Scottish & Southern Electricity Networks

Pentland Firth East (3) Cost Benefit Analysis Model

The Final Cost Benefit Analysis (CBA) Recommendation

The **Final CBA Recommendation** for the 33kV submarine electricity cable **Pentland Firth East (3)** is the base case option:

- Split pipe protection – Approximately 1,850m
- Rock placement[1] – Approximately 580m
- Concrete Mattressing – Approximately 50m
- Burial through Post Lay Jetting - Approximately 14,340m
- Cable surface laid on the seabed – Approximately 18,970m
- New cable removed at the end of its economic life.

This was deemed to be the best value solution based on the available information because it addressed the following risks, impacts and needs of stakeholders:

- Split Pipe protection at the shore end limits the risk to the marine users.
- Rock placement (rock bags) maybe required to further stabilise the cable due to the high tidal flows at strategic locations as a substitute to the volume at the shore end.
- This scenario has the same engineering installation costs and volumes relative to the baseline.
- The CBA indicates some scenarios that could have more value than the baseline, mainly through the removal of rock bagging and concrete mattressing however, these items are essential as part of the cable design to maintain cable integrity and achieve the minimum design life. These items are required for stability where burial is not possible and for crossing of third-party assets and therefore removal of them from the final design is not a feasible outcome for this project. This then indicates the base case scenario as the best societal value option available to the project that fulfils the design requirements and outputs from CBRA and OBSS.

For the purposes of this CBA, the base case for defining areas where stabilisation is required has been the PFE (2) OBS On-Bottom Stability (OBS) study. The OBS study defines 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 is considered to be unstable. Where the cable is shown to be unstable, rock bags, concrete mattresses or shallow burial are proposed to be installed to stabilise the cable.

Cast iron split pipe is also proposed to be installed at the shore ends which provides stability as well as protection against abrasion. The use of split piping has a very large impact on the overall costs to societal value, this is due to the lay rates, risks associated with diver install and future difficulties around cable repair should it be required on these sections. Based on historic cable damage due to abrasion, the mobility of the cable and the rocky nature of the seabed in these shore end locations split piping has been determined to be necessary to protect the life of the cable. It has therefore been included in all the models within the CBA.

The **Final CBA Recommendation** scenario has an overall societal value of **minus £45,206,982.** This includes consideration of impacts on health and safety, socio-economic, environmental and wider economic and engineering impacts.

[1] The current CBA model has consulted on the use of rock placement as an installation method. However, based on the final engineering design assessment, it was identified that the use of "Rock Filter Bags" instead of rock placement would achieve the required design stability requirement 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.

Background

Scottish Hydro Electric Power Distribution plc (SHEPD) undertook early engagement with the general public and stakeholders who have an interest in the Pentland Firth East submarine electricity cable. Their views have shaped the installation methods that have been modelled and ultimately how the submarine electricity cable will be installed in the marine environment.

A CBA model was designed to help 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 Pentland Firth East - Hoy submarine electricity cable.

The CBA model assigns financial values across the following key categories for each cable installation method and design:

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

These values are then aggregated to estimate the **'societal value[2]'** 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[3]. The CBA model supports our marine licence application by illustrating how we consider the cumulative impact of our engineering design.

10 different CBA models have been developed 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 Jan De Nul, the proposed protection/installation method may vary slightly from the CBA documents.

This version of the CBA recommendation report supersedes all previous versions.

This CBA analysis has been updated based upon the installation of the PFE(2) cable in 2020. The final installation parameters of the PFE(2) cable have been used as the base case for PFE(3) protection CBA analysis.

The installed PFE(2) protection was subject to full engineering design and CBA analysis taking into account detailed engineering surveys, CBRA and OBSS. This new information allowed the CBA to be updated with new details about the project length, proposed installation methods, seabed depth and seabed type. This forms a solid base case scenario for the assessment of PFE(3) installation protection.

The process to arrive at the final recommendation

[2] 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.

[3] 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.

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[4] 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 is then used to identify the **Burial Scenario** using our three[5] 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**.

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 represents the 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 represents the overall best value solution.

Pentland Firth East(3): Phase one

[4] 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.
[5] The three methods commonly used by the industry to install cables are: Ploughing, Jetting and Mass Flow Excavation.

