504_SHEPD_HSM_24_PFE3

PENTLAND FIRTH EAST 3 ENGINEERING JUSTIFICATION PAPER

Scottish & Southern Electricity Networks

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1 Executive Summary

1.1 Summary

Background

The Pentland Firth is a stretch of water in the North Sea around 15 miles across which separates the Orkney Islands from mainland Scotland. Security of supply on the Orkney Islands is provided through two distribution subsea cables, Pentland Firth East and Pentland Firth West, which cross the Pentland Firth, with Kirkwall Power Station providing support when needed.

This Engineering Justification Paper (EJP) for Scottish Hydro Electric Power Distribution (SHEPD) sets out the investment case for the Pentland Firth East '3' cable (PFE3) which was commissioned in September 2023. As this reopener submission seeks funding for the PFE3 cable retrospectively, this EJP primarily reflects on the data available and analysis carried out at the time of the PFE2 cable failure and replacement. Current data is reflected on where appropriate.

Drivers for change

Following assessment of poor condition, a replacement project for the Pentland Firth East 1 (PFE1) subsea cable was initiated in 2017. Replacement of the PFE1 cable was not in our original RIIO-ED1 business plan, but inspections carried out in 2016 and 2017, and subsequent Common Network Asset Indices Methodology (CNAIM) assessment, showed that the cable needed to be replaced quickly. Deterioration of the asset was greater and more rapid than anticipated and it was determined that replacement could not be deferred until RIIO-ED2. This assessment was further justified following two faults on the cable in 2019. These faults were repaired and the cable was returned to service on a temporary basis.

PFE1 was replaced by PFE2 in November 2020. Following a review of several replacement options, a 400mm^2 cable option was identified as the preferred solution further to cost analysis and considering our ability to deliver the required outputs associated with replacing the existing cable. The cable in this option was rated to a minimum of 30MVA.

Due to the value of the project and need for immediate replacement, it was determined that the High Value Project (HVP) reopener mechanism should be used to recover the additional and unexpected costs of replacing and protecting the PFE1 cable. In its assessment of SHEPD's HVP submission Ofgem agreed with the need to replace the cable, but challenged SHEPD on several aspects of the selection of PFE2, including its size in the context of long-term demand and generation forecasts for the Orkney islands. Consequently, no regulatory funding was secured and the cost of installed PFE2 contributed to SHEPD's Totex overspend in ED1.

PFE2 unexpectedly failed in January 2021 following a fault to one of the two 33kV electrical distribution submarine cables. The PFE1 cable was recommissioned in April 2021 on a temporary basis in order to supplement PFW in the provision of security of supply to Orkney until a solution for PFE2 could be implemented. The PFE1 cable was already in critical condition and was previously recorded and an HI5 asset at the time of its replacement. The cable had also failed twice in the past whilst the PFE2 project was being developed, and so could have failed at any time resulting in a long term security of supply risk to the Orkney Islands. This drove the need for accelerated installation of a new PFE3 cable.

Options analysis

Following a 'cut and recover' exercise and extensive technical analysis of the failed section of the PFE 2 cable, SHEPD's view was that it was clear that there was an unacceptable risk of future faults on the cable. Consequently, we took the decision to replace rather than repair the PFE2 cable. Further details of the fault assessment and associated analysis are presented in Section 6.3.2. SHEPD therefore progressed with the selection and procurement of a cable, PFE3. On review, a larger cable than originally planned was selected as a replacement for PFE2 to future-proof the cable for anticipated use in the area, given latest load growth projections available at the time.

Prior to the selection of the PFE3 cable, SHEPD assessed a range of different network and non-network solutions, including low carbon on-island generation, and single and multiple distribution and transmission link arrangements, and solutions involving combinations of these elements. Solutions were assessed against four main criteria: 1) ability to meet future demand (out to 2050 based on range of 2021 DFES); 2) ability to provide N-1 security; 3) technical readiness; and 4) ability to meet short term demand and generation needs. It was concluded that all viable solutions included at least one distribution cable. This allowed us to consider replacement of PFE2 as a no regret investment which could align with any combination of solutions to provide security of supply to 2050 and beyond (based on our DFES projections).

The next stage of the analysis assessed cable size. SHEPD assessed 400mm^2 (32MVA), 500mm^2 (35.5MVA) and 630mm^2 (c.40MVA) cables. Selecting a 630mm^2 cable would have required added time for testing, technical governance and deployment which was limited at that point. Given the risk that was being carried through re-connecting the old PFE1 cable, which had already failed, a lengthy design, procurement and installation timetable was not a viable option. Further, the 2021 DFES scenarios indicated the installation of 630mm^2 capacity would not be required by 2050 or beyond. Finally, in order to release the full capacity of a 630mm^2 cable, SHEPD would have required material spend to underground and uprate the full onshore OHL network across the Mainland, Hoy and Orkney, as well as the Orkney-Hoy subsea cables. Further, under the 2021 DFES requirements, 400mm^2 cable would have been exceeded in 2029, so continuing with that design was only a short term solution. The 500mm^2 cable, however, met 2021 Consumer Transformation (CT) and Leading the Way (LW) DFES scenarios, which were the latest available projections at the time. All of SHEPD's analysis indicated that progressing with a 500mm^2 cable was the most economic and efficient selection for PFE3, representing a low-regrets option for meeting DFES projections out to 2050.

CBA and overall cost

Various detailed CBAs have been conducted at all key stages of the project. Following the decision to progress with a cable replacement, a final CBA was developed to consider the optimum cable sizing across the four cables which supply the Orkney Islands: PFE3, Orkney – Hoy Centre, and PFW, Orkney – Hoy South (see Figure 3). These four supplying cables were considered within the CBA to ensure that a comprehensive long-term whole system view was being taken. The CBA concluded that the best long-term solution under the four-cable arrangement was for the PFE3 cable to be a 500mm^2 35.5MVA rated cable, and this result was consistent across all DFES scenarios that were considered. The CBAs were based on an original best estimated view of cost at that time.

Option	10 year NPV	45 year NPV
1. 400mm PFE and 400mm PFW. 400mm O-H Centre, 400mm O-H South	(£24.75m)	(£47.24m)
2. 400mm PFE and 500mm PFW. 400mm O-H Centre & 500mm O-H South	(£24.73m)	(£46.98m)
3. 500mm PFE and 500mm PFW. 400mm O-H Centre & 500mm O-H South	(£24.64m)	(£46.66m)
4. 500mm PFE and 500mm PFW. 500mm O-H Centre & 500mm O-H South	(£24.64m)	(£46.62m)

Table 1: Cable sizing CBA summary – LW (based on estimated costs)

The current Estimate at Completion (EAC) for PFE3 is [redacted] (2020/21 prices) (see Table 2). While the cable has been energised some aspects of the project are still being finalised, contracts being closed out and billed, and therefore this value includes a conservative estimate of the final position with the principal contractor.[1] Material savings have been realised in the management of the works under the contracts, compared to original cost estimates.

2020/21 prices	Class 3 Estimate, August 2022 (accuracy range -5%/+10%)	Outturn costs (including Estimate to Completion)
500mm² submarine cables	[redacted]	[redacted]
Other PFE3 project costs	[redacted]	[redacted]
Total:	[redacted]	[redacted]

Table 2: PFE3 2022 cost estimate and Estimate to Completion

Solution delivery

PFE3 was commissioned in September 2023 and is now operational and supplying power to Orkney in conjunction with PFW. As part of RIIO-ED2 Final Determinations, Ofgem included PFE3 within the

[1] Including OHL removal

scope of the HOWSUM.[2] The PFE1 cable has been decommissioned again following the energisation of the new PFE3 cable.

