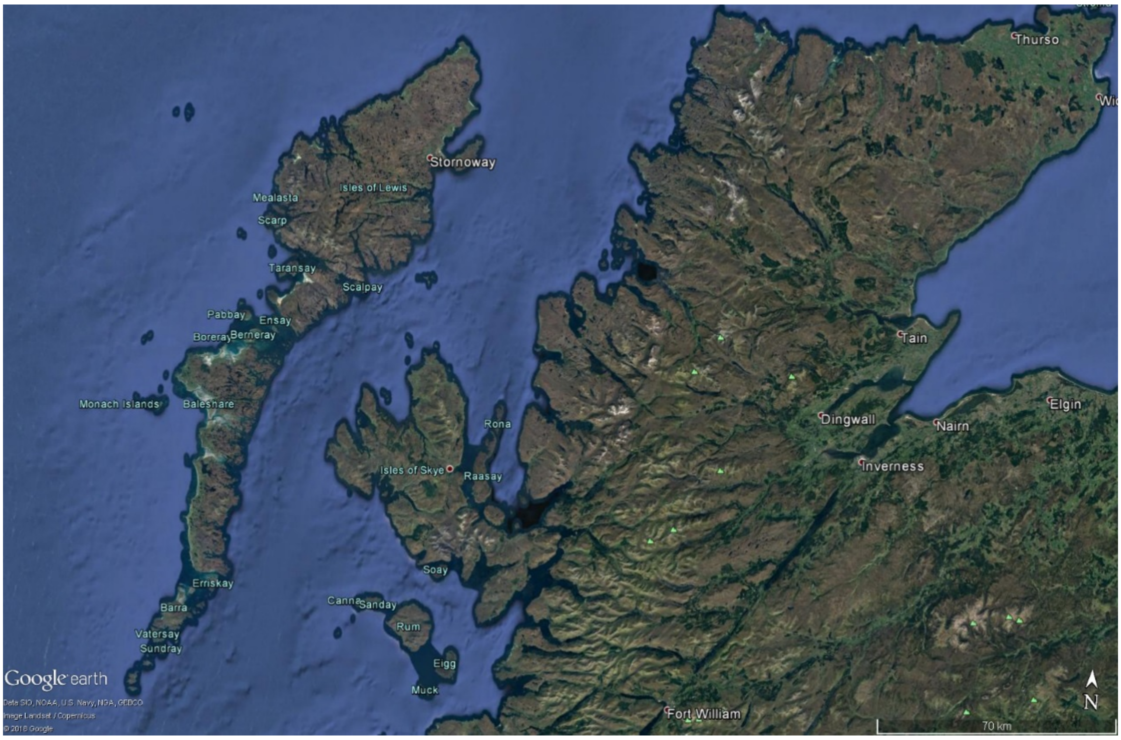
The largest island, Harris and Lewis is the largest island in Scotland and the third largest in the British Isles, after Great Britain and Ireland. It incorporates Lewis in the north and Harris in the south, both of which are frequently referred to as individual islands, although they are connected by land.

North and South Uist and Benbecula (collectively referred to as The Uists) lie to the south of Harris whilst the Isle of Barra lies south of the Uists.

The population is widely dispersed across the islands. Around 30% of the total population, (approximately 8,000 people) live within the Greater Stornoway area in Lewis with the remaining population scattered over 280 settlements on 11 inhabited islands.

A map of the Western Isles in relation to North-West Scotland and the Isle of Skye is shown in Figure 2-1.

Figure 2-1: A Map of the Western Isles and Mainland Scotland



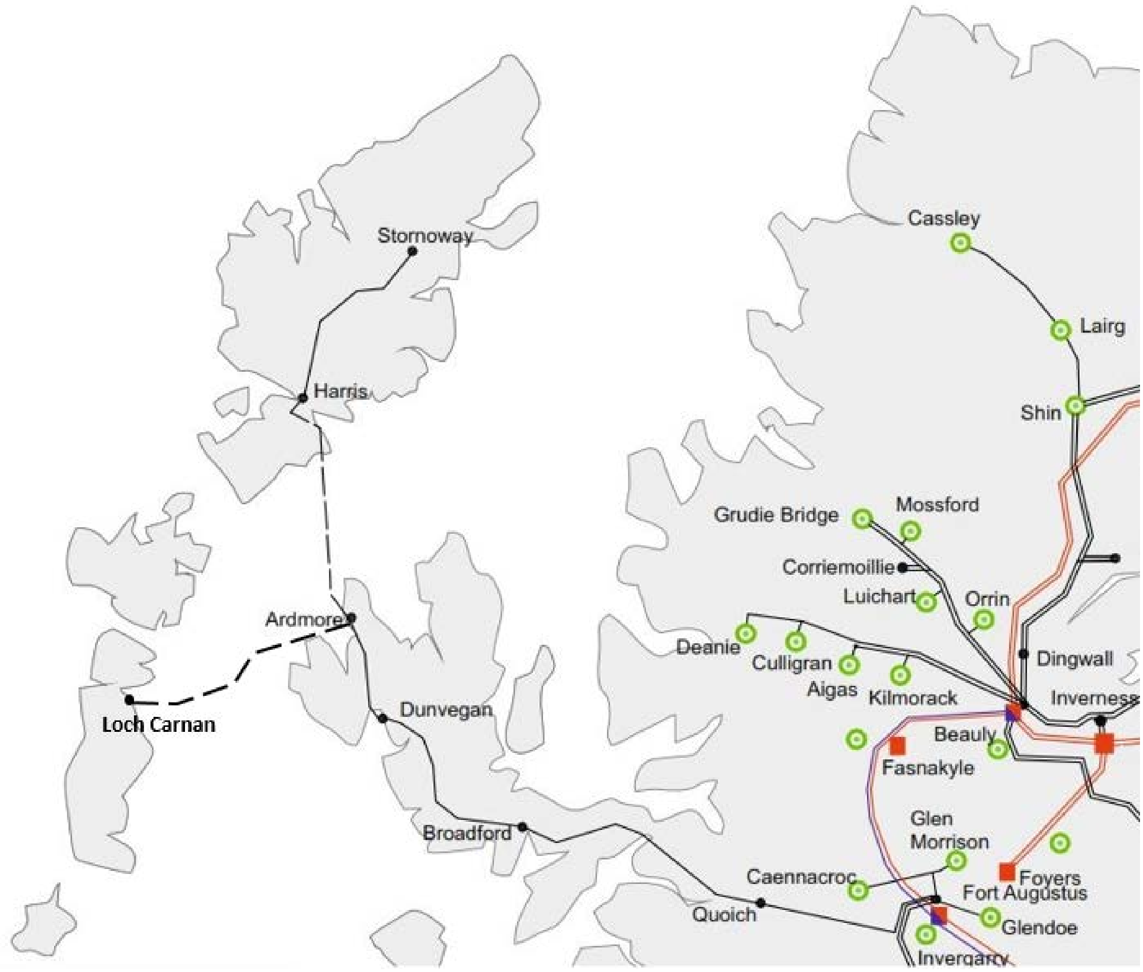
Source: Google Earth Pro

2.2 The Existing Electricity Network

Figure 2-2 provides an overview of the existing electricity network connecting the Western Isles to the Scottish mainland. At present, there are two 33kV subsea cable connections between the Islands and the Isle of Skye, in turn connected to the Scottish mainland, the dashed lines in the figure. One subsea cable of 38 km connects to Harris grid substation with the other 47km subsea cable connecting to Loch Carnan on South Uist. Both cables have a combined capacity of only 37 MVA; the Harris cable has a higher rating of 23 MVA. Both 33 kV cables are supplied from Ardmore (on Skye) via a 45 MVA 132/33 kV transformer that is supplied from Fort Augustus via a 158 km 132 kV overhead line that also supplies Dunvegan, Broadford and Loch Lundie.

The transmission infrastructure on Lewis and Harris is a 58 km 132 kV overhead line rated at 68 MVA (summer rating). There is no 132 kV infrastructure on the Uists, with all existing overhead lines owned and operated by SHEPD at 33 kV.

Figure 2-2: Existing Electrical Network (Western Isles)



2.3 Electricity Supply and Demand

As of June 2018, there is approximately 80 MW of installed generation capacity connected on the Western Isles as a whole. Of this some 51 MW is onshore wind, 23.5 MW thermal generation (Battery Point), 4.7 MW hydro and 1.1 MW solar installations.

Demand on the Western Isles is relatively small, with a 2017 peak of 23.7 MW for Lewis and Harris islands and a minimum demand of around 5.5 MW. SHEPD estimate peak demand will rise to approximately 24.9 MW by 2024[4].

[4] SHEPD Long Term Development Scenario (LTDS) extends to 2021/22. The assumed forecast growth rate has been used to extend the projection to 2024/25.

3. Approach

3.1 GHD Approach

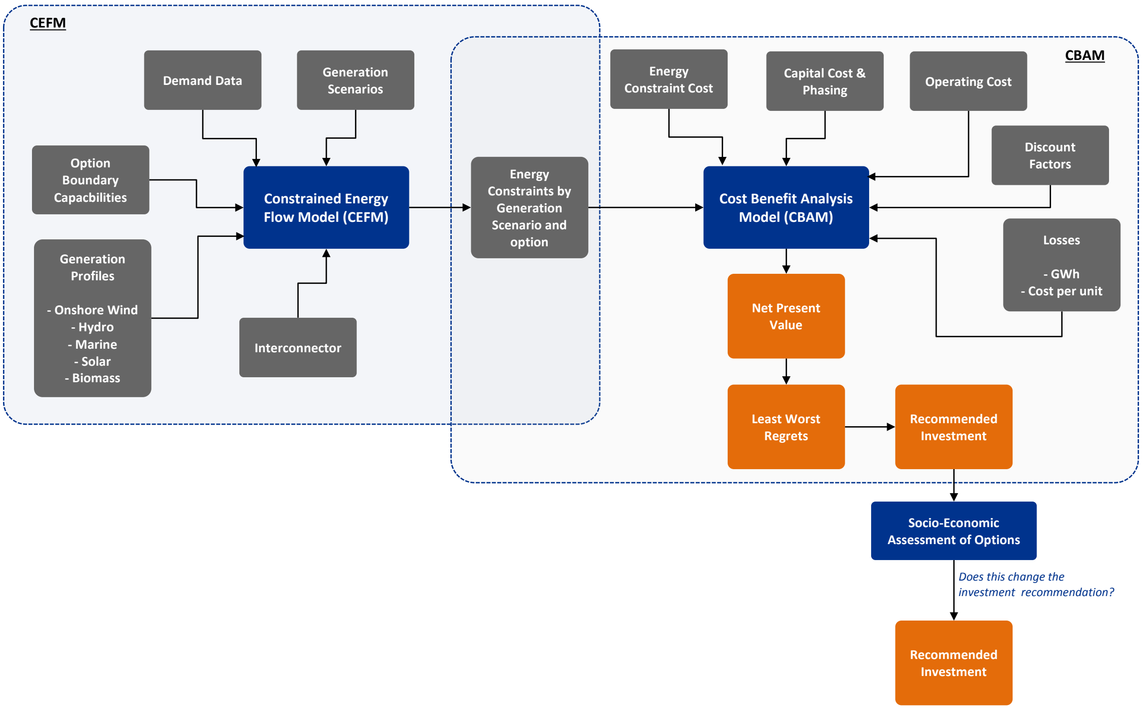
The modelling approach adopted by GHD for assessing the costs and benefits of transmission reinforcement between the Western Isles and mainland Scotland comprises two independent but linked Microsoft Excel based models:

- 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 the Western Isles 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, including Ofgem, 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[5]. GHD understands that the two largest proposed wind farms on the Western Isles (Stornoway and Uisenis) intend to compete in the 2019 CfD auction. These two projects alone currently represent at least 340 MW of consented generation and are therefore their success, or not, in the 2019 CfD auction is fundamental to the Needs Case for the proposed transmission reinforcement.

As a result, SHE-T is submitting a ‘conditional’ Needs Case to Ofgem, with the ‘need’ for reinforcement and the subsequent optimum reinforcement option, conditional on the award of CfDs.

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 and assume varying levels of awarded contracts in the 2019 CfD auction for the large transmission-connected wind farms. The scenarios do not reflect a world in which Western Isles generation completely fails to secure CfDs but present scenarios of combinations of projects (and project owners) winning CfDs at alternative capacities (consented and contracted) whilst also taking into consideration any issues of mutual exclusivity. The scenarios are supplemented by varying levels of local appetite for community and Council wind farm development should a new, high capacity transmission cable be constructed.

  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-T 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 large generation projects be awarded a CfD in 2019. This latter aspect has implications for certain options that may prove challenging to deliver in the required time period i.e. connection options involving the construction of new overhead lines.

  SHE-T’s approach to determining the options considered within this CBA and the subsequent options considered is outlined in Section 5.

3.3 Study Area

In addition to the ‘conditional’ needs case above, it is also important to understand the scope of the study area.

Since 2003, SHE Transmission has investigated the technical and economic feasibility of a number of reinforcement options on the Western Isles including consideration of various route options, the suitability of different technologies (HVDC versus AC), construction methods (overhead line versus cable) and various capacity ratings.

In 2012 expected future generation requiring connection to the grid was split between the north and south, with more certainty on those projects located in the south. Since 2012, the generation picture has changed significantly. The majority of new generation is now seeking connection in the north – supplementary guidance on local development issued by the Comhairle nan Eilean Siar (the Western Isles Local Council - referred to hereafter as ‘the

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

Comhairle') in December 2016 identifies significant constraints on new onshore wind generation developments in the South[6].

With the generation now focussed in the north, SHE Transmission has rationalised the Lewis Infrastructure works to a single circuit with a suitable landing point for the subsea cable in the north (at Arnish). The subsequent transmission reinforcement options considered by SHE-T in this study connect from Arnish (approximately 2 km South of Stornoway on the Isle of Lewis and Harris) to Dundonnell on the Scottish mainland (approximately 80 km South East of Arnish).

As there is no electrical connection between the Isle of Lewis and Harris, the Uists and Barra the scope of this CBA study is limited to the consideration of demand, electrical network and generation located on the Isle of Lewis and Harris only.

The study assumes that the Uists will continue to connect to the Scottish mainland via the Isle of Skye using the existing 33 kV connection as outlined in Figure 2-2.

[6] https://www.cne-siar.gov.uk/planning-and-building/planning-service/development-planning/development-plan/local-development-plan/

4. Generation Scenarios

To explore the long term 'need' for and assess the uncertainties surrounding the potential need for a transmission connection to the Western Isles 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-T to fully 'stress test' the requirement for transmission reinforcement in its Needs Case.

These 'credible paths of growth' are focussed on SHE-T's desire to submit a 'conditional' Needs Case submission as discussed in Section 3.2.

Determining the prospects for future onshore wind generation – location and certainty of progression – on the Western Isles (and the Scottish islands in general) is complex. The existing electricity network on the Western Isles 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 case for transmission or generation development is entirely predicated on the other. The situation is further complicated by the position of the islands (Orkney, Shetland 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.

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. This announcement represents a turnaround in fortunes for islanded onshore wind after the Government's 'minded to' position following the 2016 general election.

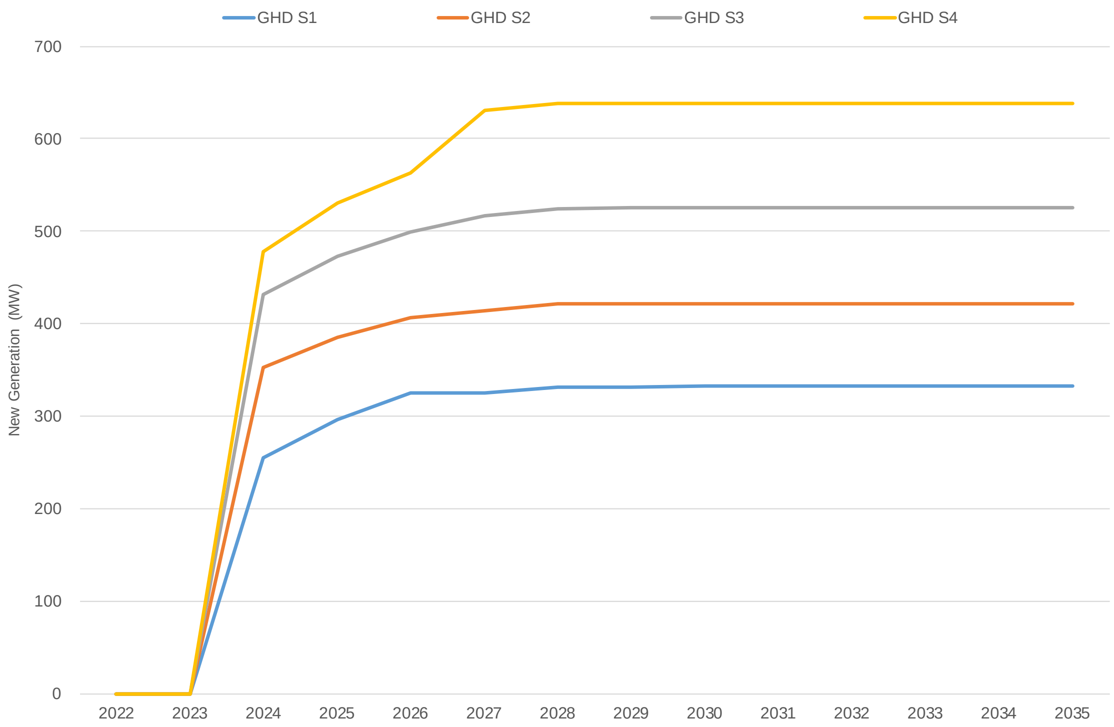
Whilst the announcement is good news for islanded onshore wind, the appetite for significant amounts of additional onshore wind to be subsidised by the UK Government is waning and does not align with the appetite within Scottish Government and Local Authorities to support the Islands in making use of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

GHD understands that the two largest proposed wind farms on the Western Isles (Stornoway, and Uisenis) intend to compete in the 2019 CfD auction. As these two projects alone currently represent 340 MW of consented generation, SHE-T wishes to submit a 'conditional' Needs Case to Ofgem with the need conditional on the award of CfDs to these generators.

