

Cost Benefit Analysis Model

The Final Cost Benefit Analysis (CBA) Recommendation

The **Final Recommendation** for the 11kV submarine electricity cable between **Coll and Tiree** is Option 2B:

- Cable surface laid on the seabed – Approximately 2.3km
- Split pipe protection on both shore ends – Approximately 1.65km
- Rock Bag Placement for protection & stabilisation– Approximately 0.15km (This is total cable coverage but will be spread along the cable route at intervals in pairs of bags, stabilising significantly more cable length)
- Concrete Mattress – Approximately 0.1km (Cable coverage)
- Decommissioning plan to be developed and submitted for regulatory approval at end of economic life or as determined by regulatory requirements

The **Final CBA Recommendation** scenario has an overall societal value of **minus £21,771,973**. This includes consideration of impacts on health and safety, socio-economic, environmental and wider economic and engineering impacts.

It should be noted that the final **Project Description** may not fully reflect the CBA recommendation which is developed to inform the design process and highlight where societal value is impacted. Any deviations from the CBA recommendation will be justified within the engineering design and reflected in the project description. Also given the granularity of the CBA model it is not possible to model exact lengths of protection which may be included in the project description and therefore results give indicative results of a generic installation approach.

The final recommendation is the preferred installation method, given the information available from the On-Bottom Stability Study (OBSS) and when considering the National Marine Plan. The preferred option has the highest value to society against all other modelled options and includes for shore end protection. The shore end protection has been determined to be essential for the mechanical protection of the cable in prolonging cable life as well as the requirement to install rock filter bags and concrete mattresses due to cable burial not being feasible along this cable route. This solution also takes into consideration views of stakeholders.

Introduction

Scottish Hydro Electric Power Distribution plc (SHEPD) holds a licence under the Electricity Act 1989 for the distribution of electricity in the north of Scotland including the Islands. It has a statutory duty to provide an economic and efficient system for the distribution of electricity and to ensure that its assets are maintained to ensure a safe, secure and reliable supply to customers. As part of this remit, it has identified a need to replace the existing subsea cable between Coll and Tiree based on existing asset condition, to maintain network security. The new cables will run between the existing landfalls on Coll and Tiree.

As such this CBA model has been developed to help select the way in which the new submarine electricity cable should be installed in the marine environment between Coll and Tiree. The model was designed to help identify the best value method of cable installation, burial, protection, inspection and maintenance which satisfies all current legislation. It allows modelling of the perceived material risks and impacts at this point in the project.

Background

SHEPD collaborated with stakeholders to develop the CBA model. The model helps SHEPD understand the impacts that different engineering decisions around cable installation can have on the safety of mariners, energy costs for communities we serve, on local and national economic activity and on the natural environment¹.

The CBA Model allows us to make informed judgements guided by a clear set of values - ensuring that every decision is as ethical, responsible and as balanced as it can be. The CBA model assigns financial values across the following key categories for each cable installation method and design²:

- Health and safety
- Socio-economic
- Environmental
- Wider economic and engineering

These values are then aggregated to estimate the '**societal value**³' of each solution. The best value⁴ solution becomes the option that we recommend in this summary.

Approach taken to arrive at the final recommendation

The starting point for the CBA process is Scotland's National Marine Plan (NMP) (2015) which highlights the following policies, in Chapter 14, which need to be considered on a case-by-case basis for reaching a decision regarding the development and activities involved in installing a submarine electricity cable:

- Cables should be suitably routed to provide sufficient requirements for installation and cable protection.
- New cables should implement methods to minimise impacts on the environment, seabed and other users, where operationally possible and in accordance with relevant industry practice.
- Cables should be buried to maximise protection where there are safety or seabed stability risks and to reduce conflict with other marine users and to protect the assets and infrastructure.
- Where burial is demonstrated not to be feasible, cables may be suitably protected through recognised and approved measures (such as rock or mattress placement or cable armouring) where practicable and cost-effective and as risk assessments direct.
- Consideration of the need to reinstate the seabed, undertake post-lay surveys and monitoring and carry out remedial action where required.

Based on the need to comply with the Scotland's National Marine Plan the following three phases of work with regards to the CBA model have been carried out as part of this marine licence application.

¹ For details of why and how the Cost Benefit Analysis Model was created see <http://news.ssen.co.uk/media/266234/CBA-Model-Statement-Executive-Summary.pdf>

² The Submarine Electricity Cables Cost Benefit Analysis Method Statement can be found here: <https://www.ssen.co.uk/CBAFULL/>

³ Societal value is the cost or benefit to society which includes the private costs / benefits plus any external costs / benefits. Private costs / benefits in the CBA model would be regarded as the Economic and Engineering category and the external costs would be noted as the Health and Safety, Socio-economic and the Environment categories.