Conclusion

When PFE2 failed it was SHEPD's assessment that there was a clear, urgent need to take action to procure a replacement solution to meet security of supply for the Orkney islands because it was considered that progressing a repair may present a considerable risk of future failure and that was deemed unacceptable. Based on the additional information gathered through further DFES analysis following the failure of PFE2, SHEPD refined its view of subsea cable requirements and its updated specification was determined on the basis of solution ability i) to support short- and long-term demand and generation needs, and ii) given the risk to security of supply of relying on the re-energised PFE1 cable and an ageing PFW cable, the focus was to ensure the investment was 'least regrets', pending the development of a wider whole system strategy.

SHEPD has no defined funding for PFE3 in RIIO-ED1 or RIIO-ED2 and is therefore seeking to recover [redacted] (2020/21) under the HOWSUM reopener mechanism provided for in Special Condition 3.2 Part O. The benefits associated with delivery of this project are significant and include improved asset health and reliability, contribution to security of supply and meeting demand and generation needs as part of a whole system solution out to 2050 and beyond. The cable will play a core and complementary role in the future Orkney whole system solution.

Further to our selection of the PFE3 distribution link as a low regrets solution required in all viable future scenarios, it forms a core part of the future whole system arrangements for the Orkney islands. We will assess and make recommendations on the options which will complement PFE3 through the 2025 HOWSUM re-opener window, and potentially also in RIIO-ED3. The whole system analysis will include assessment of the capacity of the onshore network, and the role of transmission developments, embedded generation and wider interacting factors.

Further detail on all key areas is included in the following sections. This EJP should be read in conjunction with the HOWSUM Core Narrative document and the PFE3 CBAs at Appendix 6B – Pentland Firth East 3 CBA LW and Appendix 6C – Pentland Firth East 3 CBA CT.

[2] RIIO-ED2 Final Determinations SSEN Annex (ofgem.gov.uk) Section 3.20 – November 2022

2 Meeting Ofgem's Requirements

Ofgem EJP requirements

Table 3 sets out where we meet Ofgem's EJP guidance requirements in this document.

Ofgem EJP Guidance requirement	Requirement met?	Where addressed
Summary Table	✓	Section 3
Introduction	✓	Section 5
Background Information	✓	Section 6
Optioneering	✓	Section 7
Analysis and Costs	✓	Sections 8 and 9
Deliverability and Risk	✓	Section 10
Conclusion	✓	Section 12

Table 3: Mapping Ofgem's EJP guidance

Ofgem feedback on project

Table 4 sets out Ofgem's recent feedback on the project provided through our bilateral engagement, and where we address this feedback.

Ofgem feedback on project	Feedback Resolved?	Where addressed
PFE3 solution in context of P2 - Cable options in the context of P2	✓	Sections 6.2 and 7.2
View on feasibility of 630mm option	✓	Section 7.3.1
View on feasibility of 66kV option	✓	Section 7.3.2
Health of associated assets – View of PFW and onshore network.	✓	Section 6.3
Costs of associated onshore work	✓	Section 7.3
Breakdown of subsea costs - Cost of subsea cable broken out from the overall other subsea delivery costs.	✓	Table 2 (actuals), Section 7.3 including Table 16

Ofgem feedback on project	Feedback Resolved?	Where addressed
Context of PFE3 in whole system analysis	✓	Executive Summary, Sections 5.2.2, throughout Section 6 (in particular 6.6), throughout Section 0, Section 9.1 and 9.2, and Section 11
Orkney ANM scheme - Impact of PFE3 and wider Orkney interventions on ANM scheme and link to resilience as a service.	✓	Sections 6.1, 6.4 and 6.7

Table 4: Mapping Ofgem's feedback

3 Investment Summary Table

Name of Scheme/Programme	33kV Pentland Firth East 3 subsea cable installation	
Primary Investment Driver	Faults - Failure of Pentland Firth East 2 subsea cable	
Scheme reference/ mechanism or category	504_SHEPD_HSM_24_PFE3	
Output reference/type	EHV Sub Cable addition of 36.086km of PFE3 cable EHV 33kV Transformer (GM) addition – 1 off (5MVAr Shunt Reactor)	
Cost	[redacted]	
Delivery Year	2023/24 – Installation complete and energised	
Reporting Table(s)	M11b (CV26 Faults); R3	
Outputs in RIIO ED2 Business Plan	No – Project sits under the HOWSUM. No HOWSUM Development Funding applies to this project.	
Spend Apportionment	**RIIO-ED2**	**RIIO-ED3+**
	[redacted] (2020/21 prices)	n/a
MVA released	N/A – Subsea cable uprated from 32MVA to 35.5MVA Current constraint remains on 150mm^2 Cu (50deg) OHL on the Mainland and Hoy.	n/a

Table 5: PFE3 investment summary table

4 Appendices Summary

Table 6 summarises the appendices.

Appendix	Summary of content
Appendix 6B – Pentland Firth East 3 CBA LW	RIIO-ED2 Ofgem format CBA assessing cable sizes to replace PFE2 based on LW DFES.
Appendix 6C – Pentland Firth East 3 CBA CT	RIIO-ED2 Ofgem format CBA assessing cable sizes to replace PFE2 based on CT DFES.

Table 6: Summary of appendices

5 Introduction

5.1 Background to the investment

This purpose of this investment is to fund the replacement solution for PFE2, which faulted, and was the replacement solution for the PFE1 cable (planned replacement on basis of condition).

5.2 Investment drivers

There are two main investment drivers for the project, set out below.

5.2.1 Primary investment driver

The primary investment driver was the immediate need to manage security of supply, which arose when the PFE2 cable failed in February 2021. From that stage, the Orkney islands were reliant upon the single grid connection provided by PFW alongside support from Kirkwall Power Station (KPS) to meet security of supply requirements. KPS was required to peak lop in periods of high demand.

PFE1 was identified to be in critical condition early in RIIO-ED1 and a project was initiated to replace it in 2017. The cable failed twice in short succession in 2019 before the replacement solution was implemented. The failures occurred near to shore in both instances and were able to be temporarily repaired whilst the replacement project was progressing. PFE1 was subsequently re-commissioned to restore two grid connections between the mainland and Orkney, removing the immediate reliance on KPS. PFE1 was in a critical condition and at a very high risk of failure, hence the cable had been replaced with PFE2 under an asset replacement driver.

SHEPD replaced PFE1 with PFE2 in late 2020, however PFE2 failed in early 2021, three months into service. SHEPD then undertook a line resonance analysis (LIRA) test on the cable to detect the location of the fault. This identified a fault on the blue phase of the cable suggesting an issue with a factory joint. A cut and recover campaign was then undertaken, removing the faulty section of cable back to the mainland for laboratory dissemination and investigation. This revealed an issue at the site of a factory joint. Following extensive consideration, SHEPD judged that progressing a repair may present a considerable risk of a future failure(s), which was deemed unacceptable to SHEPD.

As part of the PFE3 installation SHEPD reassessed the specification of the proposed solution and consequently procured and installed a larger cable than previously installed for PFE2. PFE3 was energised in September 2023.

Figure 1: Map indicating the routes of PFW and PFE3 and wider Orkney network.

