Cost Benefit Analysis Model

**The Final Cost Benefit Analysis (CBA) Recommendation**

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| The **Final CBA Recommendation** for the 33kV submarine electricity cable **Sanday - Eday** is to proceed with baseline option:* Split pipe protection at both shore ends – Approximately 200m
* Cable surface laid on the seabed – Approximately 4,120m
* New cable removed at the end of its economic life.

This is deemed to be the best value solution based on the current available information and because it addresses the following risks & impacts as well as needs of stakeholders:* Split pipe at the shore end limits the risk to the cable from abrasion as well as providing some cable stability. Additionally, this provided protection to public safety should the shore end be exposed.
* This scenario has the lowest overall cost to society when considering all viable options.

The **Final CBA Recommendation** scenario has an overall societal value of **minus** **-£10,059,116** This includes consideration of impacts on health and safety, socio-economic, environmental and wider economic and engineering impacts. The final recommendation of this summary report may not fully align with the final **Project Description.** This is becausefollowing a Cable Burial Risk Assessment (CBRA)and On-bottom Stability Study (OBSS), further protection/stabilisation of the cable may be required. It will be confirmed whether the proposed installation method deviates from the CBA recommendation and justification given as to why this deviation is required.Areas where stabilisation is required will be defined in the OBS On-Bottom Stability (OBS) study. The OBS study will defined how much the cable is predicated to move under storm conditions using DNV approved software, if the cable is predicted to move by more than 10 x its Outer Diameter then it is considered to be unstable. Where the cable is shown to be unstable, Rock placement[[1]](#footnote-1), burial or similar methods may be proposed in addition to the CBA recommendation in order to further stabilise the cable. The outcome of the CBRA will determine the depth of burial which is required to protect the cable from perceived risks from marine users. At present, all burial in the CBA model is assumed to be at a depth of at least 0.6m. Cast Iron Split Pipe is proposed to be installed at both shore-ends which provides stability as well as protection against abrasion. Split piping has been determined to be necessary to protect the life of the cable. |

**Background**

On the 1st November 2020, the existing Sanday - Eday 33kV submarine cable crossing between the islands of Sanday and Eday, in the Orkney Isles, faulted in service. Initially 853 customers were affected and went off supply. 125 customers on the Island of Eday were subsequently supplied by mobile diesel generation until a temporary network solution was put in place on 5th March 2021. The remaining 728 affected customers had supplies restored through their normal feeding arrangements following network re configuration. Following fault testing by the Highlands and Islands Region, a wet fault with the submarine cable was confirmed to be on a single phase (yellow) at approximately 2km offshore from the onshore network at the Sanday (East) side. This is the first fault recorded on this cable since installation in 1980.

Subsequently, Scottish Hydro Electric Power Distribution plc (SHEPD), are now undertaking the planning of an end to end replacement project following initial optioneering. This project is being carried out under a fault scenario and therefore processes are being expeditated to return the cable/circuit to service as soon as possible. This project requires additional emphasis as the second submarine cable, Eday - Westray, which feeds the Island of Eday was already in fault condition at the time of this failure. This has left the island disconnected from all grid supplies. Customers are currently being fed via mobile diesel generation.

This CBA model was designed to help with the identification of the best value method of cable installation, burial, protection, inspection and maintenance which satisfies all current legislation. It allows modelling of the material risks and impacts identified by stakeholders for the Sanday - Eday submarine electricity cable. This model must be used in conjunction with the Cable Burial Risk Assessment (CBRA) and On Bottom Stability Study (OBSS). The CBRA will indicate where there is risk of damage to the proposed cable and recommend a suitable burial depth to mitigate this risk, additionally the OBSS will show were the cable requires additional stabilisation, if the cable is determined to be “unstable”. A combination of the three assessments will be used to form the final project description. At present, due to fault scenario, a CBRA and OBSS have yet to be carried out and therefore the models run in this CBA are based on theoretical install scenarios, SHEPD knowledge of current cable install and likely achievable levels of burial from historic survey information.

The CBA model assigns financial values across the following key categories for each cable installation method and design:[[2]](#footnote-2)

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

These values are then aggregated to estimate the **‘societal value[[3]](#footnote-3)’** of each solution.

