Cost Benefit Analysis Model

The Final Cost Benefit Analysis (CBA) Recommendation

The **Final Recommendation** for the 33kV submarine electricity cable **Carradale – Arran North** is Option 2N:

- Cable surface laid on the seabed – Approximately 2.0km
- Post lay burial via Jetting – Approximately 3.4km
- HDD Shore Carradale Shore End – Approximately 0.55km
- Split pipe protection on Arran shore end – Approximately 0.3km
- Rock bagging at strategic points along the cable – Approximately 0.3km
- No decommissioning carried out on the existing cable
- New cable is decommissioned at end of economic life

The **Final CBA Recommendation** scenario has an overall societal value of **minus £11,078,152.** This includes consideration of impacts on health and safety, socio-economic, environmental, and wider economic and engineering impacts.

It should be noted that the **Project Description** and final engineering design may not fully reflect the CBA recommendation which is developed to inform the design process and highlight where societal value is impacted. The granularity of the CBA model does not permit modelling of exact lengths of protection which may have been identified in the project description and therefore the results output provides indicative results of similar install scenarios.

The final recommendation is the preferred installation method, given the information available from the Cable Burial Risk Assessment (CBRA), On Bottom Stability Study (OBSS) and when considering the National Marine Plan. The preferred option has a lower value to society that some of the other options, but based on the information available at the point of modelling allows for protection of the cable, maximised levels of burial and includes shore end protection which has been determined to be essential for the mechanical protection of the cable in prolonging cable life, although it does have an impact on the societal value of the solution. This solution also takes into consideration views of stakeholders.

SHEPD also recognise that there is the potential that rock placement could be required as part of this install and this is captured within the Project Description and supporting Marine Environmental Appraisal, however there is significant uncertainty regarding any requirement and related costs for this at this time and as such a scenario for this has not been included. If rock placement is required, then the CBA may need to be updated to reflect this.

Introduction

The Carradale – Arran North submarine cable has been identified as being in a Critical condition during SHEPD submarine cable inspections. Various options have been considered to rectify the critical conditioned cable including attempting a future piece in repair should the cable fault or replacement prior to such an event, with the latter being deemed the only viable option for this specific cable.

As such this CBA model has been developed to help in selecting how the replacement submarine electricity cable will be installed in the marine environment. 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 environment[1].
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 design[2]:

- 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 value[4] 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:
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, cost effective.

Phase three:
Hybrid solution(s) are refined and then entered 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.

Modelling Carradale- Arran North

18 different CBA models, including the baseline, have been developed across the three phases to identify the best value solution. Recent survey data indicates that there is potential to bury some of the cable along the proposed route.

For Jetting or Mass Flow Excavation to be feasible the minimum sediment depth required is 1.5m and 2m for ploughing. The outputs from the CBRA will determine the final recommended depth of burial where risks to the cable or marine users are identified.

Carradale – Arran North: Phase one

The input to phase one of the CBA analysis was standalone installation assessments for the Carradale – Arran North cable. This involved only 1 scenario which was 100% of the route to be surface laid.

Based on the initial outputs of the route surveys the seabed has been judged to be made up of sections alternating between mud and sand, rock outcrops and boulder fields. The route is more fully described in the Project Description.

Additionally, due to the shore end conditions and constraints on the Carradale side of this cable, it has been confirmed that the only suitable landing will be through a Horizontal Directional Drill (HDD) and therefore this has been included in all scenarios within the CBA.

Table 1 Standalone protection method evaluation

Option	Scenario Methods	Total Societal Value	Net change (£)	Net Change (%)

Base	Baseline Surface lay 100% (the installation method used for the cable we are replacing)	-£ 5,962,375	£ -	-
1A	Surface lay 91.54%, HDD 8.46%	-£ 6,025,211	-£ 62,836	1.05%

The scenario presented in Table 1 has almost the same societal value verses the existing baseline installation. There is a minimal increase in the cost to society with a net change of 1.05%.

Carradale – Arran North: Phase two

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

Table 2 provides an overview of the 14 scenarios that were considered in this phase of the analysis.

Table 2 Practicable and cost-effective burial and protection scenarios

Option	Scenario Methods	Total Societal Value	Net change (£)	Net Change (%)
Base	Baseline Surface lay 100% (The installation method used for the cable we are replacing)	-£5,962,375	£ -	-
2A	No Burial 0%, Rock Bagging 15.38%, Carra shore end HDD 8.46% & Surface lay 76.16%	-£10,471,019	-£4,508,645	76%
2B	No Burial 0%, Mattressing 15.38% Carra shore end HDD 8.46% & Surface lay 76.16%	-£10,182,485	-£4,220,111	71%
2C	Split Pipe 8.46%, Rock Bagging 15.38%, Carra shore end HDD 8.46% & Surface lay 67.7%	-£14,164,935	-£8,202,560	138%
2D	Split Pipe 8.46%, Mattressing 15.38%, Carra shore end HDD 8.46% & Surface lay 67.7%	-£13,876,401	-£7,914,026	133%
2E	No Burial 0%. Rock Bagging 46.15%, Carra shore end HDD 8.46% & Surface lay 45.39%	-£19,362,638	-£13,400,263	225%
2F	Split Pipe 8.46%, Rock Bagging 46.15%, Carra shore end HDD 8.46% & Surface lay 36.93%	-£23,056,554	-£17,094,179	287%
2G	Jetting 52.31%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 8.46% & Surface lay 30.77%	-£11,396,910	-£5,434,535	91%
2H	Jetting 52.31%, Rock Bagging 15.38%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 8.46% & Surface lay 15.39%	-£15,842,719	-£9,880,344	166%
2I	Jetting 52.31%, Carra shore end HDD 8.46% & Surface lay 39.23%	-£7,702,995	-£1,740,620	29%
2J	Jetting 52.31%, Rock Bagging 8.46%, Carra shore end HDD 8.46% & Surface lay 30.77%	-£10,224,150	-£4,261,775	71%
2K	Jetting 67.69%, Carra shore end HDD 8.46% & Surface lay 23.85%	-£8,203,844	-£2,241,469	38%
2L	Jetting 36.92% Carra shore end HDD 8.46% & Surface lay 54.62%	-£7,202,146	-£1,239,771	21%
2M	Jetting 36.92%, Rock Bagging 3.85%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 4.62% &	-£10,585,158	-£4,622,783	78%