5.2.2 Secondary investment driver

The secondary investment driver is future demand and generation needs of the islands. In developing the specification for PFE3 SHEPD revised its DFES analysis and determined that the appropriate specification for the solution is a 500mm^2 35.5MVA cable. This investment, combined with whole system analysis and wider investment in Orkney over the latter part of RIIO-ED1, ED2 and ED3, will implement a net zero-enabling system. These aspects are detailed further in the following sections. This future solution will consider the future roles of the PFW cable and KPS, further detail can be expected in SHEPD's 2025 HOWSUM submission.

5.3 Timing of investment

PFE3 has been delivered in 2023/24 and all of the costs associated with the project will be reported in year 2023/24.

5.4 Expected outputs and year of delivery

PFE3 was energised in September 2023 and has therefore been delivered in year 2023/24. Due to the cable being replaced under a fault scenario, SHEPD is not claiming NARMs points associated with the PFE2 cable replacement as would have been the case under a normal asset replacement project on this asset type.

6 Background Information

6.1 Existing network arrangements

The Orkney islands are supplied via two submarine cables which run from mainland Scotland, north-east of Thurso, across the Pentland Firth to Rackwick Bay on Hoy. The two cables currently across the Pentland Firth are PFW and PFE3. The PFW cable is circa 35.5km long whilst the PFE cable is around 36.1km long. Further onshore network and subsea cable assets then continue to Scorradale on Mainland Orkney. Kirkwall Power Station (KPS) provides support to meet security of supply requirements during high demand, or when one of the mainland subsea cables are unavailable.

The Orkney network also currently operates with an ANM scheme in place to manage the levels of generation which can export onto the network at any one time. This ANM system is broken down into multiple zones around the island group and managed on island network constraints as well as monitoring power flowing to and from the islands through the PFE and PFW circuits.

Figure 2 presents the overall electrical connections for the Orkney islands group from Thurso South Grid. It is noted here that the electrical schematic in Figure 2 is labeled correctly and that on the schematic the PFE cable is represented by the furthest left cable, whilst the PFW cable is represented by the line furthest to the right. This also shows the complex interconnected 33kV network that supplies the islands beyond Scorradale substation.

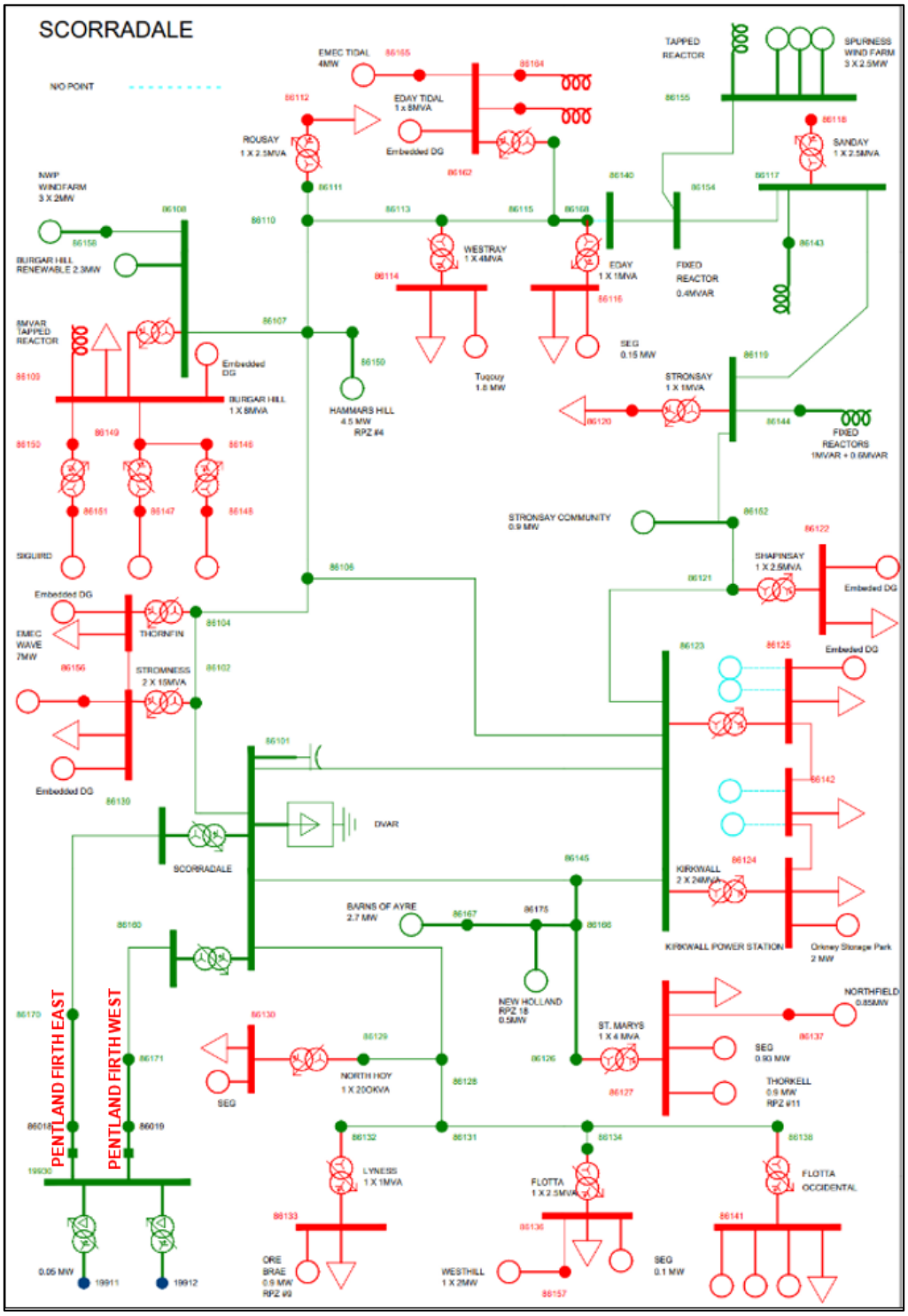

Figure 2: Network schematic diagram for Orkney

Figure 3 gives a geographic representation of the Orkney 33kV network, highlighting the sections of subsea cable operating between islands to provide the main supply and export for the wider island group.

Figure 3: Existing 33kV network supplying Orkney

The PFE circuit between Thurso and Scorradale includes the PFE3 cable and the Orkney – Hoy (O-H) Centre subsea cables. The PFW circuit includes PFW and the Orkney – Hoy South subsea cables.

- Prior to the PFE3 intervention the 33kV network was made up of the four following cables:
- PFE2 – 36.253km 400mm^2 DWA 32MVA Subsea Cable
- O-H Centre – 4.665km 240mm^2 SWA 23.4MVA Subsea Cable
- PFW – 35.5km 300mm^2 DWA 30MVA Subsea Cable
- O-H South – 4.675km 300mm^2 SWA 30MVA Subsea Cable

6.1.1 Kirkwall Power Station (KPS)

To ensure P2 compliance, the system solution on Orkney currently includes KPS. KPS provides support in the event of a fault on the mainland PFE or PFW subsea cables.

KPS has been assessed as being capable of continuing service until at least 2035; therefore, no intervention is currently required. The station currently has an operational capacity of 15.5MW.

While we are mindful of interactions with commitments to deliver net zero, KPS is only required to run as backup when either PFE or PFW is out of operation. As such the environmental impact is restricted. Further assessment of KPS' future role in the Orkney system will be conducted in 2024 as part of SHEPD's whole system assessment for the island group. Further details will be included in the January 2025 submission.