The generation scenarios outlined in this report are designed to reflect this approach and assume varying degrees of success in the 2019 CfD auction for these large transmission-connected wind farms. The scenarios developed do not reflect a world in which Western Isles generation completely fail to secure CfDs. They present scenarios of varying combinations of projects (and project owners) winning CfDs at alternative capacities (consented and contracted) taking into consideration any issues of mutual exclusivity. The scenarios are supplemented by varying levels of underlying local appetite for community and Council development should a new, high capacity transmission cable be constructed, taking into consideration the applicability of TNUoS charges to the prospective projects (i.e. distribution connected projects).

Figure 4-1 shows the resulting total installed capacity for the four GHD generation scenarios developed (S1 – S4). We conservatively assume there is no additional generation growth beyond 2030 – in common with the National Grid's Future Energy Scenarios (FES).

Figure 4-1: Total Generation by Scenario



A breakdown of the generation assumed under each scenario is shown in Table 4-1.

Table 4-1: Total Generation by Scenario 2030 (MW)

Scenario	Onshore Wind	Embedded Wind	Embedded Solar	Embedded Hydro	Floating Offshore	Total
S1	319.2	10.2	3.0	0.5	0.0	332.9
S2	408.0	9.2	4.0	0.8	0.0	422.0
S3	510.9	9.2	4.0	0.8	0.0	524.9
S4	573.1	9.2	5.0	1.0	50.0	638.3

A failure for all of the largest transmission connected projects to win a CfD in the 2019 auction is likely to result in lower generation development than has been modelled. However, as SHE-T is submitting a 'conditional' Needs Case, conditional on the success of some or all of these projects, our scenarios do not consider this outcome at this stage.

Appendix A provides a detailed description of the prospects for further generation on the Western Isles and how the GHD scenarios presented above have been derived.

5. Reinforcement Options

5.1 Option Development

As highlighted in Section 2.2 there are currently two 33 kV subsea cables connecting the Western Isles to the Isle of Skye, one of 38 km connecting to Harris and a 47 km subsea cable connecting to Loch Carnan on South Uist. The total capacity is only 37 MVA, clearly insufficient to accommodate the development of large-scale renewable generation on the islands.

To this end SHE-T has performed an option development and screening exercise to identify potential transmission reinforcement options that could support the potential renewable generation developments on Lewis and Harris (principal locations of generation development interest on the Western Isles). SHE-T has identified six reinforcement options that could connect the Western Isles to mainland Scotland:

1. 600 MW High Voltage Direct Current (HVDC) subsea and onshore underground cable connection
2. 450 MW HVDC subsea and underground cable connection
3. 237 MW AC subsea and underground cable connection
4. 237 MW AC subsea and overhead line connection
5. 138 MW AC subsea and underground cable connection
6. 138 MW AC subsea and overhead line connection

The SHE-T Needs Case submission for the Western Isles transmission connection is being submitted on a ‘conditional’ Needs Case basis, that is contingent on renewable projects on the Western Isles having success in the forthcoming CfD auction. Consequently, our analysis has principally considered those options that can be delivered by the end of 2023 and have sufficient transmission capacity to accommodate renewable projects that presently intend to complete in the future CfD auction. This notionally rules out most of the AC transmission options, the two lowest capacity options (5 and 6) providing insufficient capacity to cater for prospective CfD submission projects whilst options involving overhead line (4 and 6) are not considered to be deliverable before 2026 at the earliest due to the potential consenting and deliverability issues.

The two HVDC options do however provide sufficient capacity to cater for the main renewable projects seeking CfDs and can also be delivered in time to enable the project developers to meet CfD obligations. We have also included the remaining AC Option 3 (237 MW with subsea / underground cable) for consideration in our analysis albeit with a delivery date of end 2024, one year behind the two HVDC options, in order to provide a lower capacity transmission option for the analysis. However, implicit under this option is that only one of the two larger renewable generation projects[7] on the Western Isles would achieve CfD success in the forthcoming auction in 2019.

Note that if none of the larger renewable generation projects considered for the Western Isles achieve success in the forthcoming CfD auction then the wider pool of transmission connections options, including those currently discounted, could be reconsidered as part of a future re-submission.

[7] Either LWP Uisenis or LWP Stornoway wind farm projects

5.2 Technical Details of Considered Options

The two HVDC options are broadly similar and comprise a HVDC converter station at Arnish Point, near Stornoway, with a landing point for the 81 km HVDC subsea cable at Dundonnell on the Scottish mainland as shown in Figure 5-1.

The onshore component of the project comprises a 77 km underground HVDC cable from the Dundonnell landing point to Beauly, where a second HVDC converter station will connect to the existing SHE-T transmission infrastructure. Both HVDC options will be completed in 2023 allowing the export of electrical energy from renewable generation on the Western Isles by 2024.

Figure 5-1: Subsea Cable Route

The alternative AC transmission option utilises a 220 kV subsea and underground cable running 81 km from Arnish Point to Dundonnell (as per Figure 5-1) with a further 77 km from Dundonnell to Beauly. As this project concept design is less well advanced than the two HVDC options, it is expected the construction and commissioning works will be completed around one year after the HVDC target delivery date allowing export of renewable generation energy from the Western Isles by 2025.

For both the HVDC and AC connection options some overhead line construction could be adopted for elements of the onshore transmission works. However, given the required project completion dates overhead line construction is ruled out due to the considerable delay associated with planning and consenting new overhead line infrastructure in the areas identified.

On-Island Reinforcement Works

In addition to the works outlined above, there is further transmission investment associated with reinforcing the existing transmission infrastructure on Lewis. These works will comprise the following required with each of the three transmission connection options:

- Upgrading the existing 58 km 132 kV overhead line between Stornoway and Harris grid substations, including diversion of the overhead towards new wind farm sites.
- Construction of a new short overhead line (~3 km) between Arnish Point and the existing Stornoway grid substation.
- Decommissioning and removal of some redundant overhead line sections between Stornoway and Harris.
- Construction of a 132 kV switchyard at Arnish Point substation to connect the on-island transmission infrastructure to the HVDC terminal substation and export cable (or AC equivalent).

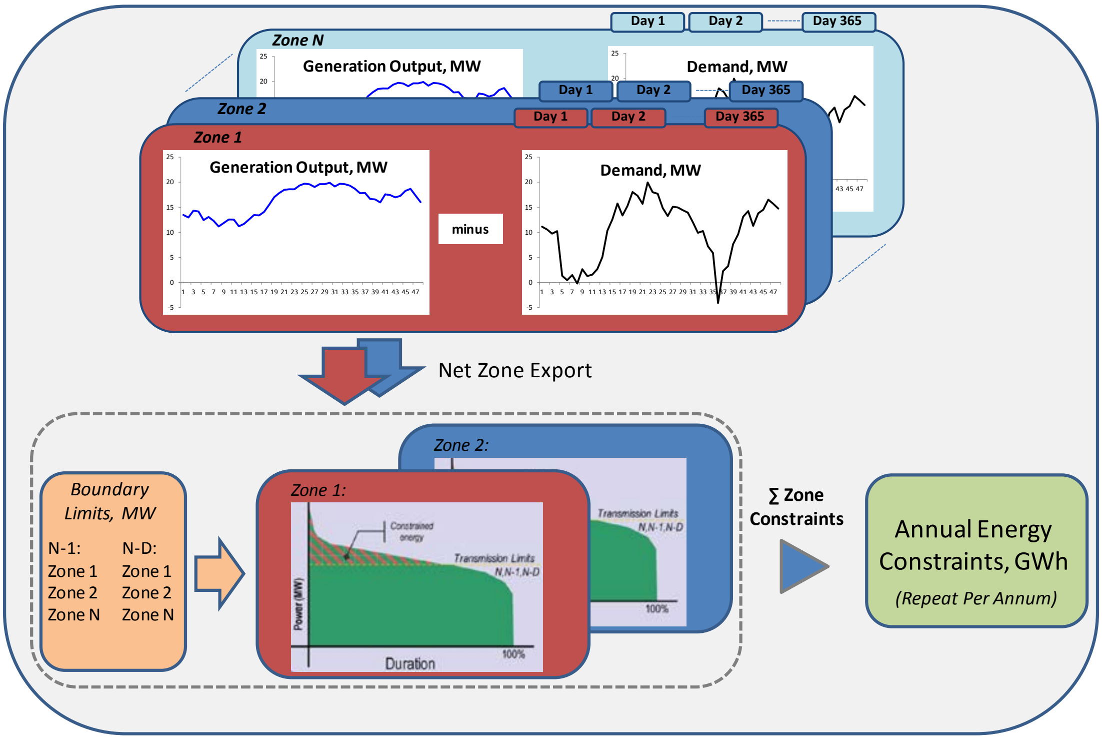
Onshore network costs are not included in the Strategic Wider Works (SWW) submission to Ofgem. However, we have considered the inclusion of onshore costs as a sensitivity in our analysis.

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 the Western Isles version of the CEFM.

6.1.1 Wind generation

Onshore wind

The Western Isles is an area of high wind resource with existing operational wind farms routinely demonstrating annual capacity factors in excess of 40%. To support the CBA analysis historic time series power output data has been provided by SHE-T for eight existing wind farms in the Western Isles for the period 2015 to 2017:

- Pentland Road, 13.8 MW[8]
- Arnish Moor, 3.9 MW
- Monan, 1.5 MW
- Beinn Ghrideag, 9 MW
- Galson, 2.7 MW
- Tolsta, 0.9 MW
- Loch Carnan, 7.5 MW
- Liniclate, 0.9 MW

All the wind farms above are located on the Isle of Lewis with the exception of Loch Carnan and Liniclate which are located on South Uist and Benbecula respectively. A summary of the annual capacity factors achieved by these wind farms is shown in Table 6-1.

Table 6-1: Western Isles Wind Farm Capacity Factors (%)

Wind Farm	2015	2016	2017
Pentland Road	[redacted]	[redacted]	[redacted]
Arnish Moor	[redacted]	[redacted]	[redacted]
Monan	[redacted]	[redacted]	[redacted]
Beinn Ghrideag	[redacted]	[redacted]	[redacted]
Galson	[redacted]	[redacted]	[redacted]
Tolsta	[redacted]	[redacted]	[redacted]
Loch Carnan	[redacted]	[redacted]	[redacted]
Liniclate	[redacted]	[redacted]	[redacted]

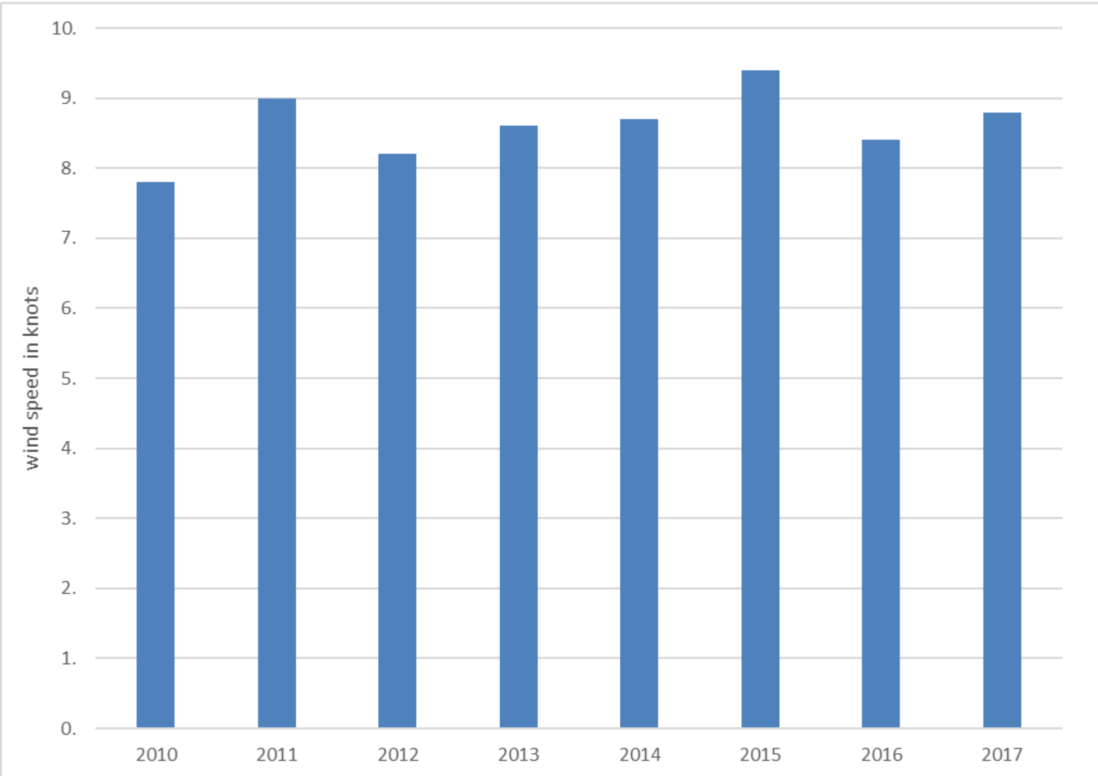
Table 6-1 shows wide ranging annual capacity factors across the wind farms. It is clear that the relatively new (commissioned in 2013) and larger multi turbine Pentland Road performs well, with capacity factors ranging from [redacted] Due to the individual

[8] The TEC for Pentland Road is currently 13.8 MW however the total installed wind turbine capacity is 18 MW. An active control system currently restricts the site output to 13.8 MW, hence the annual capacity factor achieved to date, whilst useful for information, results in a power output curve that is artificially constrained and not representative of long term power output curve.

underperformance issues of these three wind farms we do not consider their time series profiles to be representative of the long term output achievable by large, multi- turbine projects and have excluded them from our analysis.

The five remaining wind farms result of our analysis show reasonable capacity factors, but some considerable variation in annual capacity factors remains – more than expected in a relatively localised area. The results are inevitably skewed by the disproportionate impact of single turbine issues – such as the lower output at [redacted] As a result, to supplement the time series data and create a more representative time series power output profile for a larger Western Isles wind farm, wind speed measurements for the proposed Stornoway and Uisenis wind farms were provided by the project developer Lewis Wind Power (LWP) for 2010 to 2018. The 10 minute anemometer wind speed measurements have been converted by GHD into an equivalent expected time series power output profile (see Appendix B). Wind speeds for the 2010-2016 period show 2016 to be a broadly representative wind year as shown in Figure 6-2 – and can be compared with the data set of existing wind farms outlined in Table 6-1. The synthesized power output profile developed for 2016 yields an expected annual [redacted] This compares well to its closest comparator, the multi-turbine [redacted] We consider the synthesized profile represents a demonstrative long term average output for a larger wind farm and has been adopted as the central wind power profile for the CBA analysis.

Figure 6-2: Average UK Wind Speed[9]



Offshore wind

A subsidiary of Norwegian state owned energy company Statoil, Hywind Scotland is currently scoping a site to the west of the Isle of Lewis for a floating offshore wind farm. The project will require Marine Scotland consent and a Crown Estate Scotland seabed lease. Early estimates suggest turbines may be in the water by 2026. Hywind Scotland, part owned by Masdar (a

[9] https://www.statista.com/statistics/322785/average-wind-speed-in-the-united-kingdom-uk/

sovereign wealth development subsidiary of the Abu Dhabi Government), aim to seek a [redacted] connection in the first instance, rising to [redacted] or more at full commerciality.

We have assumed a maximum of 50 MW of floating offshore wind generation in our generation scenario analysis, under a high capacity scenario. As no output profile is available for offshore wind generation in the area we have adopted the synthesized onshore wind profile (44.7%) to model offshore wind.

6.1.2 Marine generation

The potential for wave generation around the coast of the Western Isles is significant. However wave technology is further from commercial viability than other marine generation, such as offshore wind and tidal flow. As a result we have not considered wave generation in this study.

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[10] 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 the Western Isles 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

The Western Isles do not have a significant hydro-electric resource potential, unlike other parts of Scotland, although there is modest potential for small-scale micro-hydro generation projects i.e. in the 10's to 100's kW range. Our scenarios include existing small scale hydro capacity, but no growth. To model the output of existing hydro plant, as no historical records are available on the Western Isles, a generic seasonal profile has been created from historic power outputs of such plant in the Kintyre area of the SHE-T transmission network.

6.1.5 Demand

The existing total electrical demand on the Isle of Lewis and Harris (shown in Table 6-2) is around 24 MW (excluding Uists), relatively small 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 Lewis and Harris for 2014-2017 and scaled based on the expected island demand growth over the coming years (Table 6-2). Post 2022 a linear extrapolation is applied for future years in order to create future half-hourly demand profile for the islands. The resulting demand subtracted from the combined prospective generation power output profile to yield a net export power flow from the islands and through each of the proposed mainland transmission connection options.

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

Table 6-2: Lewis & Harris Demand Forecast[11]

	2017/18	2018/19	2019/20	2020/21	2021/22
Arnish	0.028	0.030	0.034	0.037	0.039
Barvas	2.706	2.706	2.706	2.706	2.706
Battery Point	12.314	12.314	12.314	12.374	12.374
Callanish	1.915	1.915	1.915	1.915	1.962
Coll	2.070	2.075	2.075	2.075	2.085
Gisla	1.002	1.072	1.094	1.094	1.276
Laxay	1.698	1.698	1.698	1.698	1.698
Maaruig	0.103	0.104	0.105	0.106	0.107
Stornoway Total	*21.836*	*21.914*	*21.941*	*22.005*	*22.247*
Stockinish	0.747	0.747	0.747	0.773	0.779
Tarbet	1.747	1.747	1.747	1.753	1.771
Harris Total	*2.494*	*2.494*	*2.494*	*2.526*	*2.550*
Stornoway/Harris Max. Total	***24.330***	***24.408***	***24.435***	***24.531***	***24.797***
Minimum Demand Total	***4.726***	***4.734***	***4.737***	***4.757***	***4.790***

Note that at times of lower renewable generation power output i.e. when wind speeds are below wind turbine cut-in speed, the net power export from the islands may be negative, signifying a net demand import.