The output of the CBA model helps to demonstrate (to ourselves, our customers, our regulators and all users of the sea environment) that the method(s) proposed to deploy for installing this submarine electricity cable justifies the expenditure and provides best value[[4]](#footnote-4). The CBA model supports our marine licence application by illustrating how we consider the cumulative impact of our engineering design.

Initially 18 different CBA models were developed, including the baseline assumption, to identify the best value solution i.e. the solution with the highest **societal value** which balances the risks, impacts and the needs of stakeholders.

Following completion of the installation design by the appointed contractor, the proposed protection/installation method will be updated and included within the CBA documents to allow direct comparison to other options. This version of the CBA recommendation report now supersedes all previous versions.

**The process 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 taken into account 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.

**Phase one:**

Phase one draws on the initial burial assessment[[5]](#footnote-5) 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 model[[6]](#footnote-6) is then used to identify the **Burial Scenario** using our three[[7]](#footnote-7) 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**.

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 Mass 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

From initial engagement with contractors, the method of burial installation proposed for this cable if it is required, is by post lay jetting. Therefore, in this CBA model, post lay jetting is the only method which has been considered when considering burial.

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. The CBRA and OBSS will provide recommended minimum depths of burial/cover at given locations along the route based upon the perceived risks to the cable and marine users. For the purposes of the CBA, cable burial of 0.6m or greater will be deemed “Buried” any depth shallower than 0.6m will be deemed as surface laid.

**Phase two:**

The **Burial Scenario** is then input into phase two of the CBA model which uses the key assumptions around our three recognised protection methods to develop a **Hybrid solution(s)** which include elements of both burial and protection that are feasible. This phase seeks to address Factor 2 (a method to minimise impacts on the environment, sea bed 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 representsthe overall best value solution.

**Phase three:**

Based on the process of engagement, including the pre applications consultation events, the **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. 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 representsthe overall best value solution.

**Sanday - Eday: Phase one**

The input to phase one of the CBA analysis was standalone installation assessments for the Sanday - Eday cable. It has been identified through previous surveys that portions of burial could be achievable based on the current self-burial depth of the existing cable. From historic information it has been identified that burial up to around 30% of the route length (1.3km) could possibly be achieved.

From initial site investigations and historic inspections of the cable shore ends 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. Additionally, this will increase cable stability. Therefore, all install scenario models show split pipe protection on both shore ends, with the exception of option 1A (100% surface lay), just to show all possibilities.

Due to the confirmation that split piping will be required, this has been taken as the base case scenario in which to compare all other options. The base case shows both shore-ends with split pipe protection with the remainder of the cable being surface laid.

Table 1 provides an overview of the 7 scenarios that were considered in this phase of the analysis.

**Table 1** Initial Burial Scenarios

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| --- | --- | --- | --- | --- |
| **Option** | **Scenario methods** | **Total Societal****Value** | **Net change^****(£)** | **Net Change^****(%)** |
| Baseline | Split pipe 4.63% (0.2km) / Surface lay 95.37% (4.12km) | -£10,059,116 | - | - |
| 1A | Surface lay 100%% (4.32km) | -£7,653,278 | £2,405,838 | -23.92% |
| 1B | Jetting 30.06% (1.3km) / Split pipe 4.63% (0.2km) / Surface lay 65.31% (2.82km) | -£10,124,787 | -£65,671 | 0.65% |
| 1C | Jetting 24.84% (1.07km) / Split pipe 4.63% (0.2km) / Surface lay 70.52% (3.05km) | -£10,202,603 | -£143,487 | 1.43% |
| 1D | Jetting 20.21% (0.87km) / Split pipe 4.63% (0.2km) / Surface lay 75.16% (3.25km) | -£10,157,767 | -£98,650 | 0.98% |
| 1E | Jetting 15.03% (0.65km) / Split pipe 4.63% (0.2km) / Surface lay 80.34% (3.47km) | -£10,153,524  | -£94,408 | 0.94% |
| 1F | Jetting 10.41% (0.45km) / Split pipe 4.63% (0.2km) / Surface lay 84.96% (3.67km) | -£10,108,688 | -£49,571 | 0.49% |
| 1G | Jetting 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 90.74% (3.92km) | -£10,103,952 | -£44,836 | 0.45% |

^The net change is compared to the baseline assumption of end to end surface lay.