⁴ We define best value as the method(s) of installation which satisfy all current legislation and provides a sustainable balance of economic, safety and wider social and economic impacts, but which is not always lowest cost.

Phase one:

Phase one draws on the initial burial assessment⁵ and the ScotMap National Marine Plan Interactive Map to address Factor 1 and identify a suitable route against which the impacts included within the CBA model categories can be compared. The CBA model⁶ is then used to identify the **Burial Scenario** using our three⁷ recognised burial methods and to provide evidence to address Factor 3 (cables should be buried to maximise protection where there are safety or seabed stability risks and to reduce conflict with other marine users). The output of this phase of analysis is described as the **Burial Scenario**.

This looks at the parameters which permit different types of installation. Each scenario is developed based on the installation methods permitted by the seabed type and depth of sediment. At this point only one method is applied within each section of the model.

Phase two:

Hybrid solution(s) are then modelled which include elements of both burial and protection that are feasible. A process of engagement is then conducted to identify if these scenarios are practicable and cost effective.

This phase seeks to address Factor 2 (a method to minimise impacts on the environment, seabed and other users) and Factor 4 (where burial is demonstrated not to be feasible, cables may be suitably protected where practicable and cost-effective and as risk assessments direct).

A process of engagement is then conducted to identify if these scenarios are practicable, cost effective and address the possible risks. The **Final CBA Recommendation** will then be made for the scenario which represents the overall best value solution.

Phase three:

Hybrid solution(s) are refined and then entered into the CBA model to obtain estimated societal value. During the phase three analyses a sensitivity analysis is carried out on key assumption to understand how the value of impacts may vary.

The **Final CBA Recommendation** will then be made for the scenario which represents the overall best value solution.

Based on the process of engagement, including the pre applications consultation events, the phase 1 and 2 solution(s) can be refined and then entered into the CBA model to obtain estimated societal value. During phase three a sensitivity analysis is carried out on key assumptions to understand how the value of impacts may vary. Phase three also provides the evidence base to support consideration of Factor 5 which examines the need to reinstate the seabed, undertake post-lay surveys and monitoring and carry out remedial action on an ongoing basis. The **Final CBA Recommendation** will then be made for the scenario which represents the overall best value solution.

⁵ The initial burial assessment is the output of the process which SSEN has carried out in conjunction with stakeholders to identify a suitable route and obtain the required environmental surveys of the seabed and benthic habitats on which to carry out the cost benefit analysis.

⁶ The CBA tool methodology is available at <http://news.ssen.co.uk/submarinecables/information/>

⁷ The three methods commonly used by the industry to install cables are: Ploughing, Jetting and Mass Flow Excavation. A fourth installation method of horizontal directional drill (HDD) – could possibly be used on submarine electricity cables shorter than 1.5km in length.

Modelling Coll – Tiree Submarine Cable

Fifteen different CBA models, including the baseline, have been developed across the three phases to identify the best value solution.

Initial survey data identified intermittent sections of sediment across the proposed installation corridor. Following detailed engineering, cable burial was deemed unfeasible due to inconsistent sediment depth, which would not provide sufficient coverage of the cable.

From a technical and operational perspective, the following parameters (used in the cost benefit analysis following agreement with stakeholders) identify where burial is achievable by:

- Jetting and Controlled Flow Excavation where there is a minimum sediment depth of 1.5 metres for 50 metres along the seabed
- Ploughing where there is a minimum sediment depth of 2 metres for 500 metres along the seabed

The above statements indicate where it is deemed feasible to undertake burial activities using the stated methods as part of the CBA. The depths indicated do not represent the depths at which a cable must be covered to be deemed “buried” as part of the analysis. The minimum depth of cover which is required to deem the cable “buried” is where the top of the cable is covered by layers of sediment no less than 0.6m deep.

From initial site investigations it has been confirmed that split pipe protection will be required on both shore ends, for all installation scenarios. This will provide additional protection in the inshore area and minimise damage from abrasion. This will also increase cable stability. As such, all install scenario models show split pipe protection on both shore ends. The base case shows no split pipe as the existing cable is surface laid along its entirety. Although split pipe is likely to show a negative effect in terms of societal value it is essential to improve asset life and achieve as a minimum the cable design life of 25 years. These additional protection methods are being utilised to increase this asset lifecycle and secure the network for longer periods of time.