6.1.6 Battery Point thermal generation

The Battery Point power station in Stornoway was commissioned in 1954 to supply power to the Western Isles. The current generation installation comprises eight Mirrlees Blackstone[12], medium speed diesels with a total electrical power output of 25.5 MW. The generator units are compression ignition engines with a net rated thermal input of between 5.1 MW and 12 MW, burning low sulphur (marine grade) diesel fuel oil. The thermal efficiency of the generation units varies between 30% and 48%. Generator engines 1, 2 and 6 have a net power output of 2.0 MW, engines 3 and 9 have a net power output of 4.6 MW, with engines 5, 8 and 9 having net power outputs of 2.2 MW, 3.5 MW and 4.6 MW respectively. Engines 4 and 7 are decommissioned.

The operating regime of the power station is determined by the availability of the distribution cable to the Scottish mainland and the local power demand on Stornoway. The power station's combustion engines are maintained in a back-up role to cater for periods when the island's demand for power exceeds the supply capacity. The need for back-up occurs for planned or unplanned reasons:

- when the island's demand for electricity exceeds the supply capacity of the 33kV submarine cable from the mainland;

[11] Demand data obtained from 2016/17 SHEPD Long Term Development Statement
[12] Scottish and Southern Energy Limited, Battery Point Power Station, Stornoway: Permit Variation PPC/A/1008889 VN02

- during periods of maintenance of the submarine cable;
- in the event of failure of the submarine cable;
- when instructed for frequency control; and
- for engine testing and exercising purposes.

However, following the completion of a number of transmission projects to improve reliability, and development of wind farms locally, Battery Point output is now largely dictated by the availability of local wind energy supply. A review of the likely current and future power station requirements has been undertaken. The scenarios identified when power station operation is required, as intermittent back up, are for 3 hours per night, five days per week between November and March when "peak lopping" occurs, and in the summer during interconnector outage for planned maintenance, running continuously for two weeks every June or July and on one day per month if not otherwise running.

Going forwards, if a transmission cable to the Scottish mainland is constructed to allow the export of renewable generation power there is likely to be a reduced need to run the Battery Point generation as the new transmission cable will also provide a back-up to enable demand to be secured if the existing distribution cable is out of service.

6.1.7 Treatment of SHEPD distribution network

The principal focus of GHD's modelling and analysis is evaluating the need for a future transmission connection from the Western Isles 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-T transmission system, even if physically connected at a lower voltage i.e. 11 kV or 33 kV. This assumption is adopted as the existing 33 kV submarine cable to the Scottish mainland is already at maximum export capacity with the existing renewable generation, hence no additional generation can export via the existing 33 kV cable.

The proposed SHE-T transmission infrastructure could provide enhanced security for the SHEPD distribution network and, as highlighted above, potentially reduce the reliance on the existing thermal generation at Battery Point, but will be electrically isolated under normal operating circumstances.

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-T'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 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 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 (GWhs resulting from the CEFM and constraint costs)

6.2.1 Project costs

SHE-T has provided capex and opex estimates for the reinforcement options, shown in Table 6-3.

Table 6-3: Transmission Reinforcement Options & Costs (2018 prices)

Option	Description	Capex £m	Opex £m p.a.
1	Arnish-Dundonnell 450 MW HVDC subsea (single circuit) & Dundonnell-Beauly HVDC cable (single circuit)	[redacted]	[redacted]
2	Arnish-Dundonnell 600 MW HVDC subsea (single circuit) & Dundonnell-Beauly HVDC cable (single circuit)	[redacted]	[redacted]
3	Arnish - Dundonnell 220 kV HVAC subsea (single circuit) & Dundonnell to Beauly HVAC Cable (single circuit) – 237 MW	[redacted]	[redacted]

The phasing of capital expenditure for the reinforcement options is shown in Figure 6-3 – the HVDC options commission in October 2023, with the AC option commissioning one year later.

Figure 6-3: Capital Cost Phasing

Redacted

In addition to the capital costs outlined in Table 6-3, the costs for the inter-island onshore works have also been estimated by SHE-T. Total onshore network costs are shown in Table 6-4. In our analysis, we assume the capex phasing of onshore works concurs with that of the transmission link. While not part of the SWW submission – a sensitivity analysis has been undertaken including onshore network costs.

Table 6-4: Onshore Network Costs (£m)

Reinforcement Option	Cost of Onshore Works
450 MW HVDC (Option 1)	[redacted]
600 MW HVDC (Option 2)	[redacted]
220 kV AC Cable (Option 3)	[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[13].

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 the Western Isles. The Comhairle considers renewable energy an important development opportunity for the local economy. 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

[13] National Grid MBSS DATA

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 the Western Isles of its SWW decisions given that the impact on the Western Isles 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 the Western Isles. Our approach, explained in detail in our Socio-economic report in Appendix C 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 the Western Isles – 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 the Western Isles. 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 assumptions:

- SHE-T's central capital cost and operating cost assumptions
- An asset life of 45 years
- A constraint cost of £55/MWh and £70/MWh
- A wind farm long term average capacity factor of 44.7%
- 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	432	792	1,161	1,371
2	600 MW HVDC	382	742	1,155	1,584
3	220 kV AC Cable	482	589	679	751

Table 7-2: Central Case NPV with £70/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	731	1,189	1,658	1,926
2	600 MW HVDC	681	1,139	1,664	2,211
3	220 kV AC Cable	741	878	992	1,084

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, lowest generation scenario (S1), the 220 kV AC cable (Option 3) returns the highest positive NPV. Under scenarios S2 and S3 the 450 MW HVDC link (Option 1) returns the highest NPV, whilst under S4, the 600 MW HVDC link (Option 2) returns the highest NPV.

At a higher constraint cost of £70/MWh all NPVs are higher – with all relative positions remaining unchanged apart from scenario S3, where Option 2 returns the highest NPV.

The results suggest that the Western Isles 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:

1. 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 a NPV of £500 m and Option B a 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.
2. The maximum (worst) regret across all generation scenarios is then determined for each reinforcement option
3. The option of least worst regret is the one that returns the lowest worst regret.

The results also show that under scenario S3 Options 1 and 2 are very close, while Option 1 is the best outcome for scenario S3 the regret of adopting Option 2 is very small at only £6 m. The lower capacity Option 3 is only viable under the lowest generation scenario, when more generation emerges the regret of this reinforcement rapidly increases due to the heavy constraint incurred. Hence, under scenario S4 the regret associated with Option 3 increased to £833 m.

Table 7-3 shows the individual regret values 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 £99 m under scenario S1 compared to £213 m for Option 1 under scenario S4. The incremental difference in regret of investing in the 450 MW HVDC link over the 600 MW HVDC link is £114 m (£213 m less £99 m).

The results also show that under scenario S3, Options 1 and 2 are very close, while Option 1 is the best outcome for scenario S3, the regret of adopting Option 2 is very small at only £6 m.

The lower capacity Option 3 is only viable under the lowest generation scenario, when more generation emerges the regret of this reinforcement rapidly increases due to the heavy constraints incurred. Hence, under scenario S4 the regret associated with Option 3 increases to £833 m.

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	49	0	0	213	213
2	600 MW HVDC	99	50	6	0	99
3	220 kV AC Cable	0	203	482	833	833

Table 7-4 shows the LWR analysis with a higher constraint cost of £70/MWh. Option 2 remains the option of LWR and the higher constraint cost increases the regret of Option 1 in scenario S4. As a result, the greatest regret of adopting Option 1 increases to £284 m, while the highest regret of adopting Option 3 increases to £1,127 m – a clear widening of margins between options. With higher constraint costs, Option 2 becomes the optimum reinforcement in scenario S3, although again the results are very close between Options 1 and 2.

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	10	0	6	284	284
2	600 MW HVDC	60	50	0	0	60
3	220 kV AC Cable	0	311	672	1,127	1,127

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. While the results are driven by the higher generation in scenario S4 (638 MW), in the lower S3 generation scenario (525 MW) Options 1 and 2 are broadly identical – both returning very similar NPVs and therefore regrets. In the lower S2 generation scenario (422 MW) Option 1 is the optimum reinforcement – with the regret of adopting Option 2 driven entirely by its higher capex as both Options 1 and 2 relieve all constraints. Only under scenario S1 (333 MW) is the lower capacity AC solution (Option 3) the optimum reinforcement – with the regret of adopting this option increasing rapidly as generation increases.

7.3 Comparison with SO Results

For completeness GHD has also performed a comparison of our CBA results with those provided by the System Operator (SO) in their analysis. The SO has consider the four national generation scenarios (Two Degrees, Slow Progression, Steady State and Consumer Power[14]) considered in their Future Energy Scenarios (FES) as well as the four generation scenarios provided by SHE-T and included in the GHD analysis. The SO has also modelled all six transmission connection options presented earlier (see Section 5.1) even though Options 4, 5 and 6, have been ruled out due to their timing or capacity and hence could not facilitate a successful outcome for the large, transmission-contracted projects wishing to enter the CfD auction process. A summary of the SO results for the four SHE-T orientated generation scenarios for Options 1 to 3 (to align with the GHD analysis) is shown below in Table 7-5.

Note that these results from the SO have been determined against a national generation background and accompanying transmission network reinforcements corresponding to the Slow Progression scenario.

Table 7-5: SO Regret Results for SHE-T Scenarios (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	3	0	6	90	90
2	600 MW HVDC	44	44	0	0	44
3	220 kV AC Cable	0	157	335	542	542

From review of the SO study results shown in Table 7-5 it is evident that results are very similar[15] to those obtained by GHD for the Central Case (£55 / MWh constraint cost) for the two HVDC options. The results for Option 3 are also broadly similar in trend i.e. Option 3 is the option of least regret under scenario S1 for both the GHD and SO analysis and this option also performs poorly in comparison with the two HVDC options over the other scenarios.

[14] Note that the System Operator CBA study results have used the older FES scenarios and definitions as these are presently included along with required associated transmission system boundary reinforcements in their analysis model.

[15] Note also that the SO's results shower lower regret values for Option 1 and 3 under scenario S3, and S4 in particular, in comparison with the GHD results as the SO's analysis also captures onshore boundary constraints across GB which in turn restricts the apparent benefit provided by Option 2 in comparison to Option 1.

Overall, taking the SO results for the same range of scenarios as GHD the same conclusion is reached, that Option 2 (600 MW HVDC link) is the option of least worst regret. However, the SO also includes in their regret analysis the results derived from their four FES scenarios. When these are included, the maximum (worst) regret for Option 1 is £137 m and for Option 2 is £173 m, both achieved under the Steady State scenario. The SO does however recognise that the Steady State scenario is "an outlier in this analysis as its exports (from the Western Isles) never exceed 200 MW hence large regrets are present for all larger capacity options since their capacity is never used despite the high Capex spend". When they remove the Steady State scenario from their regret analysis Option 2 has a worst regret of £44 m (across the three remaining FES scenarios and four SHE-T scenarios) with Option 1 having a worst regret of £90 m. Option 2 is therefore the preferred option.

In their study conclusion the SO further states that as "SHE-T are submitting a Needs Case to Ofgem based on the 600 MW HVDC cable (Option 2), on the conditional aspect that CfDs are awarded to some of the major project on the island" then they "would agree with this approach as the awarding of these CfDs would eliminate SS as a viable future on the Western Isles and change the LWR answer to Option 2". Thus, the SO conclusion effectively matches with the recommendation from GHD's own analysis that Option 2 represents the most appropriate transmission connection option for the Western Isles.

7.4 Generation Breakeven Analysis

Further demonstration of the value provided by the proposed Western Isles transmission connection options can be seen from an assessment of the volume of generation (in MW) required to return a positive NPV for each reinforcement option. This is the so-called 'breakeven' point of generation, the results of which are shown in the following table (Table 7-6). This table shows the volume of generation (in MW) required to return a positive NPV for each reinforcement option – the so called 'breakeven' point of generation. The AC option has the lowest breakeven point of generation at between 93-118 MW due to its lower overall capex. The breakeven of the 450 MW and 600 MW HVDC links is similar and ranges from 128-163 MW for the 450 MW link, to between 136-174 MW for the 600 MW link. All these breakeven points are significantly below the generation outlined in any of GHD's generation scenarios.

Table 7-6: Breakeven Point of Generation

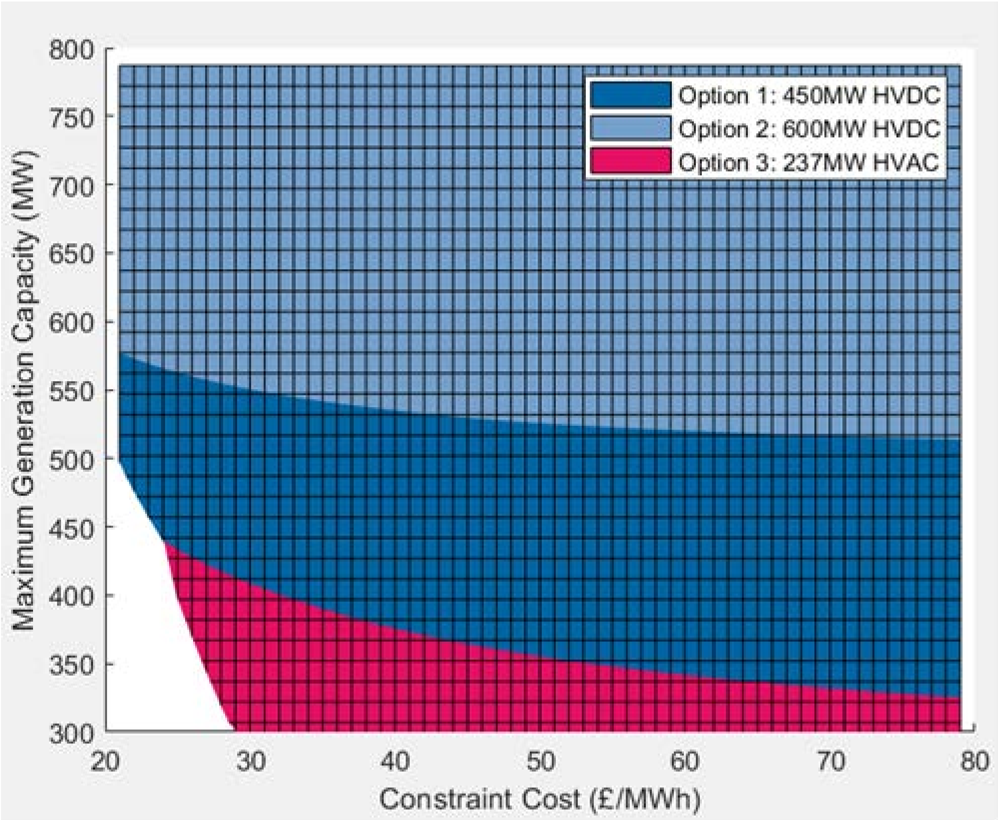
Option	Description	£55/MWh constraint cost	£70/MWh constraint cost
1	450 MW HVDC	163	128
2	600 MW HVDC	174	136
3	220 kV AC Cable	118	93

7.5 The Impact of Uncertainty

Our analysis shows that Option 2, the 600 MW HVDC link, is the option of LWR and the optimum reinforcement for scenario 4. The results also show that under scenario S3 Options 1 and 2 are very close. Our analysis shows how changes in constraint cost assumptions and generation scenarios have significant and yet often 'penny switching' impacts between the optimum reinforcement options. 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



From review of Figure 7-1, the white area represents the area of non-viability – for example at a constraint cost of £25/MWh around 440 MW of generation is required for any transmission option to return a positive NPV. The chart also shows the ‘tipping point’ between each of the reinforcement options – between Option 1 and 2 this is around 520-530 MW based on a £55-70/MWh constraint cost.

With more than 800 MW of known or prospective generation developments that could be developed across the Western Isles there are clearly a number of different combinations of individual projects that could come forward and result in this tipping point (520-530 MW) being reached.

One of the largest potential variations revolves around the eventual installed capacity of LWP’s Stornoway and Uisenis projects, with LWP considering a range of combined installed capacities between 340 MW and 430 MW for the two projects. Taking this range into account three potential compositions of the tipping point of generation between Option 1 and 2 are illustrated in the figure below (Figure 7-2). A composition without LWP’s Stornoway project is also considered, i.e. a scenario where LWP loses its ongoing court proceedings with the local crofter community but that the community projects that are proposed to take its place proceed.

Figure 7-2: Tipping Point Generation Scenarios for Options 1 and 2

Redacted

Each composition identifies generation projects that would need to be developed for the tipping point to be reached. A number of these are known projects which are being actively pursued and therefore form the basis of all tipping point compositions. The following table (Table 7-7) sets out these compositions in more detail with some commentary on each individual project that is included.

Overall, GHD considers each of these compositions to represent a realistic development path for renewable generation projects on the Western Isles that could occur if a transmission connection to the Scottish mainland of sufficient capacity was to be developed. Crucially even under the lower “D” scenario the tipping point still only represents development of around two thirds of the prospective renewable generation plant capacity that is currently known. Further prospects are also likely to develop once the transmission connection link is operational and potential generation developers have more certainty over their ability to connect.

Table 7-7: Additional Details for Tipping Point Generation Scenarios

Redacted

7.6 Socio-economic Impact

There is a clear interdependency between grid reinforcement and the realisation of potential economic benefit arising from renewable development on the Western Isles. In order to determine the materiality of the potential socio-economic benefit to the Western Isles we have assessed the gross value added (GVA) benefit to the economy of the Western Isles associated with the transmission link and the subsequent generation realised.

Appendix C of this report provides a detailed description of the methodology and assumptions underpinning GHD's analysis.

Table 7-8 shows the maximum socio-economic benefit associated with the transmission reinforcement options and the background generation enabled by the reinforcement options over the 45 year life of the link[16]. The present value of the socio-economic benefit of the 600 MW HVDC link and associated generation is around £229 m, while that of the 450 MW link is lower at £174 m. The lower capacity of the AC option and lower generation enabled leads to a lower socio-economic benefit of £94 m. The greatest GVA impact arises from the generation enabled by the link – with the 600 MW link enabling more generation, then the subsequent socio-economic impact is larger.