From this phase of analysis, only 1 option showed a positive increase in societal value when comparing against the baseline option. This was option 1A (100% surface lay). As explained previously, split pipe protection will be a requirement on both shore ends to avoid physical damage to these sections of cable, so this rules out option 1A as being feasible. The remaining 6 scenarios all show a higher cost to society than the baseline scenario however, the variance in cost to society is relatively low when considering best case and worst-case burial scenarios. The CBA shows circa 5% jetting (Option 1G) to be the optimal burial scenario with the worst/highest cost to society being circa 25% burial (Option 1C). Burial scenarios were considered from 5% up to 30% of route length in roughly 5% (200m) increments. The cost variance between best and worst option is £98,651. Phase 1 of the analysis would show that the baseline scenario (200m split piping and 4120m of surface lay) is the best option/lowest cost to society.

The initial burial assessments show that should burial be required/recommended along the route, following CBRA or OBSS, the CBA model indicates there is a relatively small increase in overall cost to society when increasing burial up to the maximum achievable 30%(1.3km) of route coverage, but that lower percentages of burial have a lower overall cost to society, with option 1G (200m of Jetting) being the optimal burial solution if deemed required.

Following the completion of the CBRA and OBSS a final engineering design recommendation will be made detailing the proposed burial scenario. This final scenario can then be included in the CBA model and compared against other scenarios to allow direct comparison.

The recommendation from this phase of analysis is that; should the CBRA and OBSS require no burial to avoid risk or for stabilisation then the cable should be surface laid in its entirety with the exception of both shore ends which should have split pipe protection. Should protection by burial be required the best value to society is option 1G Jetting 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 90.74% (3.92km).

**Sanday - Eday: Phase two**

Phase two of the analysis then sought to identify scenarios beyond the initial assessment scenarios (Phase 1 output) where burial 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 5 scenarios that were considered in this phase of the analysis.

**Table 2** Practicable and cost-effective burial and protection scenarios

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| --- | --- | --- | --- | --- |
| **Option** | **Scenario methods** | **Total Societal****Value** | **Net change^****(£)** | **Net Change^****(%)** |
| Baseline | Split pipe 4.63% (0.2km) / Surface lay 95.37% (4.12km) | -£10,059,116 | - | - |
| 2A | Jetting 4.63% (0.2km) / Rock Bagging 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 86.11% (3.72km) | -£11,140,821 | -£1,081,705 | 10.75% |
| 2B | Jetting 10.41% (0.45km) / Rock Bagging 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 80.33% (3.47km) | -£11,145,557 | -£1,086,440 | 10.80% |
| 2C | Jetting 30.06% (1.3km) / Rock Bagging 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 60.68% (2.62km) | -£11,161,656 | -£1,102,540 | 10.96% |
| 2D | Jetting 4.63% (0.2km) / Rock Bagging 9.81% (0.42km) / Split pipe 4.63% (0.2km) / Surface lay 80.93% (3.5km) | -£12,178,457 | -£2,119,341 | 21.07% |
| 2E | Jetting 4.63% (0.2km) / Mattressing 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 86.11% (3.72km) | -£12,660,497 | -£2,601,380 | 25.86% |

 ^The net change is compared to the baseline assumption of end to end surface lay.

Within the five scenarios considered in Table 2, zero scenarios provided a reduction in the societal value of the baseline surface lay, additionally, none of the hybrid solutions had a lower cost to society that the scenarios explored in phase 1. From the five scenarios considered in phase two, four utilised the protection method of rock placement along with burial, with one using mattressing. The single scenario for mattressing showed that this would have a greater cost to society than rock bagging and therefore no further scenarios where considered using concreate mats.