The O-H Centre cable was planned to be replaced as part of SHEPD's ED1 asset replacement plans following realising additional funding through the 2019 subsea cables reopener. This project was being planned and scheduled to install a 400mm^2 cable to match the rating of the PFE2 cable. However, following the failure of the PFE2 cable in 2020 and the subsequent analysis that was conducted in defining the PFE3 solution, there was sufficient time available to take account of the outcomes of this analysis and change the sizing of the install to match PFE3. This cable was therefore installed as a 500mm^2 DWA 35.5MVA cable, utilising a spare length of cable SHEPD held in stock from the Skye – Harris project. The cable was installed prior to the end of ED1, with energisation taking place in September 2023 alongside the new PFE3 cable.

The PFW and O-H South cables currently sit within the definition of the HOWSUM mechanism for RIIO-ED2. Possible future interventions as part of a wider whole system solution for Orkney will be confirmed at the January 2025 window, following further whole system assessment in 2024.

6.1.2 Active Network Management scheme

In areas where there are several, complex thermal constraints affecting a number of customers over a long period of time, a full Active Network Management (ANM) system can be implemented. The Orkney islands are one such area where an ANM scheme has been in place for some time. An ANM system continually monitors all the constraints on an area of the network, in real-time, and allocates the maximum amount of capacity available to customers in that area based on the date their connection was accepted. The Orkney ANM scheme was needed because of the demand for additional renewable generation connections within Orkney exceeding the network capacity in various locations across the network.

The ANM system on Orkney will remain unchanged following the installation of this new cable, however further assessment will be given to the long-term options for its role as part of the wider HOWSUM analysis for Orkney, which is due to be conducted over the 2024 calendar year and submitted in January 2025.

6.2 Load forecast for Orkney islands

Applying the latest net zero-compliant DFES available at the time, 2021 Leading the Way (LW) and Consumer Transformation (CT), peak demand for the Orkney islands was identified as ranging from 59.44MW to 60.99MW. Solutions were assessed against their ability to provide short-term N-1 security during periods of peak demand. It was also observed that post-2045, demand stabilised and showed a marginal reduction of 0.017% year on year under CT forecasts (0.16MW) and a very marginal increase of 0.33% under LW (3.6MW). Extrapolating out these figures shows that there is no further significant change in demand in the timeframe of the asset lifespan.

Additionally, DFES demand profiles are provided on a substation by substation basis. For the purpose of the DFES it is assumed that the peak demand figure for all substations occurs at the same time, which forms the profile in Figure 4 and also the demand forecasts within Table 7. It is extremely unlikely that all 15 primary demand peaks will align in reality, and a diversity can be assumed which would reduce the anticipated maximum demand figures which have been modelled for the network. Further, our analysis assumes no export onto the Orkney network, which is rare given wind and tidal generation already connected.

SHEPD sized PFE3 to meet 2021 LW and CT DFES these are the two scenarios with the highest growth levels and therefore the cable will provide for lower scenarios if uptake is not as high as the CT or LW scenarios predict. We were therefore satisfied that, based on this information, the asset would provide the required loading over the anticipated asset life. This is considered further in Sections 7 and 8.

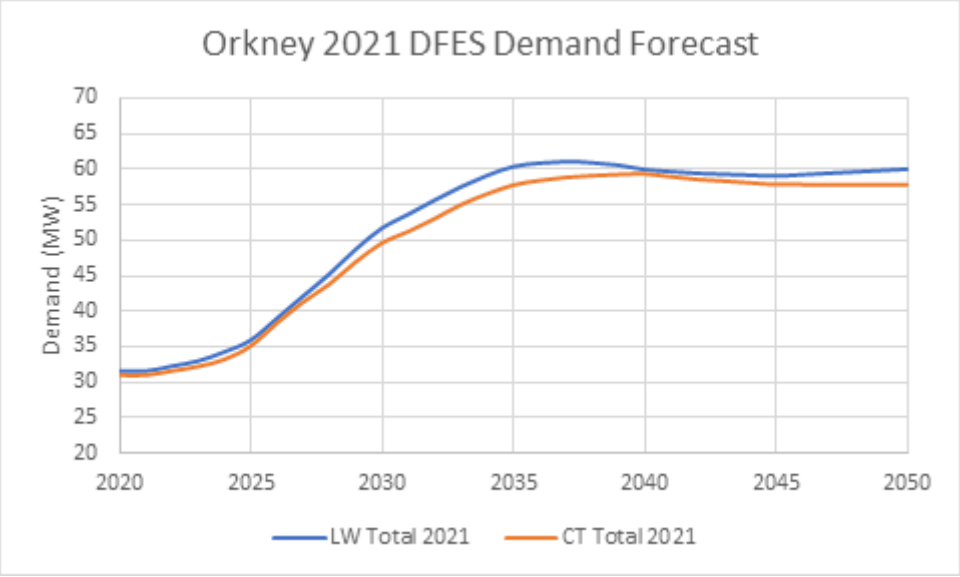

Figure 4: Orkney 2021 DFES – Leading the Way and Consumer Transformation

Current max demand*	Lowest 2050 max demand*	Highest 2050 max demand*
34.4MW (~6MW minimum demand)	59.44MW (Consumer Transformation)	60.99MW (Leading the Way)

Table 7: Summary of Orkney load forecasting

6.2.1 P2 compliance

Under ER P2, the current Orkney demand (34.4MW) is in Class C, meaning that following a First Circuit Outage approximately 22.7MW of Group Demand should be met within 15 minutes, and all Group Demand should be met within 3 hours. There is no requirement following a Second Circuit Outage.

SHEPD undertook network outage analysis at the time of the PFE2 fault considering N-1 scenarios for the replacement network infrastructure and potential long term future whole system solutions. The analysis determined that for the credible solutions identified in the long list, the PFE3 cable would form part of this level of resilience in conjunction with future infrastructure. This is shown in Table 8.

Option / Pathway	2050 CT DFES Demand	2050 LW DFES Demand	PFE3	PFW	New D-Link	T link Finstown	On-Island Solution	Total provision under worse case N-1	P2 ✓
4. Two D links plus on-island solution	60.65MVA	62.23MVA	35.5MVA	New PFW 35.5MVA	N/A	N/A	Suitably sized to cover single circuit D outage	35.5MVA + Minimum 27MVA on island	YES
5. Three D links	60.65MVA	62.23MVA	35.5MVA	New PFW 35.5MVA	New link @ 35.5MVA	N/A	N/A	71MVA	YES
6. Two D links and T-link	60.65MVA	62.23MVA	35.5MVA	New PFW 35.5MVA	N/A	224.5MVA	N/A	71MVA	YES
8. One D-Link, One T-Link and on-island solution	60.65MVA	62.23MVA	35.5MVA	N/A	N/A	224.5MVA	Suitably sized to cover single circuit T outage	35.5MVA + Minimum 27MVA on island	YES

**Assumes a pf of 0.98 throughout*

Table 8 Orkney N-1 Resilience Outcomes

More recently we have developed our net zero resilience policy for island groups fed by subsea cables, which requires that group demand is secured for a sustained long duration N-2 condition through a combination of network assets and local generation (including third party – see Section 3 in the HOWSUM Core Narrative document). This will feed into the development of our net zero strategic plan for Orkney. Consequently in 2024 we will do further assessment of the implications of this policy for the Orkney Islands which will be contained in our 2025 HOWSUM regulatory submission.