Coll - Tiree: Phase one

The input to phase one of the CBA analysis was standalone installation assessments for the Coll – Tiree cable. This involved 5 scenarios being assessed with differing levels of split piping on both shore ends, with the remainder of the cable to be surface laid along the route. Having conducted initial route design, the minimum level of split pipe installation required to achieve the cable design life is circa 1.65km.

Table 1 Standalone protection method evaluation

Option	Scenario Methods	Total Societal Value	Net change (£)	Net Change (%)
Basecase	Surface Laid (4.2km) 100%	-£5,137,276	£-	
1A	Split Pipe (0.5km) 11.90% Surface Laid (3.7km) 88.10%	-£10,368,816	-£5,231,540	101.83%
1B	Split Pipe (0.8km) 19.05% Surface Laid (3.4km) 80.95%	-£13,241,793	-£8,104,517	157.76%
1C	Split Pipe (1.5km) 35.71% Surface Laid (2.7km) 64.29%	-£18,623,179	-£13,485,902	262.51%
1D	Split Pipe (1.65km) 39.29% Surface Laid (2.6km) 60.715%	-£20,059,667	-£14,922,391	290.47%
1E	Split Pipe (1.75km) 41.67% Surface Laid (2.5km) 58.33%	-£20,902,350	-£15,765,074	306.88%

1F	Split Pipe (1.9km) 45.24% Surface Laid (2.3km) 54.76%	-£22,338,839	-£17,201,562	334.84%
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It can be seen in Table 1 that as more split piping is added to the cable, the net change gets worse. Option 1D represents the minimum length of split pipe to meet the cable design life. Due to the granularity of the modelling the exact length could not be modelled. Option 1D was progressed into Phase 2 of the assessment as it had the lowest societal impact whilst meeting design life requirement of the cable.

Coll - Tiree: Phase two

Phase two of the analysis then sought to identify scenarios beyond the initial assessment scenarios (Phase 1 output) where surface lay with split piping was the only consideration, by adding additional protection which may be practicable, cost-effective and address marine user and cable risk.

Table 2 provides an overview of the 5 scenarios that were considered in this phase of the analysis.

Table 2 Practicable and cost-effective protection scenarios

Option	Scenario Methods	Total Societal Value	Net change (£)	Net Change (%)
Basecase	Surface Laid (4.2km) 100%	-£5,137,276	£-	
2A	Split Pipe (1.65km) 39.29% Rock Bag(0.1km) 2.38% Concrete mattresses(0.1km) 2.38% Surface Laid (2.35km) 55.95%	-£21,490,908	-£16,353,632	318.33%
2B	Split Pipe (1.65km) 39.29% Rock Bag(0.15km) 3.57% Concrete mattresses(0.1km) 2.38% Surface Laid (2.3km) 54.76%	-£21,771,973	-£16,634,696	323.80%
2C	Split Pipe (1.65km) 39.29% Rock Bag(0.15km) 3.57% Concrete mattresses(0.2km) 4.76% Surface Laid (2.2km) 52.38%	-£22,468,620	-£17,331,343	337.36%
2D	Split Pipe (1.65km) 39.29% Rock Bag(0.25km) 5.95% Concrete mattresses(0.25km) 5.95% Surface Laid (2.05km) 48.81%	-£23,120,376	-£17,983,100	350.05%
2E	Split Pipe (1.65km) 39.29% Rock Bag(0.35km) 8.33% Concrete mattresses(0.25km) 5.95% Surface Laid (1.95km) 46.43%	-£23,854,970	-£18,717,694	364.35%

^The net change is compared to the baseline assumption of the existing cable.

Within the three scenarios considered in Table 2, all scenarios provided a reduction in the societal value of the baseline installation. Throughout the refinement stage of this project the analysis has assessed that the cable will be unstable if solely surface laid. As such, the scenarios presented in section two sufficiently cover potential additional protection/stabilisation which may be required to maintain the cable in a stable position and protect the longevity of the asset and achieve the cable design life as a minimum.

Option 2B provides the best societal value whilst providing the minimum required protection to allow the cable to achieve a design life of 25 years. All other scenarios where there is less protection than this, will likely result in early cable failure and therefore reduced cable life.

The outputs in Table 2 show that if additional protection is included over and above the minimum requirements then the societal value will reduce.

Risks have been based upon historic projects in this area and SHEPD's previous experience in carrying out submarine cable installations.

The **Scenario** which is deemed the most suitable for installation following phases 1 and 2 was:

Option	Scenario methods
2B	Split Pipe (1.65km) 39.29% Rock Bag(0.15km) 3.57% Concrete mattresses(0.1km) 2.38% Surface Laid (2.3km) 54.76%

It should be noted that there may be engineering justification to stabilise the cable further which could require additional rock bag or concrete mattresses to prevent the cable from excessive movement, however it is not anticipated to be required at this stage of the project design. Any further requirements will be detailed in the project description.