For clarification, the assumption has been taken that 1 rock bag will cover 2.4m of submarine cable, in each scenario where rock bags have been used. The length of cable indicated in each model to be covered with this protection method, is assumed to be covered by these bags. When it comes to installation, these bags are likely to be spread out along the cable allowing much greater lengths of cable to be stabilised. This will be determined within the OBSS.

For concreate mattressing, it is assumed 1 mat would cover approximately 6m of cable.

Should any level of rock bagging or mattressing be required following detailed route engineering, it is likely to have a negative impact on the overall value to society. Any requirement for these methods to be utilised should be clearly justified.

Options 2A, B & C are relatively comparable in terms of overall cost to society. All options assume 4.63% rock bagging, equivalent to 200m of cable coverage. When combining this with various burial levels through post lay jetting, there are minimal variances in the overall cost/benefit to society. The variance between 5% jetting and 30% jetting when combining with 5% rock bagging is only £20,835. These scenarios do vary significantly from the preferred baseline options and option 1G. Over all variance are £1,081,705 and £1,036,869 respectively. Therefore, baseline option and option 1G would be recommended over any phase 2 option.

**Sanday - Eday: Phase three**

In this phase of analysis, the best value solutions from phases 1 and 2 were 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 considered changes in predicted lifecycle of the new cable and the effects of decommissioning the existing cable, when looking at the best value solution identified in phases 1 & 2.

Table 3 shows the impact of an increase in the life expectancy of the whole cable to 45 years, when compared against the base case. In the baseline and phase 1 & 2 analysis, unprotected (surface laid) sections of cable have life expectancy set at 38 years, this is in-line with the lifecycle of the existing install. Options 3D also considers the effect of decommissioning the existing installed submarine cable.

The phase of analysis takes options 1G and 1B the lowest and highest scenarios of burial and sees how increasing complete cable life expectancy to 45 years, these are respectively represented as Option 3A and 3B. Option 3C has taken original option 2C and again extends the life of the unprotected sections of cable to 45 years. Option 3D looks at original option 1G and measured the effects on cost to society of decommissioning the existing cable. Option 3E considered the baseline with an extension in predicted cable life. All options in table 3 are compared against the baseline scenario.

Overall there is an increase in the societal value, as expected, if the cable life is extended. Extending the life of the cable was tested as the current Sanday - Eday cable has been installed for a period of longer than 25 years, the average life expectancy of SHEPD’s cables, in its current location. The current install has been in place for 38 years. It is reasonable to assume that the new installation could last at least as long, if not longer, given that the existing cable is a SWA construction and the proposed cable will be DWA, this offers additional mechanical protections throughout the full cable route. Additionally, with the installation of split pipe protection and the potential for some cable self-burial, this will further protect and stabilise this cable.

**Table 3 Sensitivity test**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Option** | **Scenario methods** | **Total Societal****Value** | **Net change^****(£)** | **Net Change^****(%)** |
| Baseline | Split pipe 4.63% (0.2km) / Surface lay 95.37% (4.12km) | -£10,059,116 | - | - |
| 3A | Jetting 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 90.74% (3.92km) **[Life expectancy of unprotected section set at 45 years]** | -£9,812,907 | £246,209 | -2.45% |
| 3B | Jetting 30.06% (1.3km) / Split pipe 4.63% (0.2km) / Surface lay 65.31% (2.82km) **[Life expectancy of unprotected section set at 45 years]** | -£9,831,749 | £227,367 | -2.26% |
| 3C | Jetting 30.06% (1.3km) / Rock Bagging 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 60.68% (2.62km) **[Life expectancy of unprotected section set at 45 years]** | -£10,824,173 | -£765,057 | 7.61% |
| 3D | Jetting 4.63% (0.2km) / Split pipe 4.63% (0.2km) / Surface lay 90.74% (3.92km)**[Existing cable decommissioned]** | -£10,779,550 | -£720,433 | 7.16% |
| 3E | Split pipe 4.63% (0.2km) / Surface lay 95.37% (4.12km)**[Life expectancy of unprotected section set at 45 years]** | -£9,770,843 | £288,273 | -2.87% |

^The net change is compared to the baseline assumption of end to end surface lay.