6.3 Existing asset conditions

6.3.1 Pentland Firth East 1

PFE1 (PFE1 - SSEN_33) was installed in 1982 to supersede Kirkwall Power Station as the main source of electricity for Orkney. PFE1 was a 240mm^2 single wire armoured cable rated at 23.4MVA. In 1998 this was supplemented with the PFW cable.

In 2016 and 2017 partial and end-to-end inspections showed that the cable was in poor condition and was classed as HI5, meaning it had reached the end of its serviceable life, and a replacement project was initiated in early 2018. In 2019 PFE1 faulted twice in quick succession. These faults were repaired and the cable was returned to service.

Inter-trip arrangements between Scorradale and Thurso ensured there was no interruption to electricity supplies on Orkney. The Active Network Management (ANM) scheme was also reconfigured to operate with PFW only and to ensure island generation export levels did not exceed the operational rating of the remaining cable (22MVA). Orkney demand was met by the PFW cable and on-island generation, including backup power supply from KPS. Standby generation was also in place as part of SHEPD's contingency plan. The ANM scheme automatically operated to ensure maximum export capacity was made available to island generation, subject to network conditions.

In May 2019 SHEPD applied for funding to replace PFE1 in the HVP re-opener window, as it did not have this intervention in its RIIO-ED1 business plan. At that stage SHEPD was proposing to replace the existing PFE 240mm^2 cable with a 400mm^2 cable in a similar submarine position. This cable provided a rating uplift from the 23.4MVA of the existing cable to 32MVA. The application was rejected on the basis that, although the needs case had been proven, SHEPD had not provided sufficient justification that the chosen solution was the most economic and efficient option. SHEPD had no choice but to progress with the project, despite the lack of additional funding.

At the time SHEPD had gone through a full options assessment and analysis which included a range of cable options. Further to this analysis a 400mm^2 cable (circa 32MVA) was identified as the preferred solution. This cable was installed, due to fault level requirements prohibiting the use of a new 300mm^2 cable, in excess of the 30MVA required to match the Orkney west circuit. The options assessment also assumed replacement of the Orkney – Hoy Centre cable with the same sized cable as PFE2 during the ED1 price control period given this cable forms part of the same circuit between Orkney and mainland Scotland.

Further details of the initial options assessment can be found in the High Value Projects Re-Opener Decision (2019) and associated documents.

6.3.2 Pentland Firth East 2

The new 400mm^2 32MVA cable (PFE2 – SSEN_166) was energised in November 2020 replacing the original PFE1 cable. This new cable subsequently failed in January 2021. The PFE2 cable was an HI1 C2 cable at the time of failure.

The PFE2 fault was identified, following testing, to be on the blue phase of the cable approximately 21km from Murkle Bay (Thurso), suggesting an issue affecting factory joint number 3. SHEPD initially considered whether undertaking a piece-in repair may be the correct course of action. In its assessment it took into account a number of factors. These included that at this location

the water is approximately 83m deep and any repair required the cable to be recovered to a vessel and repaired on deck; the manufacturer's proposed repair methodology; timing and duration of repair work; marine environmental conditions; and potential risks associated with repair and impact of repairs on overall life of the cable. Necessary investigation of these matters by SHEPD meant there was insufficient weather window left to complete any repair successfully during 2021.

SHEPD therefore agreed with the manufacturer and installation contractor to use the time instead to cut out the faulted joint, return it to shore and carry out an in-depth investigation of the cause of failure with analysis under laboratory conditions, allowing improved understanding of the fault and informed decision making as to next steps in relation to the cable from 2022 onwards.