Coll - Tiree: Phase three

The best solution(s) are refined and challenged to identify the best value solution using the societal value as an indicator of value before a **Final CBA Recommendation** was made.

Sensitivity analysis was conducted to help identify the key variables which have a major influence on the cost and benefits of a submarine electricity cable project. These are:

- Age: Life expectancy of the cable
- Full life cycle costs
- Social costs
- Decommissioning costs
- Health and safety risk

The sensitivity scenarios took the best option following Phase 1 & 2 and then applied variances in the predicted lifecycle of the new cable.

Table 3 shows the impact of an increase in the life expectancy of Option 2B. Currently with the levels of protection applied in Option 2B the overall cable is expected to last a minimum of 25 years. Options 3A and 3B investigate the effects a longer lifecycle may have on the overall option value. Options 3C and 3D investigates the situations where the cable does not meet the expected life span.

Table 3 Sensitivity testing

Option	Scenario methods	Total Societal Value	Net change^ (£)	Net Change^
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				(%)
Basecase	Surface Laid (4.2km) 100%	-£5,137,276	£-	
3A	Split Pipe (1.65km) 39.29% Rock Bag(0.15km) 3.57% Concrete mattresses(0.1km) 2.38% Surface Laid (2.3km) 54.76% [Life expectancy of whole cable - 35 years]	-£15,077,061	-£9,939,784	193.48%
3B	Split Pipe (1.65km) 39.29% Rock Bag(0.15km) 3.57% Concrete mattresses(0.1km) 2.38% Surface Laid (2.3km) 54.76% [Life expectancy of whole cable - 45 years]	-£14,198,161	-£9,060,885	176.38%
3C	Split Pipe (1.65km) 39.29% Rock Bag(0.15km) 3.57% Concrete mattresses(0.1km) 2.38% Surface Laid (2.3km) 54.76% [Life expectancy of whole cable - 25 years]	-£16,343,270	-£11,205,994	218%

^The net change is compared to the baseline assumption.

It is reasonable to assume that the life expectancy of the new cable would be extended beyond the standard 25-year design life as the cable route has been properly engineered with adequate protection placed on the cable in areas where damage would usually be anticipated, such as cable shore ends. Therefore, by protecting the vulnerable areas of the cable, they could be anticipated to last longer.

Given cable route engineering is conducted to minimise movement and abrasion, and the fact that SHEPD have cables which have worked electrically for much longer than 25 years, option 3A considers the cable to have a 35-year life whilst Option 3B considers a 45-year life. Option 3C also assumes a 25-year life if the cable may not meet its estimated design life. As anticipated, this shows that the overall societal value of the options improves as cable life is extended. The lifespans modelled as part of the sensitivity testing are theoretical and serve as an estimate only.

Interpretation of results

Phase one of the CBA model shows surface laying the new Coll – Tiree submarine electricity cable, with both shore ends protected by split piping. This scenario is taken as the minimum required level of protection and confirms no burial is achievable on this installation.

Phase two shows combinations of protection scenarios in compliance with the National Marine Plan hierarchy of installation and the need to consider the views of other stakeholders and marine users. After these considerations, the CBA shows Option 2B to have the lowest cost to society, when considering minimum levels of protection.

When applying sensitivity testing to Option 2B in phase three, the impact of an increase in expected lifecycle shows option 2B could have a lower cost to society than anticipated should cable protection extend the whole cable life to 35 or 45 years.

To date SHEPD do not currently have any cables which have been protected for a period of 45 years to confirm if this assumed life expectancy is reasonable. However, with the majority of existing subsea cable installs across SHEPD mainly being surface laid and having lasted on average 25 years, it is reasonable to assume that a new

cable with more mechanical protection could have an extended life expectancy. These assumptions have been considered when concluding the recommendation from the CBA.

Recommendation

The CBA model considers the societal value of different installation methods for the Coll - Tiree submarine electricity cable. We understand that other externalities not modelled need to be considered. These include marine planning policy, final engineering design requirements including shore end protection and the cumulative impact of our submarine electricity cables on other legitimate marine users.

Therefore, SHEPD propose that Option 2B, 1.65 km of split piping (both shore ends protected), 0.15km of rock bagging, 0.1km of concrete mattresses and 2.3km of surface lay is put forward for final design consideration.

As stated previously, there may be the requirement for additional protection for stability of the cable, but any requirement will be detailed in the project description.