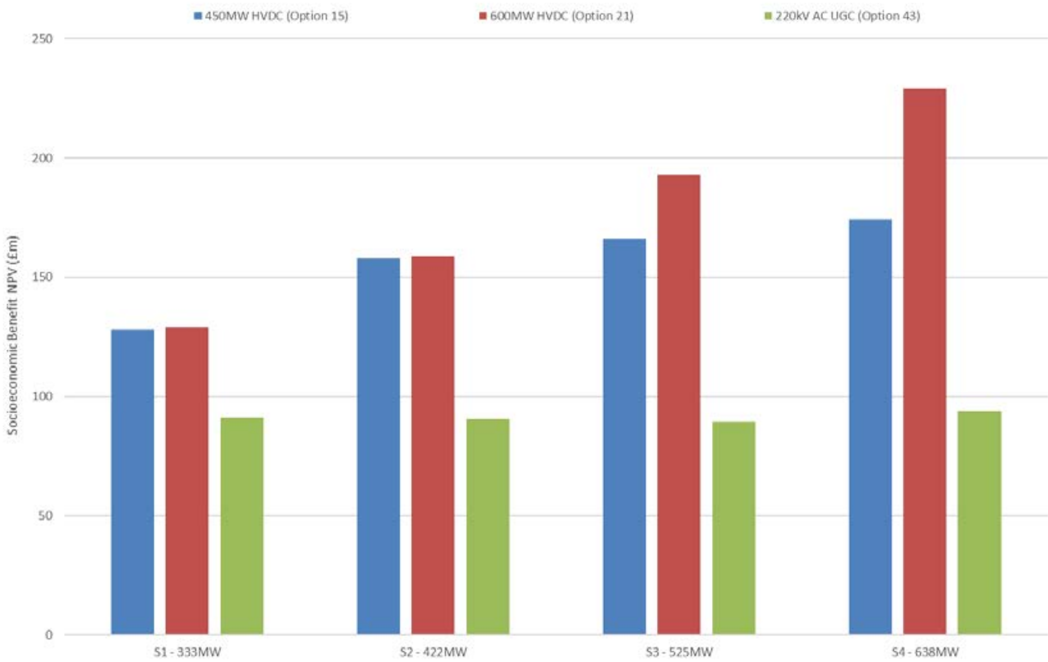
Table 7-8: Present Value of Socio-economic Benefit (£m, 2018 prices)

Option	Generation	Transmission	Total Benefit
450 MW HVDC	162.6	11.5	174
600 MW HVDC	216.9	12.4	229
220 kV AC Cable	85.7	8.1	94

Figure 7-3 shows the present value of the socio-economic benefit of each reinforcement option arising under each of the generation scenarios considered, with the values in Table 7-8 corresponding to scenario S4. For comparison the generation benefit of each option has been capped at the capacity of the link.

[16] For the socio-economic modelling the generation associated with each reinforcement option is capped at the MW capacity of the link – in reality more generation is likely to connect than the total MW capacity of the link given the intermittent nature of wind and resulting power curve

Figure 7-3: PV Socio-economic Benefit (£m, 2018 prices)



The results show that the socio-economic benefit of transmission reinforcement to the Western Isles is significant – with the 600 MW HVDC option leading to the greatest benefit to the local economy. With only 13,000 households, the potential socio-economic impact on the island communities of transmission reinforcement and associated generation is clearly considerable.

7.7 Variation in Delivery Dates

While our Central Case shows that transmission reinforcement to the Western Isles is strongly economically viable in the long term and that significant socio-economic benefits will result, uncertainty surrounds the 2019 CfD auction outcome and the impact on Western Isles projects.

In this section we explore two aspects relating to the delivery date of the consider options:

1. the impact of delaying the reinforcement projects by one year and two years under central case assumptions. This analysis has been undertaken for the option of LWR only – the 600 MW HVDC link (Option 2).
2. the impact of advancing Option 3 (the AC solution) to yield the same in service date as the HVDC options to allow identification of the potential impact this has on the resultant NPV and regret analysis.

The above aspects are now discussed.

7.7.1 Impact of Delayed Delivery

Table 7-9 and Table 7-10 show the resulting NPV’s for the 600 MW HVDC and the impact of delay for both a £55/MWh constraint cost and a £70/MWh constraint cost.

Table 7-9: NPV of Delay to Option 2 (600 MW HVDC) Central Case (£m, 2018 prices, £55/MWh Constraint Cost)

Description	S1	S2	S3	S4
On time (2023 delivered)	382	742	1,155	1,584
Delay 1 year (2024 delivered)	382	729	1,132	1,558
Delay 2 year (2025 delivered)	376	711	1,104	1,525

Table 7-10: NPV of delay to Option 2 (600 MW HVDC) Central Case (£m, 2018 prices, £70/MWh Constraint Cost)

Description	S1	S2	S3	S4
On time (2023 delivered)	681	1,139	1,664	2,211
Delay 1 year (2024 delivered)	675	1,116	1,629	2,172
Delay 2 year (2025 delivered)	660	1,087	1,587	2,123

Table 7-11 and Table 7-12 show the regret of delay in the central case under a £55/MWh and £70/MWh constraint cost.

Table 7-11: Regret of Delay to Option 2 (600 MW HVDC) Central Case (£m 2018 prices) £55/MWh Constraint Cost

	S1	S2	S3	S4
On time (2023 delivered)	0	0	0	0
Delay 1 year (2024 delivered)	0	13	22	26
Delay 2 year (2025 delivered)	7	31	51	60

Table 7-12: Regret of Delay to Option 2 (600 MW HVDC) Central Case (£m 2018 prices) £70/MWh Constraint Cost

	S1	S2	S3	S4
On time (2023 delivered)	0	0	0	0
Delay 1 year (2024 delivered)	6	23	35	39
Delay 2 year (2025 delivered)	21	52	77	88

The resulting NPVs decrease for each year of additional delay to the 600 MW HVDC link – apart from in S1 at a lower constraint cost where NPVs remain broadly unchanged. As a result we can conclude there is no benefit in delaying the investment under any scenario. The higher the constraints cost, the higher the regret of delay.

We conclude the optimum year of delivery date for Option 2 is 2023.

7.7.2 Early Delivery of Option 3

The current delivery date of Option 3 considered within the CBA study is the end of 2024, essentially a one year delay behind the two HVDC options. This is to reflect the less advanced nature of the project engineering and design. However, in order to ascertain how much impact this delay in delivery impacts on the resulting option NPVs and regret values a further study has been performed with all option in service dates aligned as end of 2023, thus the first year of full benefit is 2024 under all options.

Table 7-13 and Table 7-14 show the resulting NPV's for Option 3 (220 kV AC solution) with an expected in service date (EISD) of end of 2023 (full benefits from 2024) for both a £55/MWh constraint cost and a £70/MWh constraint cost.

Table 7-13: NPV with Early EISD for Option 3 (AC Solution) Central Case (£m, 2018 prices, £55/MWh Constraint Cost)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	432	792	1,161	1,371
2	600 MW HVDC	382	742	1,155	1,584
3	220 kV AC Cable	490	606	698	772

Table 7-14: NPV with Early EISD for Option 3 (AC Solution) Central Case (£m, 2018 prices, £70/MWh Constraint Cost)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	731	1,189	1,658	1,926
2	600 MW HVDC	681	1,139	1,664	2,211
3	220 kV AC Cable	757	903	1,021	1,115

Table 7-15 and Table 7-16 show impact on the option regret analysis with a 2024 EISD for Option 3 under a £55/MWh and £70/MWh constraint cost.

Table 7-15: Regret with Early EISD for Option 3 (AC Solution) Central Case (£m, 2018 prices, £55/MWh Constraint Cost)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	58	0	0	213	213
2	600 MW HVDC	108	50	6	0	108
3	220 kV AC Cable	0	186	462	813	813

Table 7-16: Regret with Early EISD for Option 3 (AC Solution) Central Case (£m, 2018 prices, £70/MWh Constraint Cost)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	26	0	6	284	284
2	600 MW HVDC	75	50	0	0	75
3	220 kV AC Cable	0	286	643	1,096	1,096

From review of Table 7-13 to Table 7-16 it is evident that the calculated NPVs and associated regret values for Option 3 have only changed marginally in comparison with the Central Case values (Table 7-1 to Table 7-4). That is, the NPV of Option 3 has increased by up to £21 m under the £55/MWh constraint cost and up to £31 m under the £70/MWh constraint cost. Regret values for Option 3 have largely decreased by the same amounts.

Additionally, as the NPV of Option 3 has changed this has also had an impact on the worst regret associated with Option 1 and 2, both have increased by around £8 m under the £55/MWh constraint cost (£16 m under the £70/MWh constraint cost) on account of the greater benefit provided by Option 3 under the S1 scenario. The overall impact though in terms of preferred option remains unchanged that is Option 2 (600 MW HVDC link) is the option of least worst regret across the scenarios.

8. CBA Results - Sensitivities

Following our assessment of the central case, we explore a number of sensitivities, including:

- The inclusion of onshore Lewis infrastructure works (that fall outside the required SWW assessment)
- Lower wind capacity factor – 39.5%
- Project capex – increase 20%
- The breakeven point of generation

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

8.1 Onshore Works (including Lewis infrastructure)

Our first sensitivity analyses the impact of including the onshore works in Lewis (although these are not part of the SWW submission). The Lewis infrastructure costs are the same for all three reinforcement options and total [redacted] – (see Table 6-4 for further details).

Table 8-1 shows the impact on project NPVs – NPVs continue to remain positive for all options under all generation scenarios.

Table 8-1: Lewis Infrastructure Sensitivity NPV with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	398	758	1,127	1,337
2	600 MW HVDC	348	708	1,121	1,550
3	220 kV AC Cable	449	557	646	719

Table 8-2 shows the impact on regret analysis of inclusion of the onshore Lewis infrastructure works.

Table 8-2: Lewis Infrastructure Sensitivity Regret Analysis with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	51	0	0	213	213
2	600 MW HVDC	101	50	6	0	101
3	220 kV AC Cable	0	201	480	832	832

The 600 MW HVDC link remains the option of LWR with a highest regret of £101 m, compared to £213 m for the 450 MW HVDC link and a significantly larger regret of £832 m for the 220 kV AC Cable link. The 'regret' of investing in the 450 MW HVDC link over the 600 MW HVDC link is £112 m (marginally lower than £114 m under the Central Case presented in Section 7.2)

Although not presented, at a constraint cost of £70/MWh the 600 MW HVDC link is the option of LWR – with the regret between it and the 450 MW HVDC link being significantly higher at £225 m.

We can conclude that the inclusion of onshore works, while reducing project NPVs overall, has no material impact on the results of our central case.

8.2 Lower Wind Farm Capacity Factor

We have also analysed the impact of a lower wind farm capacity factor based on the half hourly recorded power output of the [redacted] wind farms for year 2017 (see Table 6-1). These wind farms yielded the most representative power output curves for the existing, albeit limited, set of Western Isles wind farms. The resulting average annual capacity factor for these three wind farms is 39.5%.

Table 8-3 shows the results – NPV's remain positive for all options under all generation scenarios, but are lower than the Central Case.

Table 8-3: Low Wind Capacity Factor Sensitivity NPV with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	275	592	932	1,194
2	600 MW HVDC	225	543	906	1,304
3	220 kV AC Cable	378	522	636	730

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 Sensitivity Regret Analysis with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	103	0	0	110	110
2	600 MW HVDC	153	50	26	0	153
3	220 kV AC Cable	0	70	296	574	574

With a lower capacity factor the 450 MW HVDC link becomes the option of LWR at a constraint cost of £55/MWh with a maximum regret of £110 m, compared to a maximum regret of £153 m and £574 m for the 600 MW HVDC link and 220 kV AC cable link respectively. The 'regret' of investing in the 600 MW HVDC link over the 450 MW HVDC link is £50 m.

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

Table 8-5: Low Wind Capacity Factor Sensitivity NPV with £70/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	531	935	1,367	1,700
2	600 MW HVDC	481	885	1,348	1,854
3	220 kV AC Cable	610	793	938	1,057

Table 8-6: Low Wind Capacity Factor Sensitivity NPV with £70/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	79	0	0	154	154
2	600 MW HVDC	128	50	19	0	128
3	220 kV AC Cable	0	142	430	797	797

At a lower wind capacity factors, the sensitivity of the results to the constraint cost is increased.

8.3 Project Capex (+20%)

Our last sensitivity explores the impact of increasing project capex by 20%. Table 8-7 shows the results – NPV's remain positive for all options under all generation scenarios.

Table 8-7: High Project Capex NPV Sensitivity with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4
1	450 MW HVDC	308	667	1,036	1,247
2	600 MW HVDC	249	608	1,021	1,450
3	220 kV AC Cable	393	501	590	663

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

Table 8-8: High Project Capex Regret Analysis Sensitivity with £55/MWh Constraint Cost (£m, 2018 prices)

Option	Description	S1	S2	S3	S4	WR
1	450 MW HVDC	86	0	0	204	204
2	600 MW HVDC	145	59	15	0	145
3	220 kV AC Cable	0	166	446	788	788

With higher capex the 600 MW HVDC link remains the option of LWR with a maximum regret of £145 m. The maximum regret of the 450 MW HVDC link is £204 m whilst the maximum regret of the 220kV AC Cable link is £788 m. The regret of investing in the 450 MW HVDC option over the 600 MW HVDC option is around £59 m.

Although not presented, at a constraint cost of £70/MWh the 600 MW HVDC link is the option of LWR – with the regret between it and the 450 MW HVDC link being significantly higher at £170 m.

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.

8.4 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 enabling onshore works is included in total project costs or if the long term wind farm capacity factor is below 40%.

9. Other considerations

9.1 Impact on TNUoS Charges

The results of our analysis suggest that Option 2 is the reinforcement of LWR – driven by the highest generation scenario (S4). Under the lower scenario S3, then Options 1 and 2 are broadly identical in terms of NPV results. Under scenario S2, the regret of adopting Option 2 over Option 1 is £50 m. The results suggest that, under the 'mid' generation scenarios, Options 1 and 2 are very similar. The situation is further complicated by the position of the Western Isles outside the GB main interconnected transmission system (MITS). As a result transmission connected generators will be subject to a 'local spur' transmission use of system (TNUoS) charge for the link 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.

Table 9-1 shows an estimated local spur charge associated with Options 1 and 2, together with the wider TNUoS charge for the relevant zone. Option 1 leads to an overall TNUoS charge for an indicative Western Isles wind farm of around [redacted] compared to that of Option 2 of [redacted]. The impact on the lifetime levelised cost (LLC) of this indicative Western Isles transmission connected wind farm is significant – Option 1 leads to a [redacted] higher LLC than Option 2.[17]

Table 9-1: Indicative TNUoS Tariffs & Lifetime Levelised Cost for a WI Wind Farm (2018 prices)

	Option 1 (450 MW link)	Option 2 (600 MW link)
Local circuit charge (£/kW)	[redacted]	[redacted]
Wider TNUoS (£/kW)	[redacted]	[redacted]
Total TNUoS (£/kW)	[redacted]	[redacted]
Levelised TNUoS (£/MWh)	[redacted]	[redacted]
Estimated lifetime levelised cost indicative Western Isles WF (£/MWh)	[redacted]	[redacted]

Stakeholders have suggested to SHE-T that the higher TNUoS associated with Option 1 will lead to an uneconomic outcome for a transmission connected wind farm on the Western Isles. While clearly a range of inputs and assumptions will influence the LLC of a Western Isles WF and its subsequent bid into the upcoming CfD auction, our analysis suggests that Option 2 will result in a more competitive bid.

In the forthcoming CfD auction scheduled for 2019, Western Isles wind will be competing largely against other islands wind and offshore wind. In the 2017 auction three offshore wind farms were successful in securing a CfD – with an average strike price of £70/MWh (2018 prices) as shown in Table 9-2[18].

If we assume that offshore wind will bid into the upcoming CfD auction at similar prices, then our illustrative analysis suggests that, with the TNUoS associated with Option 1, the LLC of Western Isles onshore wind may lead to an uncompetitive bid.

[17] Based on the following assumptions – capex £1250/kW, opex 5% capex, capacity factor 44.7%, discount rate 6%, amortisation period 20 years
[18] Source https://lowcarboncontracts.uk/cfd-allocation-round

Table 9-2: CfD Round 2 Offshore Wind Farm Strike Prices

	CfD price (2012 prices)	CfD price (2018 prices)
Triton Knoll	74.75	82.75
Hornsea	57.5	63.66
Moray	57.5	63.66
Average offshore wind strike price (£/MWh)	**63.2**	**70.0**

9.2 Socio-economic Impact

The 'Islands (Scotland) Bill' unanimously backed by MSPs in May 2018 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.

We have explored the socio-economic impact on the Western Isles of each transmission reinforcement option and associated enabled generation (see Appendix C) – Option 2 leads to the highest benefit of around £229 m present value – some £55 m greater than Option 1. Clearly while socio-economic benefit alone cannot justify the transmission link, we believe Ofgem should consider the evident social and economic benefit to the Western Isles, particularly in light of its obligations as a relevant body under the Islands Bill. Securing additional economic benefit is fundamentally dependent on reinforcement of the network and Option 2 results in greater socio-economic benefits to the Western Isles economy.

9.3 Summary

Our analysis suggests that Option 2 will result in significantly lower TNUoS charges than Option 1 that will appreciably improve the competitive position of Western Isles wind vis-à-vis offshore wind in the 2019 CfD auction. Option 2 also results in greater long-term socio-economic benefits to the Western Isles. While not necessarily part of the SWW CBA, we believe these other, highly relevant, factors should be taken into consideration by Ofgem when determining its conditional approval.

10. Analysis and Conclusions

This report details the Cost Benefit Analysis undertaken by GHD to support SHE-T's Needs Case submission for the Western Isles transmission connection project. As part of this process we have performed a rigorous assessment of the proposed WI 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 least worst regret. This conclusion is influenced to some extent by the highest capacity generation scenario (S4) as the performance of both HVDC connection options (Option 1 and 2) are actually very similar across the mid-scenarios (S2 and S3). Both options also perform commensurately worse under the lowest capacity S1 scenario where the lowest capacity AC connection (Option 3) is the preferred option. This option does however incur a significant regret cost under the mid and high generation scenarios and would offer insufficient overall transmission capacity for those projects wishing to compete in the forthcoming CfD auction.