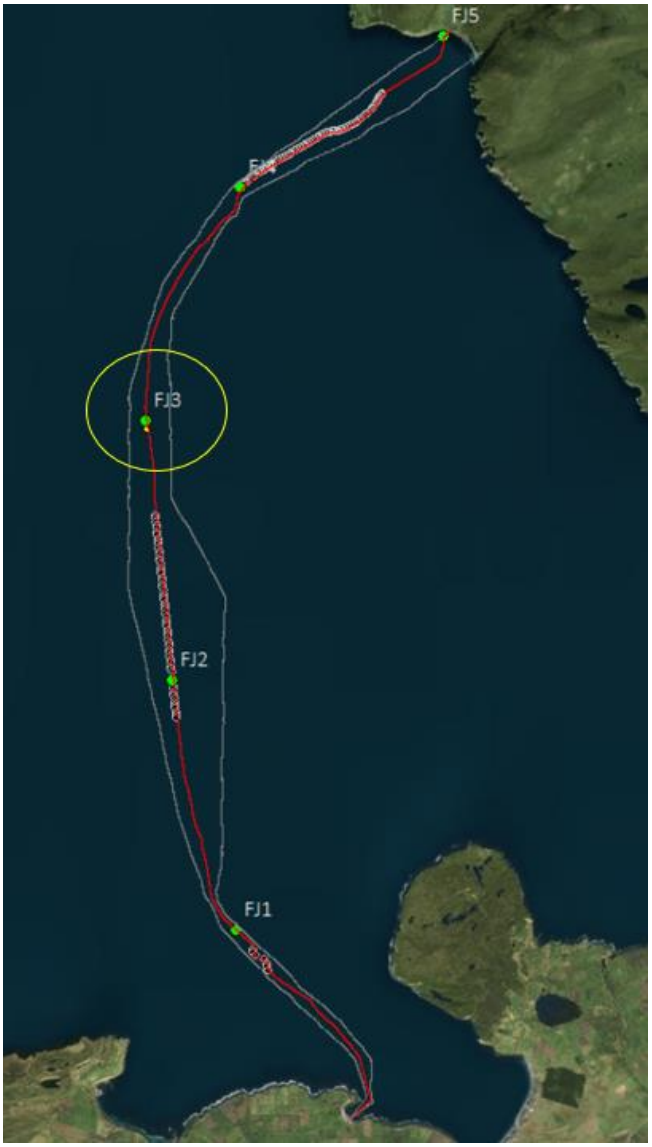

Figure 5: Location of PFE2 factory joints

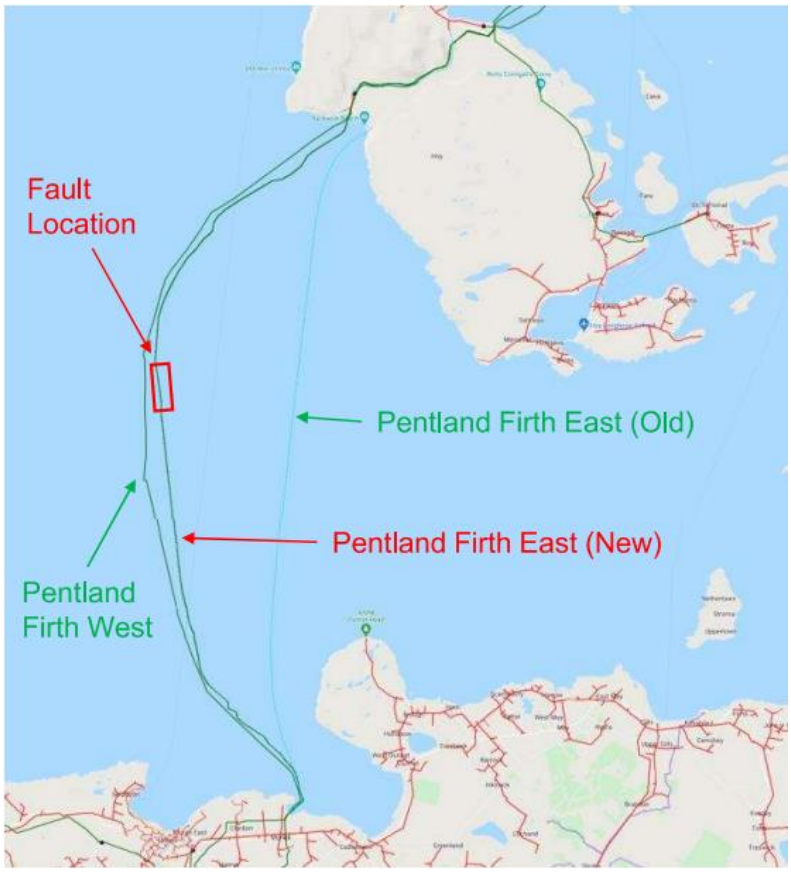

Figure 6: Map of PFE2 fault location

The 'cut and recovery' campaign mobilised on 1 September 2021 and concluded on 12 September 2021. The testing performed from both shore ends during the campaign, plus the testing performed on the vessel, confirmed earlier results and identified the fault location. The fault location coincided with the manufacturing factory joints. The faulted section of cable with the factory joint containing all three cable cores was recovered in a ~10m section.

A laboratory examination of the fault location was carried out by the cable manufacturer, witnessed by SHEPD and the installation contractor. We appointed an independent technical expert to witness the investigation process. The investigation involved dissection of the samples recovered from the seabed, with further examinations and analysis. The outcome of that review found that progressing a repair may present a considerable risk of a future failure(s), which was deemed unacceptable to SHEPD. Discussions with the manufacturer are ongoing in that regard.

Our response to the PFE2 failure and subsequent cable analysis was to progress its immediate replacement with a new cable. The PFE1 cable had been recommissioned in the interim and re-energised following the PFE2 outage. Given PFE1 was established to be in a critical condition and could fail at any time, there was a high-risk Orkney could have been dependent on a single supply and export cable for a prolonged period. In SHEPD's opinion following extensive review, cable replacement was required immediately to protect security of supply and the generation export route for the islands.

PFE1 was subsequently decommissioned following the energisation of PFE3. It will be left in place and could possibly be returned to service again if required; however this would require re-construction of temporary OHL and it is likely the subsea cable will continue to deteriorate and likely fail/be unable to

operate in the very near future. This cannot be relied on as a credible back up/contingency solution. PFE2 has been left in place on the seabed but has had some short sections of cable decommissioned and removed in the inter-tidal areas, including the section which was removed at the fault location, and other parts to allow the new PFE3 cable to be installed; therefore PFE2 cannot be re-energised.

6.3.3 Pentland Firth East 3

The new PFE3 cable was installed in the summer of 2023 and energised at the end of September 2023. The cable is a 500mm2 Cu XLPE DWA Cable with a rating of 35.5MVA, and is classified as HI1C2. The supply of electricity from mainland Scotland to Orkney is therefore currently provided by PFE3 and PFW, and the two further cables which transport supply onwards on Orkney, at O-H South and Centre between Hoy and Mainland Orkney. Standby generation remains in place at KPS as part of SHEPD's network contingency plan. Further whole system assessment in 2024 and beyond will determine additional network infrastructure or on-island solutions to complement the PFE3 cable. This will be submitted as part of SHEPDs January 2025 submission under the HOWSUM.

6.3.4 Other associated network asset condition

Aside from the four subsea cables which provide supply and export routes to and within Orkney, there is additional network infrastructure which links up the substations at Thurso South Grid on mainland Scotland and Scorradale on mainland Orkney.

Almost all of the associated network infrastructure is recorded as being in good condition, with only a small number (<10) of EHV poles being HI4/5, and the remainder falling under an HI1/2 condition. There are two regulators at Scorradale substation, Regulator R1 and Regulator R2. These are aged 41 and 25 years, with current HI scores of HI2 and HI1 respectively.

At Scorradale there is also a DVAr unit which is required to support the network to and from Orkney ensuring it remains within acceptable network limits. Two 4MVAr units were replaced in 2020 and the DVAr system is not forecast to have any immediate investment requirements. All underground cable on the associated network is assumed in good condition.

Considering the PFW and Orkney – Hoy South subsea cables (which form the full PFW supply route) these cables have the following asset health parameters:

PFW: 35.5km - current HI2C2, future (End of ED2) HI3C2

- O–H South: 4.675km - current HI5C2, future (End of ED2) HI5C2

Both of these cable sections currently fall under the scope of the HOWSUM and will be considered as part of the whole system assessment in 2024. No onshore assets across the route currently give a major cause for concern from a health point of view, and therefore any consideration of their replacement or augmentation is likely to be triggered by the Orkney whole system analysis or on the basis of load reinforcement if required.

6.4 Existing operational issues

The following ongoing operational issues have been identified:

- *Regulator sizes:* The two regulators currently at Scorradale are two different sizes, so if there is an outage on one it affects both import and export of both PFE and PFW. This issue will be reviewed as part of the long term whole system assessment to be undertaken by SHEPD in 2024.

- *OHL rating and peak demand:* The OHL Winter rating of 29.3MVA means that during periods of winter high demand with low generation, should a single circuit outage (N-1) be required or occur, then the total circuit capacity is lower than max demand and there may be scenarios where KPS has to run to peak-lop. Due to this, most planned outages are taken in summer. The OHL has a summer rating of 23.5MVA and can limit the circuit for export capacity where there is low demand and high generation, this is currently managed through the island ANM scheme. Both of these issues with be reviewed as part of the whole system assessment to be undertaken by SHEPD this year.

6.5 Network analysis summary

Systems studies were conducted within Siemens PSSe software to confirm the suitability of the proposed network solution. This confirmed the cable thermal rating and fault level capability were appropriate for this location.

The network studies confirmed a high cable charging current on the circuit between Thurso and Scorradale due to the size of the proposed conductor. This indicated a shunt reactor would be required as part of the works to limit this current and protect the associated switch gear. Further studies confirmed a 5MVAr reactor would provide the required support.

It is identified that, based on the 2021 DFES data, further assessment will be required to determine the optimum solution to provide for Orkney under N-1 scenarios. SHEPD's options assessment to rectify the PFE2 fault scenario provides security for customers in the short- to medium-term alongside KPS as standby back up, but wider network development will be required to support long term N-1 and N-2 requirements. This will be explored further in the next HOWSUM submission and considered as part of future investments in PFW and O-H South cables. This mirrors the findings from the initial replacement of the PFE1 cable with PFE2.

The option taken forward to install the 500mm PFE3 cable to rectify the immediate fault and restore security of supply to the islands does not preclude the development of the wider whole system solution.

6.6 Regional stakeholder engagement and whole systems analysis summary

As part of the marine licence application process for the PFE2 cable, SHEPD undertook full consultation with the statutory consultees amongst other wider stakeholder groups. Due to the PFE3 installation taking place such a short period after the installation of PFE2, SHEPD was not required to formally conduct wider stakeholder engagement for the re-installation of PFE3 following consultation with Marine Scotland Licencing Operations Team (MS-LOT).. We did, however, continue to engage with our main stakeholders in the area throughout the design and delivery programme: Marine Scotland, RSPB, Scottish Fisheries Federation, Scottish White Fish Producers Association, Orkney Fishermen's Association, Orkney Islands Council, and Highland Council, among others.