**Interpretation of results**

Phase one of the CBA model shows surface laying the new Sanday – Eday submarine electricity cable results in the highest societal value (i.e. lowest net cost) when compared to the baseline scenario, however, it has already been pre-determined that split pipe protection will be required on both shore ends for mechanical protection of the cable, and thus this option is eliminated. The remaining 6 scenarios all show a higher cost to society than the baseline scenario however, the variance in cost to society is relatively low when considering best case and worst-case burial scenarios. The CBA shows circa 5% jetting (Option 1G) to be the optimal burial scenario with the worst/highest cost to society being circa 25% burial (Option 1C)

Phase 1 of the analysis would show that the baseline scenario (200m split piping and 4120m of surface lay) is the best option/lowest cost to society.

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. The baseline option remains the scenario with highest societal value. In assuming that some level of burial / rock bagging may be required to stabilise the cable, following completion of the CBRA and OBSS, option 2A would be the lowest overall cost to society. Option 2A assumes there is circa 5% burial, and 5% rock bagging. However, there is a very small variance in cost between 5% burial and 30% burial, so both options were taken into the phase 3 analysis.

Phase three shows the impact of other possible outcomes to the potential recommended option (Option 1G) compared to the baseline assumption. Additionally, the preferred options from the phase 2 analysis were also considered in this phase. The sensitivity testing examined if the cable life expectancy was greater what societal benefit this would produce. The effects of decommissioning the existing cable were also considered. The results from this were that as life expectancy increased the overall societal benefit also increased. Also, that decommissioning the existing cable would have an overall negative effect on the total cost to society. Therefore, this is not recommended unless specifically required through engineering design to route the new cable.

In order to compare options 3A-3C properly against the baseline, the baseline option was also modelled in option 3E with an extension in predicted life out to 45 years. This shows that the baseline option would still have the best overall value to society if considering extended life.

**Recommendation**

The CBA model considers the societal value of different installation methods for the Sanday - Eday submarine electricity cable. It is understood that other externalities not modelled need to be considered. These include marine planning policy, final engineering design requirements including any requirements for shore end protection and the cumulative impact of our submarine electricity cables on other legitimate marine users. It is therefore proposed, at this stage, that the baseline option, which is a combination of 0.2km of split pipe protection and 4.12km of surface lay is put forward for further design consideration.

The CBA has modelled this as section 1 and 9 (Split piping) with the remainder surface laid. The specific locations will be derived at detailed design stage (Project Description) to mitigate the risk to other marine users and minimise the environmental impacts at a micro siting basis.

There may be the requirement for additional protection or burial for stability of the replacement cable, which is not presented in the CBA. This will be determined throughout the detailed design phase and based on the CBRA and OBSS. If required, this will be re-modelled in the CBA to give direct comparison against the other models considered. The CBA indicates that additional burial would be more beneficial rather than the use of rock bags or mattresses.

1. The current CBA model methodology has consulted on the use of rock placement as an installation method. However, based on the previous engineering design assessments, it has been identified that the use of “Rock Filter Bags” instead of rock placement would achieves the required design stability requirements but with a reduced environmental and health and safety impact. Therefore, the use of Rock Filter Bags should be noted as a further positive benefit in addition to the current predicted CBA Societal value using rock placement. [↑](#footnote-ref-1)
2. The Submarine Electricity Cables Cost Benefit Analysis Methodology Statement can be found here: [http://news.ssen.co.uk/media/266365/SSEN-CBA-Method-Paper-120pp-22336-WEB.pdf](http://news.ssen.co.uk/media/147004/4731-ssepd-submarine-cables-doc-july-2016_06.pdf)  [↑](#footnote-ref-2)
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. [↑](#footnote-ref-3)
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. [↑](#footnote-ref-4)
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. [↑](#footnote-ref-5)
6. The CBA tool methodology is available at <http://news.ssen.co.uk/submarinecables/information/> [↑](#footnote-ref-6)
7. The three methods commonly used by the industry to install cables are: Ploughing, Jetting and Mass Flow Excavation. A forth installation method of horizontal directional drill (HDD) - can be used on submarine electricity cables shorter than 2km in length. [↑](#footnote-ref-7)