The NPVs returned in our Central Case assumptions 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 enabling onshore works is included in total project costs. Delaying the delivery of the SHE-T proposed Option 2 beyond the planned delivery date of 2023 also provides no benefit.

Further supporting the GHD recommendation that Option 2 represents the preferred connection option we have examined both the break-even point of generation capacity required to economically support Option 2 and further investigated the tipping point of generation capacity required to result in Option 2 being the preferred connection design. Our analysis suggests that the 'breakeven' point of generation for Option 2 is less than 174 MW – below the capacity of generation even in our lowest scenario – with the 'tipping point' of renewable generation capacity resulting in Option 2 having the superior overall NPV being around 520-530 MW. The generation required to meet the 'tipping point' between Option 1 and 2 could come from a wide range of potential combinations of generation projects as currently there is over 800 MW of potential project capacity known, with potentially more that could be developed over the longer term. As a result, the risk of transmission connection capacity being underutilised is fairly low even under Option 2.

GHD has also reviewed the CBA and regret costings provided by the SO for the same range of generation scenarios and transmission connection options. We note that the SO analysis has identified that Option 1 (450 MW HVDC link) is the option of LWR when examining the wider range of scenarios, including the four FES generation scenarios and the four SHE-T derived scenarios. However, they also confirm that this outcome is based on the inclusion of the Steady State (SS) scenario which in their own words is something of "an outlier in this analysis as exports never exceed 200 MW". They further indicate that this scenario is essentially incompatible with the basis of SHE-T's Needs Case submission which is conditional on the two larger wind farm projects on Lewis achieving success in the forthcoming CfD auction. When they remove the Steady State scenario from their regret analysis Option 1 has a worst regret of £90 m with Option 2 having a worst regret of £73 m and therefore representing the option of least worst regret. Thus, the SO conclusion effectively matches with the recommendation from GHD's own analysis that Option 2 represents the most appropriate transmission connection option for the Western Isles.

With Options 1 and 2 providing having a very similar performance other factors should also be taken into account in the CBA. Stakeholders have suggested to SHE-T that the higher TNUoS associated with Option 1 will lead to an uneconomic outcome for a transmission connected wind farm on the Western Isles. While clearly a range of inputs and assumptions will influence the lifetime levelised cost of a Western Isles wind farm and its subsequent bid into the upcoming CfD auction, our analysis nonetheless suggests that Option 2 will result in a more competitive bid into the CfD auction. Option 1 therefore runs the risk of leading to no transmission connected generation on the Western Isles given the less competitive lifetime costs that would be seen by project developers.

The ‘Islands (Scotland) Bill’ unanimously backed by MSPs in May 2018 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. We have explored the socio-economic impact on the Western Isles of each transmission reinforcement option and associated enabled generation – Option 2 leads to the highest benefit of some £229 m present value – some £55 m greater than Option 1. If the higher TNUoS charges associated with Option 1 lead to uncompetitive bids into the CfD auction, then the Western Isles may forgo the economic benefit resulting from transmission reinforcement.

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 Western Isles***. This recommendation is fully aligned with the SHE-T Needs Case submission.

Appendices

Appendix A – Generation Scenarios

A.1 Complexity of Generation Development on the Western Isles

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-T to fully 'stress test' the requirement for transmission reinforcement in its Needs Case.

For Scottish islands such as the Western Isles, a key uncertainty in the investment in transmission infrastructure is whether any new generation projects will emerge over the next 5 years – the development period required for a transmission link. The Western Isles 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[19]. Whilst there is clearly potential for significant wave resource, it remains some distance from achieving commercial viability without a significant shift in Government subsidy policy. As such, wind power will form the basis of near term generation growth in the Western Isles.

However, determining the prospects for future onshore wind generation – location and certainty of progression – on the Western Isles (and the Scottish islands in general) is complex. The existing electricity network on the Western Isles 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 the Western Isles 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

As stated above, the case for transmission or generation development is entirely predicated on the other. The situation is further complicated by the position of the islands (Orkney, Shetland 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*

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

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 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[20] 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[21]

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[22]. 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[23] was issued alongside the Draft Energy

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

Strategy. The strategy makes clear Scottish government support for further onshore wind development in Scotland, and in particular on the Islands:

> **"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."** [24]

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 the Western Isles, Orkney and Shetland. 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 sea bed around the islands, allowing revenues currently paid to the Crown Estate to be channelled into local needs.

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

- New grid connections to the Scottish mainland to allow world class wave, tidal and wind energy resources to generate maximum benefits for the islands.
- 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 November 2012 the Comhairle published the adopted Outer Hebrides Local Development Plan (LDP). The purpose of the plan was to outline a sustainable land use strategy for the Outer Hebrides. With regard to energy production, the plan stated:

> **"The Comhairle will support proposals that contribute to meeting the targets and objectives of the National Planning Framework 2, the Climate Change Act, and the National Renewables Infrastructure Plan in relation to electricity grid reinforcement, infrastructure and renewable energy generation."[25]**

In December 2016, detailed Supplementary Guidance for Wind Energy Development was published by the Comhairle. The Supplementary Guidance states:

> **The Outer Hebrides has a rich renewable energy resource that communities, householders and developers can utilise for a range of important purposes. The generation of power from wind energy has potential throughout our Islands albeit at different scales in differing parts of the Islands. Although there are constraints in relation to the resource, the Comhairle is supportive and seeks to encourage appropriate renewable energy generation projects. Wind energy has the potential to deliver many benefits to communities and individual householders, and the Comhairle is particularly keen to see community generated projects coming forward in appropriate locations."[26]**

The local council is supportive of further wind energy development on the Western Isles. In particular:

- The Supplementary Guidance outlines a detailed spatial plan for Wind Farm Development on the Western Isles
- Comhairle nan Eilean Siar and The Stornoway Trust (the elected community landlord) have entered into a joint venture (JV) agreement to maximise the shared ownership potential of Stornoway and Uisenis Wind Farms
- Comhairle nan Eilean Siar and The Stornoway Trust plan to construct a wind farm of its own in due course as part of its JV.

Further details on the Comhairle's participation in Western Isles onshore win development is provided in the following sections.

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

[25] The Outer Hebrides Local Development Plan, Comhairle nan Eilean Siar, Page 39, November 2012
[26] The Outer Hebrides Local Development Plan, Supplementary Guidance for Wind Energy Development, Comhairle nan Eilean Siar, Page 1, December 2016

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 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 the Comhairle are strongly in favour of more onshore wind on the Western Isles.

A.2 Generation Prospects

As outlined above, onshore wind will form the basis of generation growth in the Western Isles. 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 the Western Isles is significant. A number of wind farms have secured contracts with SHE-T and SHEPD. In addition, there is a significant amount of crofter-led, community-owned and council-stakeholder interest in onshore wind farm development on the Islands – outlined by the local appetite for onshore wind development discussed in Section 0.

Below we discuss contracted generation, followed by crofter-led proposals, community-owned proposals and the role of the council in securing onshore wind generation development.

Transmission Connected Contracted Generation

There is currently 330 MW of transmission-connected generation contracted with SHE-T comprising four projects, shown in Table A.1.

Table A.1: Transmission Connected Contracted Generation – Contracted and Planning Capacities (MW)

Wind Farm	Owner	Contracted Capacity	Consented Capacity
Stornoway	LWP	130.0 MW	180.0 MW
Uisenis	LWP	150.0 MW	162.0 MW
Druim Leathann	Forsa	46.2 MW	46.2 MW
Pentland Road	Pentland Road Wind Farm Limited	4.2 MW	4.2 MW
Total		330.4 MW	396.1 MW

Lewis Wind Power (LWP) is main developer on the Western Isles. It has two projects with a contracted capacity of 280 MW. However, LWP's consented capacity is significantly higher at 342 MW. [redacted]

Forsa (the developer of the Druim Leathann wind farm) currently has a contracted capacity and planning permission for 46.2 MW. Forsa [redacted] has made initial enquiries regarding an increase in planning permission to 49.9 MW.

Both of the LWP projects, and potentially others, are expected to compete in the 2019 CFD auction.

The existing Pentland Road Wind Farm is currently limited to 13.8 MW due to network capacity constraints. An additional 4.2 MW from the site is sought by its owners and is subject to transmission reinforcement.

The total amount of contracted capacity with SHE-T is currently 330 MW, although the total amount consented via the planning process for the same projects is significantly higher at 396 MW.

Distribution connected Contracted Generation

There is currently 21.3 MW of onshore wind generation contracted with SHEPD comprising:

- 1.8 MW contracted to connect in October 2018
- 12.2 MW contracted but is currently transmission constrained

A further 7.3 MW is currently seeking to terminate its contracted status due to either a lack progress regarding the transmission infrastructure or changes in investment conditions.

Given the local commitment to onshore wind development, these smaller projects are considered highly likely to develop if there is sufficient network capacity.

Crofter Proposals

Crofting is the predominant form of land use in the Western Isles. About 77% of the land area is held in crofting tenure and is therefore subject to crofting legislation. There are some 6,000 crofts distributed among 280 townships throughout the Western Isles[27].

It is understood that the proposed Stornoway Wind Farm to be developed by LWP is located on Crofting land. More than 200 crofters have objected to LWP's proposals. Wind is increasingly seen as a key natural resource in the Western Isles, with the potential to boost the economic future of the islands. The crofters want to build their own development, with the profits going to the local community[28].

A group of Crofters have submitted development applications for wind farms on their common grazings which directly rival plans for the LWP project. The crofter turbines are sited in exactly the same locations as LWP. The crofter proposals are detailed in Table A.2.

Table A.2: Crofter Developments (Opposing LWP's Stornoway Wind Farm)

Wind Farm	Proposed Capacity (MW)
Aiginish Community Wind Farm	10.0
Melbost Community Wind Farm	40.0
Sandwick East Community Wind Farm	49.0
Sandwick North Community Wind Farm	5.0
Total	114.0

[redacted] As such, the Stornoway Wind Farm and the crofter proposals are mutually exclusive – only one project or the other will be developed – not both.

[27] https://www.cne-siar.gov.uk/strategy-performance-and-research/outer-hebrides-factfile/economy/agriculture-and-crofting/
[28] https://www.theguardian.com/uk-news/2018/feb/04/windfarm-crofters-lewis-fight-edf-wood-group-scottish

The Druim Leathann wind farm only covers one area of crofting land (whereas Stornoway covers four). The Druim Leathann project has not been subject to a competing proposal from the crofters.

Community Projects

In addition to the crofter-led proposals, SHE-T has received a number of expressions of interest for future connection from community-owned or partial community stakeholdership projects, totalling approximately 108 MW. These projects are shown in Table A.3

Table A.3: Proposed Community Projects

Wind Farm	Proposed Capacity (MW)
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
[redacted]	[redacted]
Total	108.2 MW

[redacted]

Community Energy Scotland, acting on behalf of 15 community groups, has submitted an application for a scoping opinion on a 50 MW Wind Farm on the Arnish Moor (Arnish Community Scheme). [redacted]

SHE has received further interest by developers seeking to connect up to 33 MW of community owned generation.

Given the local commitment to onshore wind development, a number of community owned and community led projects are highly likely to be developed if there is sufficient export capacity.

Council Ownership and the Stornoway Trust

The Comhairle and the Stornoway Trust (the elected Community Landlord) has entered into a JV agreement to maximise the shared ownership potential of the Stornoway and Uisenis Wind Farms being developed by LWP.

The Comhairle has been offered 30% of Uisenis Wind Farm to purchase on behalf of the community while The Stornoway Trust has been offered 20% of Stornoway Wind Farm. The purpose of the JV is to combine the two share offers into one large shared ownership agreement. In doing so, around 100 MW of consented generation would be in the hands of the community.

Whilst the JV does not add additional potential onshore wind capacity, the JV also aspires to construct a wind farm of its own in due course, based on its learnings from its involvement in the LWP projects.

The Stornoway Trust owns 28,000 Hectares of land around Stornoway. [redacted].

The Comhairle's onshore wind spatial plan

In December 2016 Supplementary Guidance for Wind Energy Development was issued as part of the Outer Hebrides Local Development Plan[29]. The guidance encourages wind farm development in a number of areas in the Western Isles. The Spatial Strategy is based on the framework approach set out in Scottish Planning Policy, augmented by constraints (both statutory and non-statutory) which have a bearing on wind turbine developments in the Outer Hebrides including: consented developments; low landscape capacity for turbine development; and setting of specific historic assets.

The document states the Comhairle:

> **"will support proposals that contribute to meeting the targets and objectives of the National Planning Framework 2, the Climate Change Act, and the National Renewables Infrastructure Plan in relation to electricity grid reinforcement, infrastructure and renewable energy generation….**
>
> **…. Though appropriate development of renewable energy resources from all sectors is welcomed the Comhairle is particularly keen to see communities and community land owning bodies realise the potential of wind energy power generation and the benefits associated."**

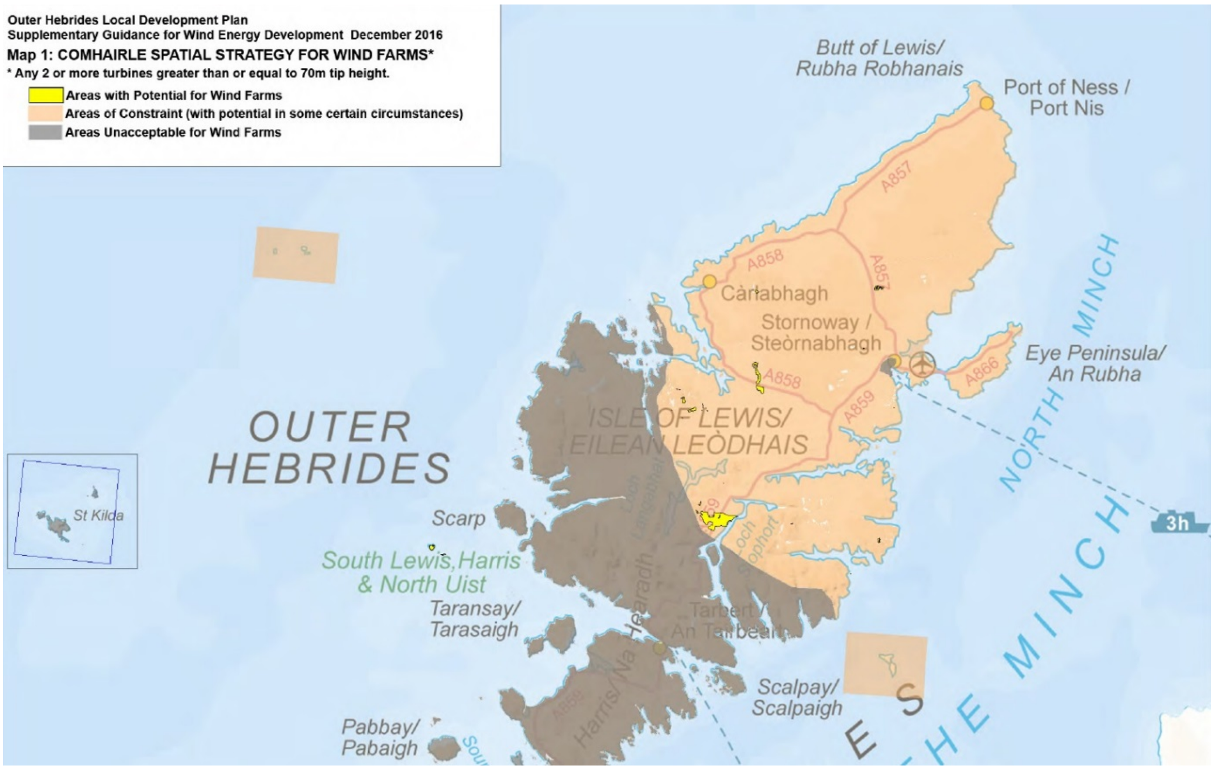
As part of its energy policy, the Comhairle has developed a spatial heat map that categorises the Western Isles into three:

- Areas with potential capacity to accommodate wind farms are identified as 'Areas with Potential for Wind Farms'; representing the areas of least constraint to wind energy development. Wind energy development is supported in principle within these areas, subject to proposals complying with the development criteria from Supplementary Guidance and any other material planning consideration.
- Within the 'Areas of Constraint (with potential in some certain circumstances)' wind development may be supported when a proposal complies with the development criteria from Supplementary Guidance and where it can be demonstrated by the applicant that any significant effects on the qualities of these areas can be overcome by siting, design or other mitigation.
- Areas where a wind farm will not be considered in any form are identified as 'Areas Unacceptable for Wind Farms'.

The spatial heat map is shown in Figure A.3 for the Isle of Lewis and Harris.

[29] Outer Hebrides Local Development Plan, Comhairle nan Eilean Siar, December 2016 (https://www.cne-siar.gov.uk/media/3434/sg-wind-energy-dev-2016-reduced-for-web.pdf)

Figure A.3: WI Council Onshore Wind Heat Map



Source: Outer Hebrides Local Development Plan, Comhairle nan Eilean Siar, December 2016

'Areas with Potential for Wind Farms' on the Isle of Lewis and Harris totals approximately 700 hectares which, using the site areas of Stornoway and Uisenis as a guide, could accommodate projects of around 90 MW shown in Table A.4.

Table A.4: Council Spatial Plans for the Isle of Harris and Lewis

Site	Hectares	Approximate Capacity (MW)
1	462	60
2	76	10
3	49	6
4	15	2
5	25	3
6	20	3
7	25	3
8	6	1

Applications for wind project development must take into account the Spatial Strategy Framework for windfarm development. The heat map provides further evidence of the pro-active nature and support from the Comhairle towards onshore wind farm development on Western Isles.

With such a good planning policy position there is a high likelihood that planning permission will be granted for these projects, subject to any unforeseen environmental issues. However, there could still be technical or commercial issues that would prevent developments from coming forward.