Furthermore through SHEPD's work with Regen on the DFES scenarios 2050 multiple island stakeholder groups are engaged to allow a better understanding of future demand and generation requirements on the islands. A wide range of stakeholders have been consulted by Regen as part of the works to develop the 2021 DFES scenarios and subsequent versions of the prediction models. This includes details of future connections activities, industrial electrification, local development plans and independent stakeholder ambitions.

SHEPD is continuing to directly engage with key stakeholders in relation to the wider whole system analysis and solution which will be proposed for the Orkney Islands in later HOWSUM submission

windows. This has included recent HOWSUM webinars and bilaterals, with further engagement planned throughout 2024.

Additional engagement with SSEN Transmission is also ongoing on the planning and development of a coherent future whole system solution for the islands. Further details will be contained in the HOWSUM submission in January 2025.

In this document we set out the role of PFE3 as a core component of the long-term whole system arrangements for Orkney, recognising that it was specified to be compatible with the most ambitious DFES available at the time, and that all viable whole system solutions include at least one subsea distribution link. We are carrying out further whole systems analysis for Orkney over the course of 2024 ahead of our January 2025 HOWSUM submission, which will capture updated DFES and island-specific drivers, wider system interactions including in relation to transmission network developments, and consequent interventions required on the distribution network. These aspects are also discussed in sections 0, 8 and 9, and in the HOWSUM Core Narrative document.

6.7 Flexible market viability

We are committed to considering flexible alternatives to traditional engineering solutions on our networks. We have created and continue to optimise Active Network Management (ANM) schemes including on Orkney, Shetland and the Isle of Wight, we have introduced Constraint Managed Zones (CMZ), and also flexible connection arrangements.

In assessing whole system solutions for Orkney careful consideration must be given to the network configuration and the ability to achieve P2 compliance. Any flexible solution must be sufficiently reliable and capable of supporting island demand as part of a whole system solution should a subsea cable fault occur. Due to the length of time a subsea cable could be out for repair, which could be months or years, any flexible solutions forming part of N-1 would need to be capable of guaranteeing availability and must be capable of committing to run for this extended duration. The reliability of any flexible solution is of paramount importance as there are not multiple connections to other areas of the distribution system as there may be on the mainland.

Although in theory a flexible solution could be a possible solution, the nature of the majority of generation on Orkney (wind and tidal) means these services would be intermittent and cannot currently be relied upon to provide supplies on demand without further development of storage solutions of material scale. This risks security of supply and does not address generation export requirements. Flexibility solutions tend to offer the bridging of small capacities for short timescales (2 to 3 hours) on a few occasions a year. The availability of third parties to provide for the significant level of demand required on Orkney, for a prolonged period of time, remains unclear.

Flexibility options could play a role in reducing reliance on KPS, and in future cable / solution sizing. SHEPD will aim to identify whether there are other solutions capable of meeting island needs whilst being reliable and dispatchable, capable of being called upon and guaranteed to be available when required, as part of a future whole system solution, in SHEPD's future options analysis plans. We are currently running a global call for flexibility[3], and will launch another in later 2024 – we will also monitor these processes for potential providers. Please also refer to our analysis Section 7.

[3] Flexibility Services - SSEN

6.8 Regulatory context

6.8.1 Treatment in RIIO-ED1

Replacement of the PFE1 cable was not in our original RIIO-ED1 business plan. Due to the value of the project and need for immediate replacement, it was determined that the HVP reopener mechanism should be used to recover the additional and unexpected costs of replacing and protecting the PFE1 cable. In its assessment of SHEPD's HVP submission Ofgem agreed with the need to replace the cable, but challenged SHEPD on several aspects of the selection of PFE2, including its size in the context of long-term demand and generation forecasts for the Orkney islands. Consequently, no regulatory funding was secured and the cost of installed PFE2 contributed to SHEPD's totex overspend in ED1.

6.8.2 Treatment in RIIO-ED2

As part of RIIO-ED2 Final Determinations, provision was made by Ofgem for SHEPD to submit costs for PFE3 under the HOWSUM, defined in SHEPD's Special Conditions, Section 3.2 Part O. We are therefore seeking to recover [redacted] (2020/21) under the HOWSUM reopener mechanism.

6.9 Confidence table

Table 9 describes our level of confidence on the justification for the evidence which has identified the constraint.

Confidence Factor	Certainty (High, Medium, Low)	Comments
Load Forecast	High	Analysis based on 2021 LW DFES scenario. DFES based on extensive stakeholder engagement and research. Second iteration of full DFES so was deemed to be more reflective taking account of 2020 learnings. LW is worst case so solution would also be suitable for lower demand increases.
Existing Asset Condition	High	Assets regularly inspected. Underground cables cannot be visually inspected. Condition assumed based on fault history. Subsea cables not electrically inspected but for PFE2 the asset actually failed, and we also undertook cut and recovery process, confirming issue.
Existing Operational Issues	High	Orkney network is long established with well-known operational parameters. Existing PFE2 cable was in failure. PFE1 cable re-energised and known to be of smaller capacity and critical condition.
Connections Activity	Medium	Connections are regularly changing, and new applications can be received at any time. However, we had reasonable certainty based on DFES analysis and research and connections pipeline at time of PFE2 failure.
Regional Stakeholder Engagement	Medium	Various regional stakeholders engaged as part of PFE2 marine licence applications. Further engagement undertaken through DFES and wider community engagement sessions.
Flexible Market Viability	Low / Medium	At the time of failure, and given the nature of the failure, there was no suitable flexible market alternative. There are a number of emerging technologies which may be possible considerations for flexibility as part of a long-term solution for Orkney. Storage may have a part to play in supporting the network for short periods. This will be further assessed in 2024.
Funding Position	Medium	At the time of PFE2 failure, SHEPD did not have an agreed funding mechanism for its replacement. We now have agreement to use the HOWSUM, and the outcome of the submission is subject to Ofgem's assessment. Ofgem has previously confirmed agreement with the clear

Confidence Factor	Certainty (High, Medium, Low)	Comments
		need for investment. Based on our analysis and the island needs at the time we believe we identified and implemented the correct solution. Further, this does not preclude future whole system solutions for the Orkney islands.

Table 9: Confidence table

7 Summary of Options Considered

7.1 Summary of options

7.1.1 Minimum intervention required

At present SHEPD remain compliant with ERP2/8 due to the presence of two distribution subsea cables, with KPS available on standby in the event of an outage of one of these main import / export routes to Orkney. With the PFE2 cable having faulted, this well-established contingency was enacted. Additional mobile generation can also be moved to the islands to support as further back up during long term fault scenarios.

In general, should a fault occur on a relatively new submarine cable, a repair attempt would be made; this is usually the cheapest and quickest level of intervention. However, this option must be considered for any fault based on its merits, which includes an assessment of viability (due to the location of the fault, and the cable route engineering and protection requirements as part of the cable installation, significant portions of the cable would have to be unprotected to allow the lifting of the cable), cable condition, weather and other risk, location and costs benefit analysis over repair and replace solutions (noting that the estimates and indicative costs for a repair were significant). In the case of PFE2, the outcome of that review found that progressing a repair was a process which itself involved risk. Additionally, a repair may present a considerable risk of a future failure(s), which was deemed unacceptable to SHEPD. Taking account of all relevant considerations, it was concluded that repair was not the option which was optimal or which would involve long term minimum intervention.

In order to restore network security and mitigate the risks and costs associated with potential diesel supply, SHEPD's assessment was that the minimum intervention would be to re-install a replacement second submarine cable between mainland Scotland and Hoy. SHEPD has progressed with the minimum required intervention at this time. Section 7.1.2 summarises the further options which were considered at the time.