	Surface lay 46.15%			
2N	Jetting 52.31%, Rock Bagging 3.85%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 4.62% & Surface lay 30.76%	-£11,078,152	-£5,115,777	86%

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

Within the fourteen scenarios considered in Table 2, no scenarios provided a reduction in the societal value of the baseline installation. Option 2L is the closest to the baseline from the initial assumptions. Following on from detailed design investigation it has been confirmed that split pipe protection will be required on the Arran shore end to protect the cable from damage due to abrasion. Additionally, this split piping will stabilise the cable.

Due to confirmation that split piping will be required, and the knowledge that an HDD shore end pull in will be required on the Carradale shore end, this has reduced the number of valid models from fourteen to seven.

The options which are no longer considered valid have been highlighted in yellow.

Options 2M and 2N provide the lowest cost to society against the baseline. At this phase of the analysis the baseline would show as the best value to society, however this option offers no cable protection and is not deemed to be a viable installation method in this case given the protection requirements of both shore ends.

The process of identifying risks has been informed by historic projects and SHEPD's previous experience in carrying out submarine cable installations. Stakeholder consultation has also informed this process this feedback has been summarised within the *Pre-Application Consultation Report*.

The **Scenario** which is deemed the most suitable for installation was:

Option	Scenario methods
2N	Jetting 52.31%, Rock Bagging 3.85%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 4.62% & Surface lay 30.76%

It should be noted that engineering justification to stabilise the cable may require additional rock bag installation or concrete mattresses to prevent the cable from excessive movement.

Carradale – Arran North: 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** is 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 from Phase 1 & 2 and then applied variances in the predicted lifecycle of the new cable.

Table 3 shows the impact of an increase or decrease in the life expectancy of Option 2N. Currently any protected section of cable is predicted to last 45 years which may not be the case after installation.
Overall, there is an increase in the societal value, as expected, if the cable life is extended. Consequently, there is a decrease in the societal value if the cable life is reduced.

It is reasonable to assume that the life expectancy of the new cable would be extended beyond the currently installed cable as the existing is only a SWA cable and has lasted 28 years. The new cable will be a DWA cable, which will therefore have more mechanical protection, hence the assumption that this could be expected to last longer than the current installation. Also, when considering that the existing cable was installed with no protection or stabilisation then it is reasonable to assume that the replacement cable will have a longer life expectancy.

Table 3 Sensitivity testing

Option	Scenario methods	Total Societal Value	Net change^ (£)	Net Change^ (%)
Baseline	Surface lay 100% (The installation method used for the cable we are replacing)	-£5,962,375	-	-
3A	Jetting 52.31%, Rock Bagging 3.85%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 4.62% & Surface lay 30.76% **[Life expectancy of whole cable - 45 years]**	-£9,520,810	-£3,558,435	60%
3B	Jetting 52.31%, Rock Bagging 3.85%, Carra shore end HDD 8.46%, Split Pipe Arran shore end 4.62% & Surface lay 30.76% **[Life expectancy of whole cable - 35 years]**	-£10,161,081	-£4,198,706	70%

^The net change is compared to the baseline assumption.

Interpretation of results

Phase one of the CBA model shows surface laying the new Carradale – Arran North submarine electricity cable, plus a section of HDD results in almost a net zero change in societal value when compared to the baseline of the original cable.

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 2M to have the lowest cost to society, however option 2N is deemed to be the preferred installation method based on the design process undertaken up to this point.

When applying sensitivity testing to Options 2N in phase three, the impact of an increase or decrease in expected lifecycle shows option 2N could have a lower cost to society than anticipated. Even if cable life expectancy is only 35 years instead of 45 years.

These assumptions are not un-warranted as SHEPD do not currently have any cables which have been protected for a period of 45 years to date to confirm if this assumed life expectancy is reasonable. However,

with the existing cable being surface laid and having lasted 28 years it is reasonable to assume that a new cable with more mechanical protection laid in a similar area could have an extended life expectancy, especially when considering one shore end would be protected through a HDD and the other will be protected through split piping. Typically, the shore ends of a cable are where most damage is normally seen due to abrasion. 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 Carradale – Arran North 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 2N, Jetting 3.4km, Rock Bagging 0.3km, Carradale shore end HDD 0.5km, Split Pipe Arran shore end 0.35km & Surface lay 2km is put forward for final design consideration. This is on the basis that SHEPD believe the new DWA cable will have an extended life period when compared with the existing SWA cable installation.

As stated previously in the CBA summary, there may be the requirement for additional protection or burial for stability of the replacement cable and this will be determined upon conclusion of the detailed design and engineering processes.

SHEPD also recognise that there is the potential that rock placement could be required as part of this install but there is significant uncertainty regarding the costs for this at this time and as such a scenario for this has not been included. If rock placement is required, then the CBA may need to be updated to reflect this.