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 also 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 qualify for the scheme, including:

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

Table A.5 presents the number of FIT installations and the installed capacity in the Western Isles, Orkney, Shetland, the Highlands and Scotland as of 2017/18. The table also includes an estimate of the total number of households in each location. The Western Isles has a higher concentration of FIT qualifying onshore wind turbines (1.3% of all households) compared to Scotland as a whole (0.13%). Solar PV penetration is in line with overall Scottish uptake, as shown in Table A.5.

The FIT tariff has 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 is scheduled to end by March 2019 and it appears at present that there will be no replacement.

The removal of the FIT scheme is counterbalanced by the falling cost of wind and solar generation. Small-scale generation is likely to remain relatively attractive on the Western Isles due to the excellent wind speeds. Those interested in small scale wind turbines will likely be able to benefit as the cost of electricity is likely to be lower than that available from national suppliers (the levelised cost of generating electricity on a per MWh basis is likely to be lower than buying that MWh from a supplier).

Table A.5: 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 Offshore wind generation

The potential for offshore wind generation around the coast of Western Isles is significant. However, at present there is only one offshore wind project in scoping, as detailed below.

Hywind Scotland (Statoil)

A subsidiary of Norwegian state owned energy company Statoil, Hywind Scotland is currently scoping a site to the west of the Isle of Lewis. The project will require Marine Scotland consent and a Crown Estate Scotland seabed lease. Early estimates suggest turbines may be in the water by 2026. Hywind Scotland, which is part owned by Masdar (a sovereign wealth development subsidiary of the Abu Dhabi Government), aim to seek a [redacted] MW connection in the first instance, rising to [redacted] MW or more at full commerciality.

Marine Scotland has launched the latest draft Regional Locational Guidance (RLG) for floating offshore wind and identified an area west of Lewis (between the Flannan Isles and the Butt of Lewis) as a search area for the technology. Once the RLG is adopted, schemes deploying in that area will enjoy a fast tracked consenting process.

Marine Scotland, Statoil and the council met on the Western Isles in May 2018 to discuss this activity.

A.2.3 Marine generation

The potential for wave generation around the coast of the Western Isles is significant. However to date, wave technology is not as close to commercial viability as tidal and therefore we have not considered wave generation in this study. This view aligns with the view of FES 2017 and 2018, which does not expect any wave project development on the Western Isles under any generation scenario - including its most prosperous and green ambitious scenario.

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 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[30]. 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 two largest proposed wind farms on the Western Isles (Stornoway, and Uisenis) intend to compete in the 2019 CfD auction. As these projects alone currently represent 340 MW of consented generation, SHE-T 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 are designed to reflect this approach and assume varying degrees of success in the 2019 CfD auction for these large transmission-connected wind farms. The scenarios developed do not reflect a world in which Western Isles generation completely fail to secure CfDs. They present scenarios of varying combinations of projects (and project owners) winning CfDs at alternative capacities (consented and contracted) taking into consideration any issues of mutual exclusivity. The scenarios are supplemented by varying levels of underlying local appetite for community and Council development should a new, high capacity transmission cable be constructed, taking into consideration the applicability of TNUoS charges to the prospective projects (i.e. 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 is based on a detailed generation database identifying all proposed projects in the public domain. This provides an indication of developments that could come forward in a relatively short period. These developments are outlined in Section 0 of this report.

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

Clearly, there will be potential for other projects to come forward that are not currently in the public domain. In order to reflect this we have examined the Comhairle's spatial strategy for wind energy development. This document identifies potential areas where future wind farm development may be supported by the Council through the planning system, which we havethen included in our generation database for consideration in developing our range of scenarios.

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

A.3.3 Scenario Drivers

Utilising the top down drivers for development and the specific project based information from the bottom up assessment, we have developed four generation scenarios, each with varying amounts of onshore wind. Our assessment of onshore wind is split into six categories of generation as shown in Figure A.4.

Figure A.4: Onshore Wind Generation Categories

Contracted Generation Projects contracted to either SHE-T or SHEPD, including major wind farm developments Stornoway, Uisenis and Druim Leathann.	**Crofter Projects** Specific projects identified by Crofters who currently contest the LWP Stornoway project and wish to develop their own wind farms on the same land.	**Commercial scale council owned projects** Consortia identified generation projects greater than 5 MW in capacity fully or partially owned by the Council and areas identified by the Council for wind farm development.
Commercial scale community owned projects Consortia identified generation projects greater than 5 MW in capacity owned in full by Western Isles communities.	**Constrained Generators** Existing wind farm at Pentland Road will increase output on arrival of an improved transmission link.	**Small scale projects** Consortia identified generation projects less than 5 MW in capacity. This includes community owned, developer owned and landowner projects.

Table A.6 provides a summary of the generation growth assumptions for all four generation scenarios broken down by each of the onshore wind alongside other categories of generation including embedded Solar, hydro and offshore wind.

A.3.4 Small-scale Generation

In each scenario, we have assumed that a reasonable appetite for small scale onshore wind generation and solar projects would continue.

We have assumed a further 1 to 5 MW of wind turbine projects would arise by 2030 whilst a further 3.5 MW to 6 MW of solar and hydro projects would arise over the same period.

Table A.6: Generation Growth Assumptions

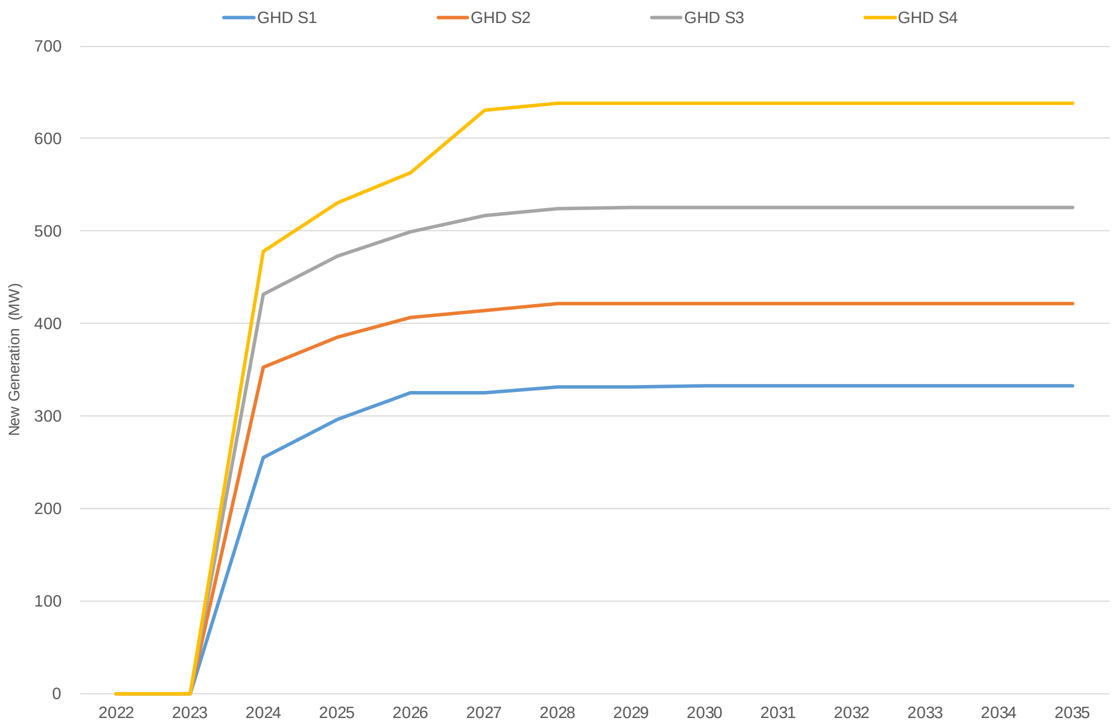
Scenario	Onshore Wind								Other		
	Transmission Contracted		Distribution Contracted	Crofter Developments (Stornoway)	Community Owned (Partial / Full)	Council & Stornoway Trust Owned / Identified	Existing Constrained Generation	Small Scale (<5MW)	Offshore Wind	Wave	FIT (Solar, CHP, Hydro)
	LWP Projects	Druim Leathann									
S1	Stornoway loses Crofter challenge, only Uisenis progresses 162 MW	Druim Leathan progresses at current capacity 46.2 MW	No identified projects developed 0 MW	Crofter challenge prevails - significant development progress 60 MW	Reasonable development of non-conflicting community schemes 46 MW	Limited uptake of council spatial plans 10 MW	Existing Pentland Road WF constraints removed 4.2 MW	Limited small scale developments 1 MW	None 0 MW	None 0 MW	Some development of Solar as costs reduce and limited hydro 3.5 MW
S2	Both projects win CfD and are developed 342 MW	Druim Leathann does not progress 0 MW	Limited number of identified projects developed 5 MW	None - Stornoway developed 0 MW	Reasonable development of non-conflicting community schemes 46 MW	Limited uptake of council spatial plans 15 MW	Existing Pentland Road WF constraints removed 4.2 MW	Stronger growth in small-scale developments as crofter sites do not proceed 5 MW	None 0 MW	None 0 MW	Some development of Solar as costs reduce and limited hydro 4.8 MW
S3	Both projects win CfD and are developed 342 MW	Druim Leathann developed at increased capacity 49.9 MW	All identified projects developed 14 MW	None - Stornoway developed 0 MW	Reasonable development of non-conflicting community schemes 60 MW	Reasonable uptake of council spatial plans + modest JV on council land 45 MW	Existing Pentland Road WF constraints removed 4.2 MW	Stronger growth in small scale developments as crofter sites do not proceed 5 MW	None 0 MW	None 0 MW	Some development of Solar as costs reduce and limited hydro 4.8 MW
S4	Both projects win CfD and are developed 342 MW	Druim Leathann developed at increased capacity 49.9 MW	All identified projects developed 14 MW	None - Stornoway developed 0 MW	Strong development of non conflicting community schemes 102.2 MW	Reasonable uptake of council spatial plans + sizeable JV on council land 65 MW	Existing Pentland Road WF constraints removed 4.2 MW	Stronger growth in small scale developments as crofter sites do not proceed 5 MW	Limited development of floating offshore 50 MW	None 0 MW	Some development of Solar as costs reduce and limited hydro 6 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.5 shows the resulting total installed capacity for the four generation scenarios developed (S1 – S4). We conservatively assume there is no additional generation growth beyond 2030 – in common with the FES.

Figure A.5: Total Generation by Scenario



A breakdown of the generation assumed under each scenario is shown in Table A.7.

Table A.7: Total Generation by Scenario 2030 (MW)

Scenario	Onshore Wind	Embedded Wind	Embedded Solar	Embedded Hydro	Floating Offshore	Total
S1	319.2	10.2	3.0	0.5	0.0	332.9
S2	408.0	9.2	4.0	0.8	0.0	422.0
S3	510.9	9.2	4.0	0.8	0.0	524.9
S4	573.1	9.2	5.0	1.0	50.0	638.3

A.3.6 Summary

The generation scenarios outlined in this report are designed to reflect alternative outlooks of future generation development based on varying degrees of success in the CfD auction for the largest proposed transmission-connected wind farms, alongside community and Council developments.

A failure for all of the largest transmission connected projects to win a CfD in the 2019 auction would likely result in lower generation development than has been modelled. However, as

SHE-T wishes to submit a 'Conditional Needs Case', conditional on the success of some or all of these projects, it was considered unnecessary to model this outcome at this stage.

A.4 Comparison to National Grid's FES

The generation scenarios presented in Section A.3 are developed using both a top-down and bottom up approach. These scenarios are detailed and localised and take 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 and Council ownership.

The Future Energy Scenarios (FES) scenarios developed by National Grid for GB include the Western Isles 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. It is upon this basis that the FES are compared to the GHD generation scenarios. 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 2017 (FES 2017). Although not fully released, National Grid has updated the FES for 2018. SHE-T has provided GHD with the details of the FES 2018. Both FES 2017 and FES 2018 comprise of four scenarios, as outlined in Table A.8 below.

Table A.8: FES Scenarios / Drivers

FES 2017	FES 2018
Steady State (SS): Business as usual prevails and the focus is on ensuring security of supply at a low cost for consumers. This is the least affluent of the scenarios and the least green. There is little money or appetite for investing in long-term low carbon technologies, therefore innovation slows.	**Steady Progression (SP):** This is a more centralised pathway that makes progress towards but does not meet the 2050 target. It combines elements from last year's Steady State and Slow Progression scenarios.
Consumer Power (CP): In a Consumer Power world there is high economic growth and more money available to spend. Consumers have little inclination to become environmentally friendly. Their behaviour and appetite for the latest gadgets is what drives innovation and technological advancements. Market-led investments mean spending is focused on sources of smaller generation that produce short to medium-term financial returns.	**Consumer Evolution (CE):** In this scenario there is progress towards the decarbonisation target, but it is not met by 2050. This is also a world with greater decentralisation, building on a blend of Consumer Power and Slow Progression from FES 2017.

FES 2017	FES 2018
Slow Progression (SP): In Slow Progression low economic growth and affordability compete with the desire to become greener and decrease carbon emissions. With limited money available, the focus is on cost-efficient longer-term environmental policies. Effective policy intervention leads to a mixture of renewable and low carbon technologies and high levels of distributed generation.	**Community Renewables (CR):** For this scenario we explore how the 2050 target can be met through a more decentralised energy system. It is based on the Consumer Renewables sensitivity from FES 2017.
Two Degrees (TD): Two Degrees has the highest level of prosperity. Increased investment ensures the delivery of high levels of low carbon energy. Consumers make conscious choices to be greener and can afford technology to support them. With highly effective policy interventions in place, this is the only scenario where all UK carbon reduction targets are achieved.	**Two Degrees (TD):** The decarbonisation target is met with less focus on decentralised energy. This scenario builds on Two Degrees from FES 2017.

As can be seen in the table above, the underpinning drivers and names of the four scenarios in FES 2017 and FES 2018 differ Figure A.6 summarises the underpinning political, economic, social, environmental and technological assumptions supporting the 2017 FES.

Figure A.6: FES Scenario Assumptions (2017)

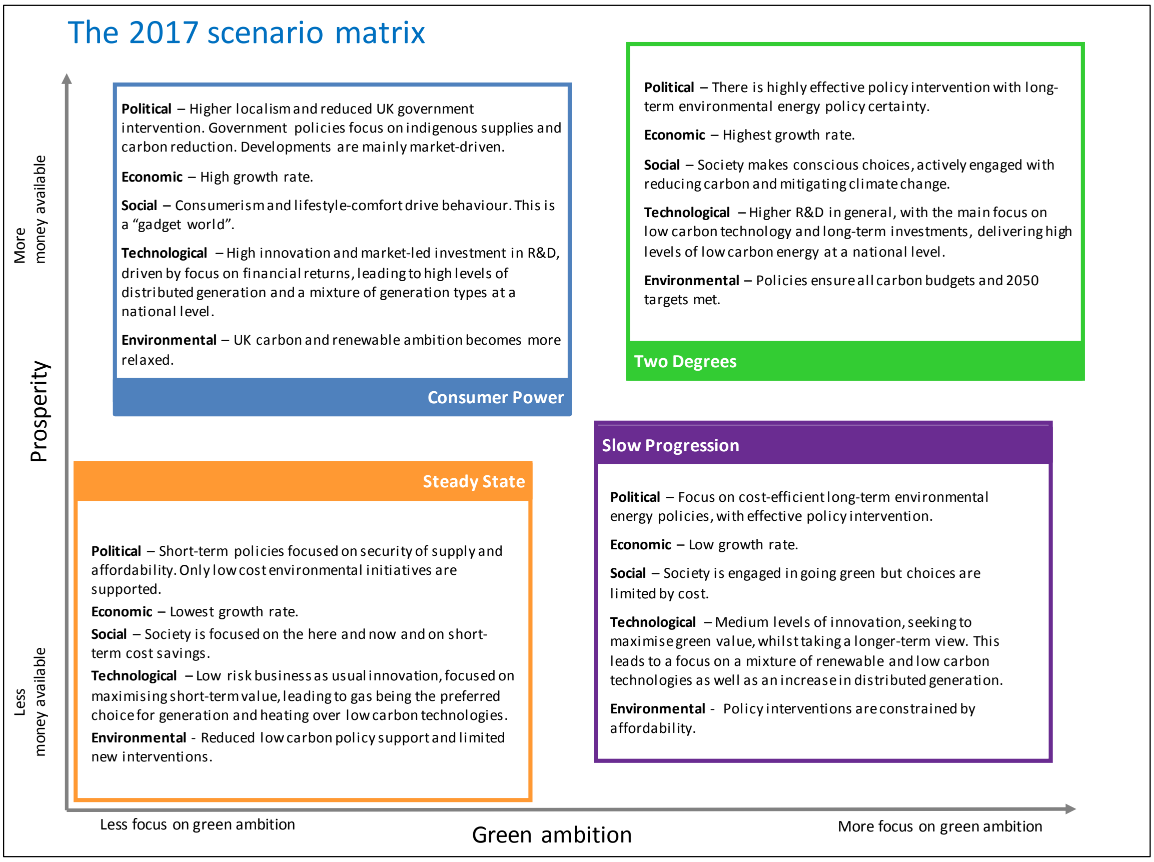


Figure A.7 presents the drivers supporting the 2018 FES. The structure of the 2018 FES differs to the 2017 FES such that the two axes comprise of 'speed of decarbonisation' and 'level of decentralisation' as shown below. Each scenario considers the broad themes of power demand, transport, heat and energy supply.

Figure A.7: FES Scenario Assumptions (2018)

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. National Grid is expected to base its Western Isles CBA on FES 2018.