The input to phase one of the CBA analysis was standalone installation assessments for the Pentland Firth East (3) cable. These included Option 1A (Jetting 40.06%, surface lay 54.77%, Split Piping 5.17%) and Option 1B (Surface lay 94.83%, Split Piping 5.17%). It has been identified through initial surveys and previous installations that large portions of burial should be achievable due to the majority of the route being of a sandy or sandy-gravel make up. There are large sections of sand wave fields where burial should be achievable. The beach and immediate inshore area is covered in boulders and additional protection may be required if burial is not possible.

The initial burial assessment identifies that it would be technically feasible to obtain high percentages of burial for the new proposed route.

Based on the PFE (2) cable experience there will be a requirement to provide additional protection in the inshore area, this will be in the form of cast iron split piping. This is to minimise damage from abrasion and also stabilises the cable. Additionally rock bags will be required to ensure cable stability where burial is not achievable, and stability is identified as a concern in the OBSS. Furthermore, concreate mattresses will be required where the new cable crosses over third party assets. Therefore, none of the scenarios from phase 1 will be feasible on their own to achieve the cable installation design.

Pentland Firth East (3): 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 as well as address requirements from the cable installation design.

Table 1 provides an overview of the 6 scenarios that were considered in this phase of the analysis.

Table 1 Practicable and cost-effective burial and protection scenarios

Option	Scenario methods	Total Societal Value	Net change^ (£)	Net Change^ (%)
Baseline	Surface Lay 53.00% (18.97km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km)	-£45,206,982	£-	
2A	Surface Lay 52.74% (18.88km) / Rock placement 1.89% (0.675km) / Concrete Mattressing 0.14 (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km)	-£45,698,845	-£491,862	1%
2B	Surface Lay 49.38% (17.67km) / Rock placement 1.89% (0.675km) / Concrete Mattressing 0.14 (0.05km) / Jetting 43.42% (15.54km) / Split Piping 5.17% (1.85km)	-£45,766,151	-£559,169	1%
2C	Surface Lay 49.64% (17.77km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 43.42% (15.54km) / Split Piping 5.17% (1.85km)	-£45,273,909	-£66,926	0%
2D	Surface Lay 42.59% (15.24km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 50.47% (18.06km) / Split Piping 5.17% (1.85km)	-£45,372,525	-£165,543	0%
2E	Surface Lay 29.31% (10.49km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 63.75% (22.82km) / Split Piping 5.17% (1.85km)	-£45,523,918	-£316,936	1%
2F	Surface Lay 0.81% (0.29km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 92.25% (33.02km) / Split Piping 5.17% (1.85km)	-£45,804,222	-£597,240	1%

^The net change is compared to the baseline.

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Within the seven scenarios considered in Table 1, zero scenarios provided an improvement in the societal value against the baseline. This includes scenarios increasing burial through jetting from circa 40% of the route up to circa 92% of the route.

Based on this analysis it was therefore identified that the most practicable and cost-effective solution and the option with greatest societal benefit is the base case scenario, this was therefore taken forward into Phase 3.

The key risks identified by stakeholders for the Pentland Firth East (3) submarine electricity cable for the CBA model categories of health and safety, socio-economic, environmental, wider economic and engineering are outlined in the main body of the document 'PFE Additional PAC Report Nov 2022'.

The **Hybrid Scenario** which was deemed to address the concerns of stakeholders including marine users and electricity customers was:

Option	Scenario methods
Baseline	Surface Lay 53.00% (18.97km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km)

Rock placement protection in this scenario is 1.63%. This is focused on the areas identified by the engineering need to stabilise the cable.

Pentland Firth East (3): Phase three

Based on the process of engagement, including the previous pre applications consultation events, the **Hybrid solution** was 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

Initial CBA's for PFE(2) looked at various sensitivity scenarios with the latest CBA for PFE(3) looking at variances in predicted lifecycle of the new cable.

Table 2 shows the impact of an increase in the life expectancy of Option 2B and the baseline. 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 Pentland Firth East cable has been installed for a period of longer than 25 years in its current location. If the new cable is in operation for as long as the current cable (37 Years) then overall results of this protection method would be in line with option 3B in Table 2 below. Given that protection is being proposed on the sections of the existing cable that have seen the most damage, there would be an expectation that the new cable life expectancy could be increased to 45 years which would give an even greater positive societal value over the life of the cable as seen in option 3C.