A.4.2 FES 2017 Results

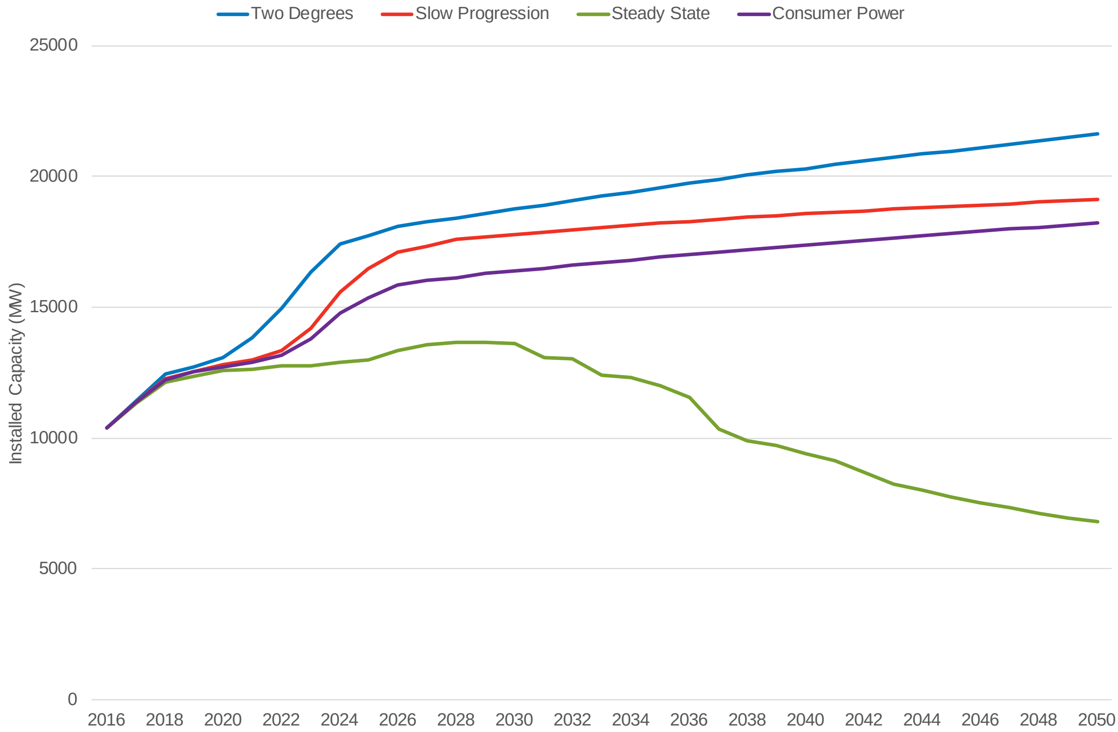
National Grid publishes FES scenario data for the whole of the GB online[31]. Differing outcomes for GB renewable growth are presented over the period to 2050. Figure A.8 shows the growth in GB renewable generation particularly relevant to the Western Isles (onshore wind) in the 2017 FES scenarios.

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.

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.

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

Figure A.8: 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-T has provided GHD with the FES generation assumptions for the Western Isles area[32].

The information was provided for each of the scenarios and includes a list of generation projects in the Western Isles 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.9.

Under the SS scenario, around 176 MW of onshore wind generation is developed (Druim Leathann and Stornoway). Under the CP scenario, around 326 MW of onshore wind generation is developed by 2026 (Druim Leathann, Stornoway and Muaithebheal) whilst under the SP scenario, 326 MW of onshore wind generation is developed by 2025. Under the TD scenario, 326 MW of generation is developed by 2024.

[32] This information is not available publically.

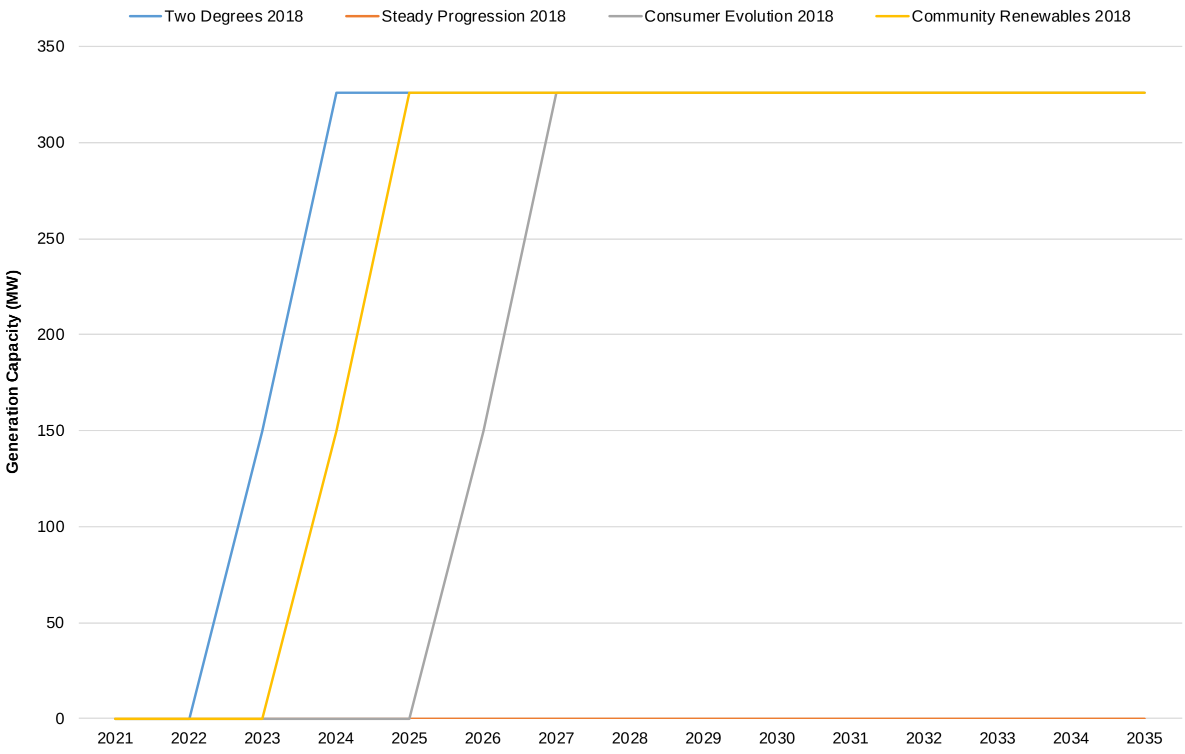
Figure A.9: Western Isles Generation (FES 2017)

A.4.3 FES 2018

Although FES 2018 is not yet publically available, SHE-T has provided GHD with the generation assumptions for the Western Isles area. As for 2017, the information provided for each of the scenarios includes a list of generation projects in the Western Isles area and their assumed operational capacity from 2018 to 2050. 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.10.

Under the SP scenario, zero onshore wind generation development is assumed. Under the CE scenario, around 326 MW of onshore wind generation is developed by 2027 (Druim Leathann, Stornoway and Muaithebheal) whilst under the CR scenario, 326 MW of onshore wind generation is developed by 2025. Under the TD scenario, 326 MW of generation is developed by 2024.

Figure A.10: Western Isles Generation (FES 2018)



A.4.4 Comparison

Figure A.11 and Figure A.12 provides a comparison of GHD's generation scenarios to the FES 2017 and 2018 scenarios respectively.

Figure A.11 shows that the majority of the FES 2017 scenarios assume that projects could begin to come online as early as 2021/22. GHD scenarios are predicated on the transmission link being available in 2023, hence no generation comes online before this date.

By 2024 the FES 2017 and GHD scenarios begin to diverge, ultimately bearing little resemblance in terms of total installed capacity. The same could largely be said with respect to the FES 2018 scenarios. We believe that this divergence is primarily for the reasons outlined below:

- The FES scenarios 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 (totalling 326 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 and community ownership).
- The GHD scenarios include all known projects, sites identified by Comhairle for future development and some degree of background growth. The GHD scenarios also 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 Stornoway and Uisenis Wind Farms at their contracted capacities, some 62 MW lower than their consented capacities. SHE-Ts stakeholder engagement activities has indicated that LWP are likely to develop up to their consented planning capacity and as such, the GHD scenarios are based on the LWP projects higher, consented capacities, which has a material impact when comparing the scenarios.

- Therefore, with the FES being effectively unaware of, or unable to consider a significant amount of known projects, it is unlikely that the FES and GHD scenarios could be closely correlated in the long term.

Figure A.11: Comparison of GHD Generation Scenarios and FES 2017

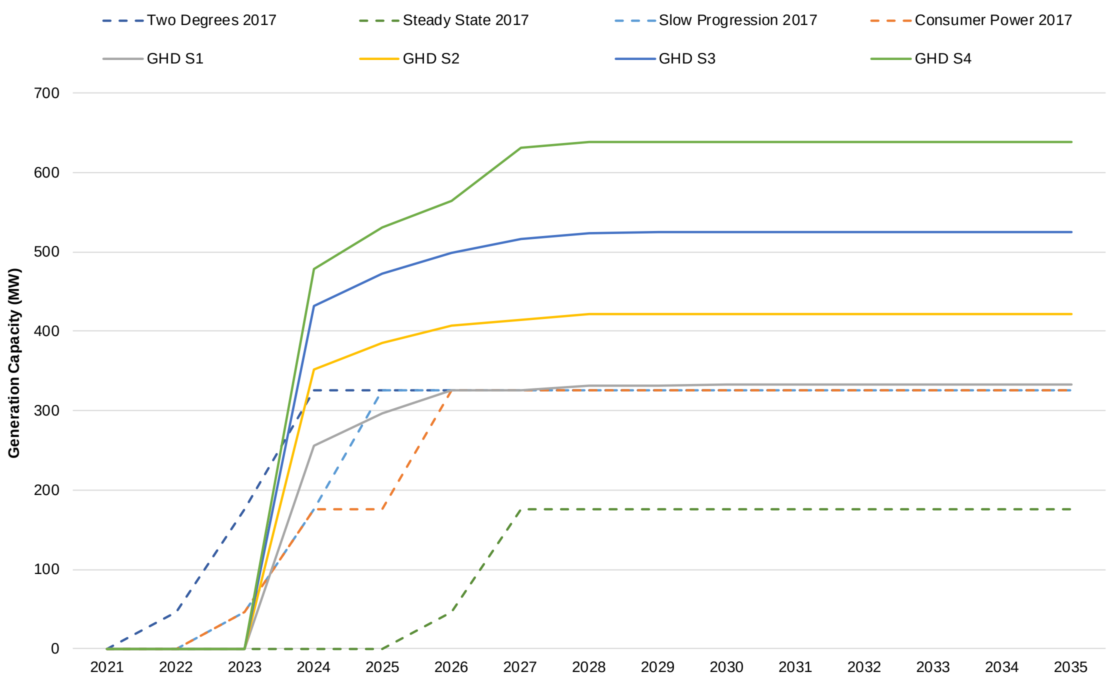
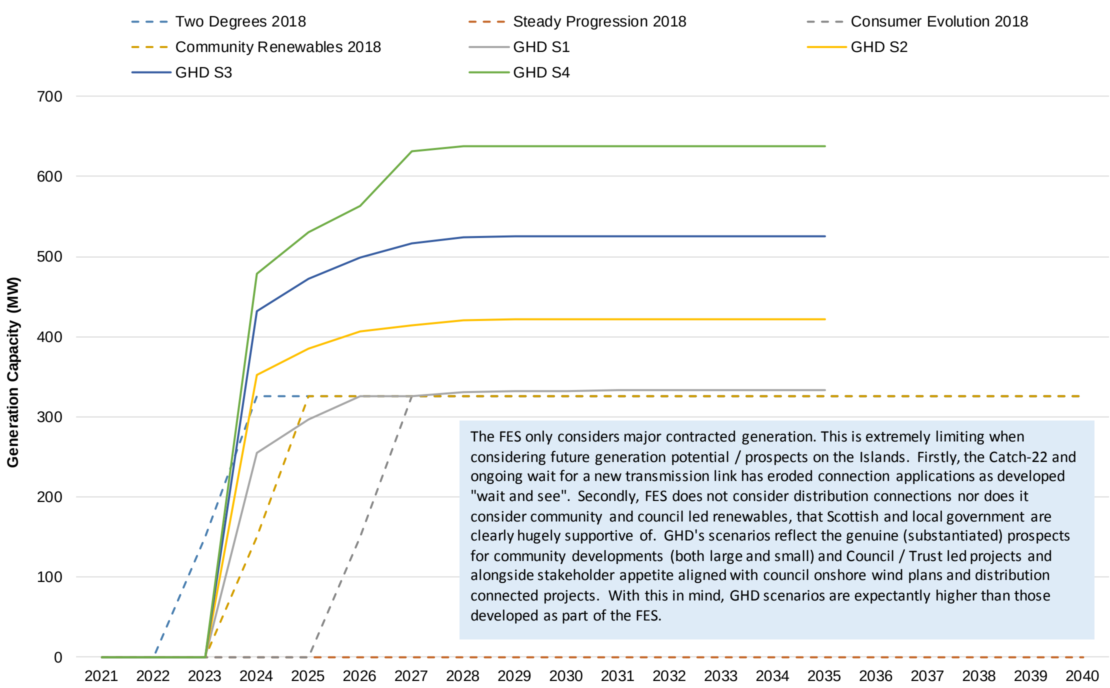


Figure A.12: Comparison of GHD Generation Scenarios and FES 2018



A.4.5 Summary

The FES scenarios developed by National Grid are based on a macro view of GB drivers (economic, political, environment etc) and understandably do not focus on localised investment conditions and factors that may encourage renewable generation development (such as council ownership, community acceptance, wind resource etc). The GHD scenarios are developed with the micro investment conditions and drivers considered alongside the wider macro environment outlined within the FES.

Due to the macro nature of their development, the FES scenarios do not provide a sufficient range of generation scenarios for the purposes of the proposed conditional needs case CBA.

A.5 Summary

Four generation scenarios have been developed by GHD that provide a spectrum of alternative generation growth paths in the Western Isles – ranging from approximately 330 MW of additional generation to 640 MW of additional generation. The generation scenarios reflect alternative outlooks of future generation development based on varying degrees of success in the CfD auction for transmission-connected wind farms, alongside varying development of community and Council developments.

A failure for all of the largest transmission connected projects to win a CfD in the 2019 auction would likely result in lower generation development than has been modelled. However, as SHE-T wishes to submit a ‘Conditional Needs Case’, conditional on the success of some or all of these projects, it was considered unnecessary to model this outcome at this stage.

Appendix B – Western Isles Wind Profiles

Redacted

Appendix C – GHD Approach to Socio-economic Modelling

C.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 (Orkney, Shetland 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'*[33]. 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.[34]

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.'[35]

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

33 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/245381/scottish_islands_additional_support_consultation.pdf

34 https://www.gov.uk/government/publications/scottish-islands-renewable-project-final-report

35 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/245381/scottish_islands_additional_support_consultation.pdf

communities.[36]" 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*.[37]'

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.[38] 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[39]

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 the Western Isles of its SWW decisions given that the impact on the Western Isles 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 the Western Isles.

The Western Isles has very limited grid connections with the mainland, and while some novel active network management technologies have been deployed to maximise the amount of renewables integrated within the islands' grid, these are now 'full', and further 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. 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 discriminates against consumers on the Scottish Islands and additional grid capacity created by new transmission links would be beneficial in this respect.

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

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 toalleviate the situation.

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

C.2 Methodology

Our analysis focuses on the beneficial economic impact that may arise from further renewable development on the Western Isles 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 the Western Isles
- Renewable and transmission projects do not typically have strong backward linkages into a local economy like the Western Isles – 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.[40] [41] [42] [43] [44] Our approach attempts to determine the Gross Value Added (GVA) to the Western Isles 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

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[40] 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)
[41] https://www.thecrownestate.co.uk/media/5468/socio-economic-methodology-and-baseline-for-pfow-wave-tidal-developments.pdf
[42] Socio economic impacts of community wind power projects in Northern Scotland, Okkonen et al, Renewable Energy 85 (2016)
[43] Economic benefits from onshore windfarms, BVG Associates, September 2017
[44] 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[45], World Energy Council[46], International Renewable Energy Agency[47] and various industry reports[48]

- These costs are then further deconstructed into relevant ONS Standard Industry Classifications (SIC)[49]
- A local content for each SIC is determined based on similar studies for Scottish regions, Western Isles, Orkney and Shetland[50] [51] [52] [53]
- We have used Input Output multipliers to determine GVA impact and employment effects based on regional IO data published by Comhairle nan Eilean Siar (Western Isles Council)[54]. 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[55] Gross Value Added by SIC for the Western Isles, published by the ONS[56], show the structure of the Western Isles 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

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[45] 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
[46] World Energy Resources, Wind 2016, WEC
[47] Wind Power Technology Brief, IRENA, March 2016
Solar and wind cost reduction potential to 2025, IRENA, June 2016
[48] 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
[49] https://www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities
[50] Socio economic impacts of community wind power projects in Northern Scotland, Okkonen et al, Renewable Energy 85 (2016)
[51] 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
[52] Economic benefits from onshore windfarms, BVG Associates, September 2017
[53] Clyde Wind Farm Extension – Impact Analysis June 2015
[54] http://stratus.cne-siar.gov.uk/factfile/economy/regaccounts03/multiplier.asp
[55] http://stratus.cne-siar.gov.uk/factfile/economy/regaccounts03/multiplier.asp
[56] Regional gross value added (income approach) reference tables published on 15 December 2016

benefits are not part of the IO assessment but are potential important contributors to the Western Isles economy.

- Not all renewable 'rent' will stay within the Western Isles – some is assumed to 'leak' from the economy[57]. The retained rent will have an additional economic impact which we have determined by assessing Western Isles 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 the Western Isles economy to be taken into consideration, along with the impact of retained rent from renewable development depending on the ownership structure adopted.

C.2.1 Western Isles Economy

The Western Isles had the fifth lowest gross disposable household income (GDHI) per head in Scotland in 2016 at £16,479 (less than it was in 2015 at £16,525). The Scottish average was £18,331.

Table C.1 shows the contribution to Western Isles GVA of individual sectors of the economy and compares to that of Orkney, Shetland and Scotland as a whole. The relatively large contribution of the public sector in the Western Isles economy is apparent, contributing 33% to GVA, compared to 23% in Scotland overall. The contribution of construction to the Western Isles economy is higher than the Scottish average, but lower than in Orkney or Shetland. Finance and business services is also relatively low in the islands compared to Scotland as a whole.

Table C.1: Contribution to 2015 Gross Value Added by Industry (£m) [58]

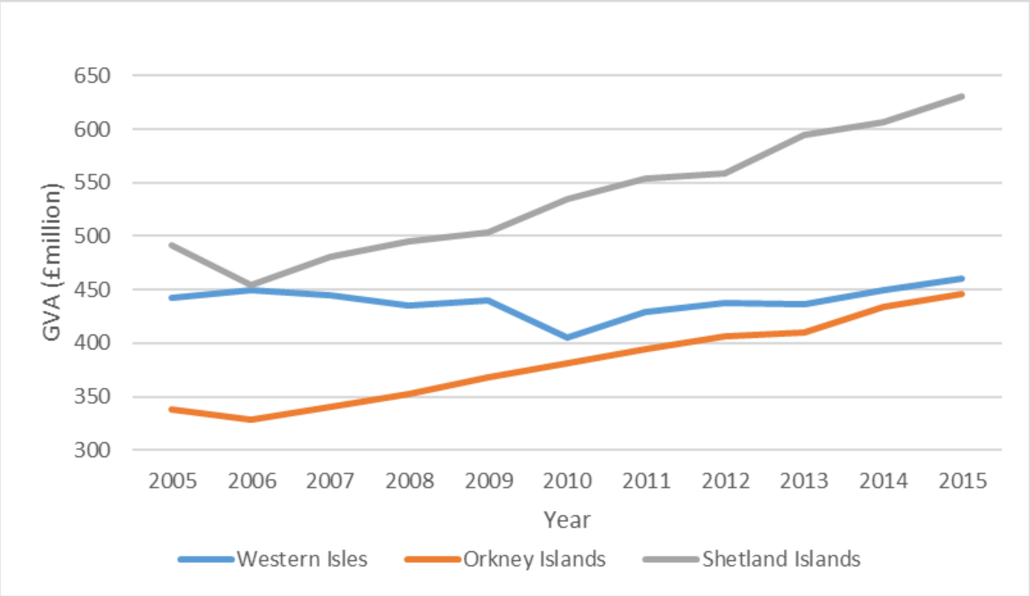
	Western Isles		Orkney		Shetland		Scotland	
Agriculture, forestry and fishing	15	3%	34	8%	34	5%	1,607	1%
Production	7	2%	16	4%	51	8%	6,943	5%
Manufacturing	31	7%	25	6%	57	9%	14,261	11%
Construction	38	8%	50	11%	88	14%	8,194	6%
Distribution; transport; accommodation and food	92	20%	113	25%	142	23%	23,983	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%

[57] In the form of central taxation and spending outside Orkney
[58] GVA reference tables – table 6 – GVA (Income Approach) by SICo7 industry at current basic prices

	Western Isles		Orkney		Shetland		Scotland	
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 the Western Isles has changed relatively little since 2005, while that of Orkney and Shetland has grown – as shown in Figure C.1.

Figure C.1: Islands Total GVA Growth



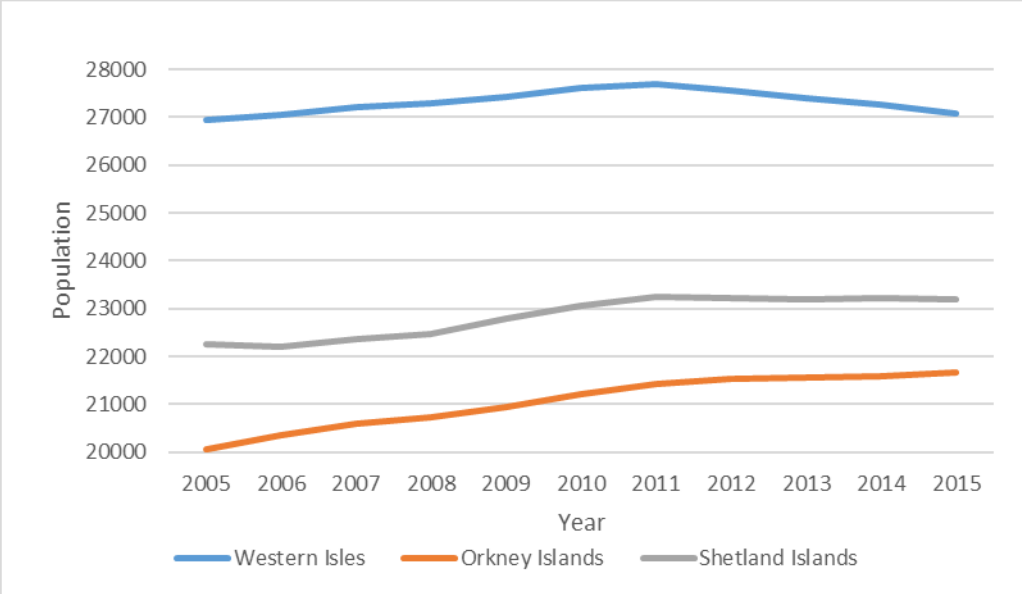
Population

National Records of Scotland published its latest population projections in October 2016. 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 predict a decline in the population of the Western Isles of 13.7% over the period to 2039 – with the largest decline (28%) in the 0-15 age group and a similarly large decline (21%) in the working age population. This is the largest projected percentage decline in Scotland. [59]

The population of the Western Isles is aging as well as declining. In 2016, the population of the Western Isles was 27,070, a fall of 2% since 2010 compared to a 2.7% increase in Scotland (Figure C.2). More than a fifth of the population are aged 65 or over, a higher proportion than across Scotland (18%).

[59] https://www.cne-siar.gov.uk/media/5563/socio-economic-update-33.pdf

Figure C.2: Islands Population



Depopulation is considered a potential problem– indeed Roddie MacKay, leader of Comhairle nan Eilean Siar, claims that depopulation is 'one of the greatest threats to our Island way of life." [60]

Despite an aging population, Western Isles has a relatively high proportion of those considered economically active[61] at 84%, compared to 78% in Scotland. Of those economically active, a high proportion are in employment, 81% compared to 75% in Scotland. Employment in the Western Isles is skewed towards administrative/skilled trade jobs, with 30% of employment in these occupations compared to 21% in Scotland. Conversely those in professional occupations are fewer, accounting for 34% of employment compared to 43% in Scotland. [62]

Future growth

The Scottish government claim that the Western Isles is impacted by issues of geography, such as distance from main markets, costs of business, peripherality, sparseness of population and demographic imbalance. A low carbon/renewable Enterprise Area has been created at Arnish where packages of support are available aimed at encouraging early investment, boost growth and stimulate job creation. According to the Scottish government the scale of development and job creation has been constrained by delays in upgrading grid connections to the Western Isles and, to enable it '*to fully benefit from Enterprise Area status, and to maximise the renewables opportunities presented by their natural resource asset base, the Scottish Government will extend the timeframe for Enterprise Areas at…Arnish by three years to 2020*.'[63]

Comhairle nan Eilean Siar considers energy has the potential to make a significant contribution to the future economic prosperity of the Western Isles. The Outer Hebrides Fuel Poverty Action Plan outlines a number of initiatives and actions the Council intends to adopt to combat fuel poverty, including the creation of the Hebrides Energy Community Interest Company (CIC) to develop local electricity supply, including assessing opportunities to directly invest in renewable schemes[64].

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[60] http://www.orkney.gov.uk/Files/Committees-and-Agendas/Development%20and%20Infrastructure/DI2017/16-02-2017/I18_App1_Draft_Orkney_Sustainable_Energy_Strategy.pdf
[61] People who are either in employment or unemployed
[62] https://www.nomisweb.co.uk/reports/lmp/la/1946157417/report.aspx?town=Stornoway
[63] http://www.gov.scot/Publications/2014/06/2708/7
[64] https://www.cne-siar.gov.uk/media/9959/outer-hebrides-fuel-poverty-action-plan-2017.pdf

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.

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.[65].

C.3 Investment Scenarios

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

C.4 Economic Methodology

Input-Output Model methodology

Input-Output (I-O) modelling was used to evaluate the economic impact of investment of onshore wind in Western Isles 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 the Western Isles.

Expenditure arising from wind development will impact the Western Isles 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 II' and 'Type II' multipliers. While these are available for Scotland, we have used multipliers calculated for Shetland that has a relatively similar GVA industry contribution to Western Isles (Table C.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.

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[65] 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 C.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 C.3: Wind/tidal Project Elements

Element	Subelement
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 the Western Isles 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, these payments are paid by non-community owned wind farms at a rate of £5000/MW/year
- 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 generated generation 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 £5000/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, such as the Local Authority, were to secure funding at a rate of 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.

For the purposes of modelling the impact on the Western Isles economy we have conservatively assumed that income arising from community ownership is limited to a community payment of £5,000/MW/year (i.e. the community would opt out of taking an ownership stake if forecast returns are less than the standard community benefit payment of £5000/MW/yr).

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. 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 only 20% of this 'avoided cost' will be available to the local economy as an avoided cost has potential benefit to the local economy than 'actual' profits received from the sale of electricity.

For offshore wind projects we have conservatively assumed that no community benefit nor community ownership.

We assume the economic rent identified is distributed in the local economy in line with GVA contribution as outlined in Table C.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[66], 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'[67]

C.5 Results

C.5.1 Western Isles Content

We have assessed the local content of wind projects in the Western Isles based on output of a number of reports, including Renewable UK's Economic Impacts of onshore wind[68] [69] [70].

Onshore wind farms

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

- Development and project management

[66] Socio-economic impacts of community wind power projects in Northern Scotland, Renewable Energy 85 (2016)
[67] 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
[68] http://c.ymcdn.com/sites/www.renewableuk.com/resource/resmgr/Publications/Reports/onshore_economic_benefits_re.pdf
[69] Clyde windfarm extension – Impact Analysis, PWC June 2015
[70] Economic benefits from the development of wind farms in the Western Isles, BVG Associates 2017

- Turbines
- Balance of plant (supply and installation)
- Operation, maintenance and decommissioning

Development and project management

Development and project management is assumed to include a local content of some 6%, with much development activity taking place outside the Western Isles.

Turbines

None of the main turbine components will be sourced from the Western Isles – 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 Western Isles sourced. For small scale wind turbines we assume a higher contribution of Western Isles 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 Western Isles 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

The Western Isles 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 C.4: Western Isles Content of Wind Projects

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

Table C.5 - shows that the overall Western Isles 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 C.5: Local Content Comparable Studies

Local content	Renewable UK[71] (2017)	BVG – Western Isles (2017)	Biggar Economics – Scottish Boarders[72] (2013)	BVG Scotland[73] (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, however conversely we do not assume a reduction in capex. We consider these two assumptions are broadly offsetting in effect.

Floating offshore wind

A recent survey of marine energy companies working in the UK by RenewableUK found the industry has already invested over £578 million developing various technologies with over 77% of this spent in the UK economy.[74] Research conducted by Scottish Renewables in 2014 showed that to date, the companies surveyed had invested more than £200 million into the Scottish economy, and that more than 62% of the companies' supply chain is Scottish[75]. Stornoway Port is a key infrastructure site for the sector in the west of Scotland, with the range of port services complementing the offer at Arnish. The Comhairle aims to support the Port Authority on its proposals for the further development of the Port in relation to energy supply chain services. The Comhairle published 'Outer Hebrides Ports & Harbours Study' identified Arnish as a suitable site for fabrication, operation and service bases that might support the nascent Marine Energy industry.[76] For marine generation we have assessed a 'local' Western Isles content for the following areas:

- Development and project management
- Device development and manufacture
- Balance of plant (mooring installation, electrical systems)
- Operation, maintenance and decommissioning

Development and project management

We assume a relatively low development and project management local content of 2%.

Device development and manufacture

While large scale device manufacture is unlikely to be located in the Western Isles, some supply chain activities and some smaller component manufacture could occur locally. We calculated 0.5% local content in device and 10% of transport costs will be Western Isles sourced.

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[71] http://c.ymcdn.com/sites/www.renewableuk.com/resource/resmgr/Publications/Reports/onshore_economic_benefits_re.pdf
[72] Economic Impact of Wind Energy in the Scottish Borders, Biggar Economics, Mar 2013
[73] Economic benefits from onshore wind farms - A report for ScottishPower Renewables, BVG, September 2017
[74] http://www.marineenergywales.co.uk/wp-content/uploads/2016/01/Capitalising-on-Capability-2015.pdf
[75] Scottish Renewables, Marine Milestones 2013-14
[76] Scottish Offshore Renewables development sites – West coast cluster, HIE, Scottish Enterprise and Scottish Development International

Balance of Plant

Balance of plant covers moorings, installation and electrical systems. For the civil works (foundations and moorings), we have assumed a local content of 10%. For electrical works local content is also 10%.

Operation, maintenance and decommissioning

Operating and maintaining offshore projects is likely to involve some local input. Some technology developers envisage that devices will be maintained partially in-situ while others will require disconnection and towing to shore for maintenance. The developments at port facilities, such as Arnish harbour, will encourage supply chain development and clustering. The vessels used for O&M may be locally based. Overall we assume a total local content of 17% for O&M of tidal projects.

Table C.6 summarises local Western Isles content for each key development stage of tidal generation, overall local content in total project spend is some 9%.

Table C.6: Local Content Floating Offshore Wind Generation

	% of TOTEX	Western Isles content
DEVEX	1.4%	2%
CAPEX	70%	6.6%
OPEX	28.6%	16.7%
TOTEX	100%	9%

Transmission reinforcement

The breakdown of transmission investment costs is based on information providing by SHE-T 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%.

C.6 Gross Value Added

Table C.7 shows the resulting total present value GVA impacts for each generation scenario considered. GVA impacts include all wind developments (large and small), marine and the transmission link.

Table C.7: Present Value GVA Impact for Each Scenario (£m)

Scenario	Onshore wind	Offshore wind	Transmission	Total
S1	116.6	0	8.1 - 12.4	125 - 129
S2	146.6	0	8.1 – 12.4	155 - 159
S3	180.3	0	8.1 – 12.4	188 - 193
S4	219.7	10.9	8.1 – 12.4	239 - 243

The overall GVA benefit to the Western is substantial, ranging from £125 m to £243 m depending on scenario and reinforcement option considered. In terms of GVA impact, the benefit of the transmission link is small due to the relatively minor local content assumed (2%). Conversely, the GVA impact of onshore wind is large with a higher local content.

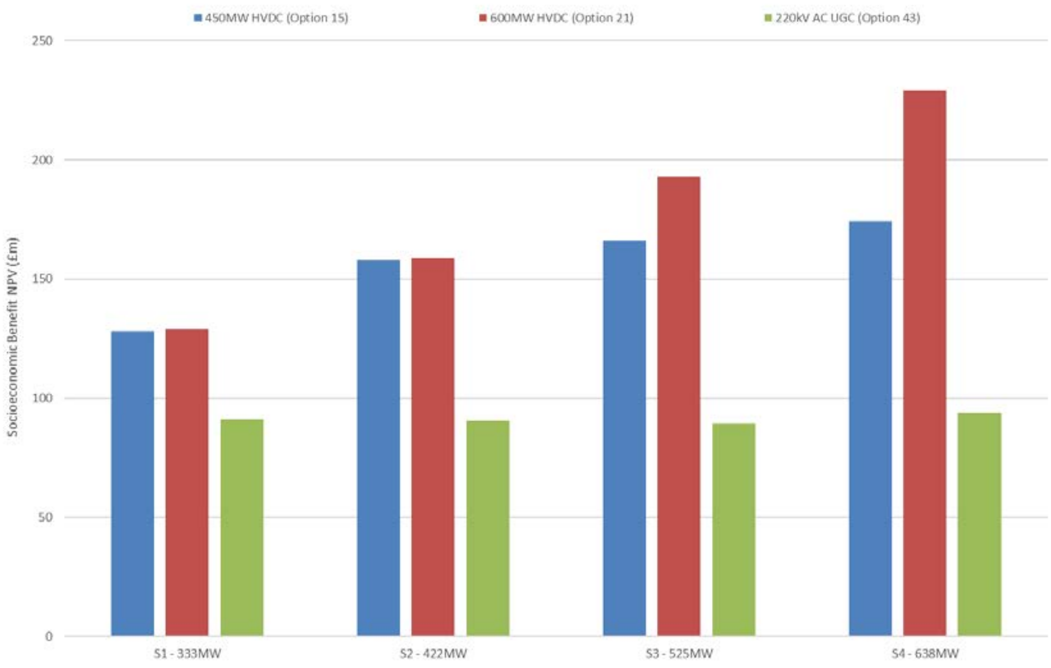
We have also assessed the GVA impact of each transmission option – for simplicity we have capped the MW generation at the size of the reinforcement, i.e. the generation associated with Option 1 is capped at 450 MW. Clearly additional generation may economically connect without incurring significant constraint costs, therefore our analysis is conservative. Table C.8 shows the present value impact – Option 2 leads to the highest GVA impact of £229 m, while that of Option 1 is £55 m lower. Option 3, with generation capped at its 237 MW capacity leads to the lowest GVA benefit.

Table C.8: Present Value GVA Impact for Each Option (£m)

Option	Generation	Transmission	Total
Option 1	162.6	11.5	174
Option 2	216.9	12.4	229
Option 3	85.7	8.1	94

Figure C4 shows the present value of the socio-economic benefit of each reinforcement option arising under each of the generation scenarios considered, with the values in Table C8 corresponding to S4. As for table C8, for comparative purposes, the generation benefit of each option has been capped at the capacity of the link.

Figure C4: PV Socio-economic Benefit (£m, 2018 prices)



The results show that the socio-economic benefit of transmission reinforcement to the Western Isles is significant – with the 600 MW HVDC option leading to the greatest benefit to the local economy. With only 13,000 households, the potential socio-economic impact on the island communities of transmission reinforcement and associated generation is clearly considerable.

C.7 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 C.8 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 C.8: Socio-economic Studies for Onshore Wind in Scotland – with GHD Replication (2017 prices)

Study		Assumptions and comments	£m/MW GVA	GVA
Shetland/Orkney 27.6 MW wind (2014)	Okkonen et al	Annual opex not over entire project life, national coefficients with 30% reduction for Orkney. Multiplier impact only. Revenue reinvestment targeted to maximise GVA impact – corresponding significant result	0.17	4.8
	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, Orkney 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.

C.8 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 Western Isles 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 £240 m the impact on the social and economic fabric of the Western Isles will be significant, with the greatest benefits realised with Option 2 – the 600 MW HVDC link.

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