Table 2 Sensitivity test / 10 year increase in life expectancy

Option	Scenario methods	Total Societal Value	Net change^ (£)	Net Change^ (%)
Baseline	Surface Lay 53.00% (18.97km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km) **[Only protected sections at 45years with surface laid at 25 years]**	-£45,206,982	£-	
3A	Surface Lay 53.00% (18.97km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km) **[Whole cable life expectancy set at 45 years]**	-£37,773,198	£7,433,785	-16%
3B	Surface Lay 53.00% (18.97km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km) **[Whole cable life expectancy set at 35 years]**	-£40,801,967	£4,405,015	-10%
3C	Surface Lay 53.00% (18.97km) / Rock placement 1.63% (0.582km) / Concrete Mattressing 0.14% (0.05km) / Jetting 40.06% (14.34km) / Split Piping 5.17% (1.85km) **[Whole cable life expectancy set at 25 years]**	-£45,206,982	£-	0%

^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 installation the new Pentland Firth East (3) submarine electricity cable in a similar way to the base case results in the highest societal value (i.e. lowest net cost). Although some scenarios in phase 1 show improvement of societal value, when removing rock bags and concrete mattresses, this is not a practical approach when considering the cable engineering requirements.

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 basecase remains the scenario with highest societal value, it does also show that even with significant increases in post lay burial through Jetting, there is no further positive societal value gained based on the modelling assumptions. Within the constraints of the modelling approach this indicates that should SHEPD bury more of the cable than in the baseline, this will only increase SHEPDs costs without giving additional societal value, in fact, in all cases it would decrease the societal value.

Phase three shows the sensitivity testing put upon the preferred options, in this case, the base case scenario. This sensitivity analysis examined if the cable life expectancy was greater or lesser than expected what societal benefit this would produce. The results from this were that as life expectancy increased the overall societal benefit also increased. The thought here is that should the cable be protected where recommended through engineering analysis then the cable sections which are not protected should not be at risk, or at least a much smaller risk. Therefore, it is likely that the whole cable will achieve the increase life expectancy and not just the sections which have been buried or protected. Model 3C also shows that as long as the cable survives its design life of 25 years then, there will be no impact on societal value against the base life, but in practice, with the protection measures propose, models 3A and 3B 45 years and 35 years life expectancy are more likely, therefore adding significant societal value over the base case.

Recommendation

The CBA model considers the societal value of different installation methods for the Pentland Firth East (3) submarine electricity cable. SHEPD 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 and so we propose that the base case option which is a combination of 18.97km of surface lay, 14.34km of burial via post lay jetting, 0.582km of rock placement, 0.05km of concrete mattresses and 1.85km of split pipe protection along the cable route is put forward for further design consideration.

The CBA has modelled this as section 1 (Split Pipe), 2 (Rock bags), 3 (Concrete Matts), 4 & 8 (Jetting) with the remainder surface laid. The specific locations will be derived at detailed design stage to mitigate the risk to other marine users and minimise the environmental impacts at a micro siting basis.

Whilst the marine licence CBA has identified the base case to have the lowest societal impact, the National Marine plan suggests that burial should be maximised as far as possible for replacement subsea cables. SHEPD will therefore continue to investigate where further burial may be achievable throughout the final detailed design stage which would provide a greater level of burial, given the CBA demonstrates this will add no further societal value, this will be explored where no significant cost implications will be put on the project installation.

It is anticipated that a burial depth of 0.6m and 0.4m in the specified burial areas will offer sufficient cover to stabilise and protect the cable, whilst mitigating against fishing interaction, and to a more limited extent, anchor strike. This burial depth would also set the proposed cable to a similar depth as the existing cable. The PFE (2) CBRA in conjunction with the OBS determined this shallow burial would be sufficient to protect the cable from the low risk of fishing activities whilst there being a minimal chance of the cable becoming unburied due to seabed movement.

Therefor the final recommendation, when taking into account all elements presented in this CBA, is to proceed with the base case option of 18.97km of surface lay, 14.34km of burial via post lay jetting, 0.582km of rock placement (rock bags), 0.05km of concrete mattresses and 1.85km of split pipe protection.