7.1.2 Wider options considered

SHEPD undertook comprehensive optioneering as part of its selection. As part of that review, SHEPD determined that an increase in cable size could be available, given the time passed since the prior procurement process, to take account of refreshed DFES, and also how the cable installation would form part of SHEPD's future whole system solution for the Orkney Islands.

SHEPD constructed a long list of possible 2050 solutions for Orkney which had a future whole system pathway with a starting point of today's needs and security of supply requirements. Our aim was to ensure that the immediate solution we implemented to meet imminent network security needs would form part of, and would not preclude, wider whole system arrangements.

SHEPD developed a list of 10 long term possible options which would be deemed whole system solutions. Table 10 exhausted all options which were seen as possible future solutions at the time. The options which were identified are noted in Table 10, which also highlights the different elements which are considered under each scenario. At this stage, consideration was not given to the fine detail of which cable size or distribution / transmission voltage the solution would operate at, i.e. the 'Single distribution link' option covers a host of sub-options including 300/500/630mm cables, and potential voltages of 33kV/66kV, etc. This similarly applies to the other option descriptions.

Option		One D link	Two D links	Three D links	One T link	Two T links	New, on Island generation	Kirkwall PS
Current			✓					✓
1	Low carbon generation on Orkney (on island)						✓	
2	Single distribution link	✓						
3	Two distribution links		✓					
4	Two distribution links plus on-island generation		✓				✓	
5	Three distribution links			✓				
6	Two distribution links and a Transmission link		✓		✓			
7	One Distribution link and Transmission link	✓			✓			
8	One Distribution link, one Transmission link and on island generation	✓			✓		✓	
9	One Transmission link and on island generation				✓		✓	
10	Two Transmission links					✓		

Table 10: Range of options considered by SHEPD in determining solutions to replace PFE2

7.2 Summary of core options

Each of the core options were initially assessed against the following criteria:

Is the option capable of meeting future demand? Using Consumer Transformation and Leading the Way 2021 peak demand is 59.44MW to 60.99MW.

1. Does the option meet planning standards to provide long term N-1 security?
2. Does / Will the option meet technical readiness requirements?
3. Does this option meet the short term needs for Orkney? If we plan for this eventuality now, will the supplies on Orkney be secure in the short term?

These criteria were used to narrow down options to those which were viable, and we then assessed if replacement of PFE2 limited any viable future solutions. Table 11 sets out our assessment of option viability.

Future Scenario	Meets future demand	Provides security	Technical rediness	Short term needs met	Feasible Solution
1. Low carbon on-island solution	Uncertain	No	Uncertain	No	No
2. Single distribution link	No	No	Yes	Yes	No
3. Two distribution links	Yes	No	Yes	Yes	No
4. Two distribution links plus on-island solution	Uncertain	Yes	Uncertain	Yes	Uncertain
5. Three distribution links	Yes	Yes	Yes	Yes	Yes
6. Two distribution links and a Transmission link	Yes	Yes	Yes	Yes	Yes
7. One distribution link and a Transmission link	Yes	No	Yes	Yes	No
8. One D-Link, One T-Link & and on-island solution	Yes	Uncertain	Uncertain	Uncertain	Uncertain
9. One transmission link and on island solution	Yes	Uncertain	Uncertain	No	No
10. Two transmission links	Yes	Yes	Yes	No	No

Table 11: Identifying feasible options

A summary of the rationale to conclude the feasibility of solutions to replace PFE2, carried out in 2022, is included in Table 12.

Future scenario	Feasible	Rationale
1. Low carbon on-island solution	No	**Demand:** Unclear whether a low carbon, on-island solution of adequate scale is technically available. **Security:** Would not provide security of supply in the event of an outage. Even more uncertain as it's unclear if on-island solution of adequate scale is technically available. **Technical readiness:** Unclear whether a low carbon, on-island solution of adequate scale is technically available. **Short-term needs:** Unclear whether a low carbon, on-island solution of adequate scale is technically available. This would not be in place quickly to secure short-term security of supply issues. **P2 compliance:** Unclear whether a low carbon, on-island solution of adequate scale is technically available for normal demands. Additional solution would be required to provide back up in event of an outage.

Future scenario	Feasible	Rationale
2. Single distribution link	No	**Demand:** Would not provide for demand under normal scenarios. **Security:** Would not provide security of supply - in the event of an outage there would be no supply to the islands. **Technical readiness:** Meets technical readiness requirements. **Short-term needs:** Does not restore security of supply. **P2 compliance:** Is non-compliant in event of an outage.
3. Two distribution links	No	**Demand:** Meets future demand under DFES scenarios for normal conditions. **Security:** Would not provide for long-term security of supply without additional solution. **Technical readiness:** Meets technical readiness requirements. **Short-term needs:** Covers off short-term needs and restores network to current arrangements. **P2 compliance:** Is not P2 compliant in the long term on its own.
4. Two distribution links plus on-island solution	Uncertain	**Demand:** Two distribution links will provide for demand under normal scenarios based on DFES profiles. Unclear whether a low carbon, on-island solution of adequate scale is technically available to provide contingency. **Security:** Possible but unclear whether a low carbon, on-island solution of adequate scale is technically available. **Technical readiness:** Unclear whether a low carbon, on-island solution of adequate scale is technically available. **Short-term needs:** Would restore current network arrangements to provide short term security whilst on-island solution is developed longer term. **P2 compliance:** Uncertain whether a low carbon, on-island solution of adequate scale is technically available to provide long term back up in event of cable outage/fault.

Future scenario	Feasible	Rationale
5. Three distribution links	Yes	**Demand:** Provides for all demand whilst minimum of two cables are in service. **Security:** Provides long term network security as long as two cables are serviceable at any time. **Technical readiness:** Meets technical readiness requirements. **Short-term needs:** Covers short term needs and builds on current network arrangement. Likely require additional onshore infrastructure or switching. **P2 compliance:** Could make network P2 compliant.
6. Two distribution links and a transmission link	Yes	**Demand:** Provides for all demand either through single transmission link, two distribution links or combination of transmission and distribution. In the event of a single cable failure demand is secure. **Security:** Provides long term network security. **Technical readiness:** Meets technical readiness requirements. **Short-term needs:** Covers short term needs and builds on current network arrangement. Likely require additional onshore infrastructure or switching. **P2 compliance:** Could make network P2 compliant.
7. One distribution link and a transmission link	No	**Demand:** Meets demand under normal scenarios **Security:** Does not provide security as distribution link cannot provide for long term demand on its own in event of transmission outage. **Technical readiness:** Meets technical readiness requirements. **Short-term needs:** Provides in the short term under normal scenarios. **P2 compliance:** Is non-compliant under a transmission outage.

Future scenario	Feasible	Rationale
8. One distribution link, one transmission link and on-island solution	Uncertain	**Demand:** Unclear whether a low carbon, on-island solution of adequate scale is technically available to work in conjunction with a distribution link should transmission be out of service. **Security:** Possibly but depends on an on-island solution of adequate scale being technically available. **Technical readiness**: Unclear whether a low carbon, on-island solution of adequate scale is technically available. **Short-term needs:** Unclear whether a low carbon, on-island solution of adequate scale is technically available. **P2 compliance:** Unclear whether a low carbon, on-island solution of adequate scale is technically available to support the distribution link under a transmission outage.
9. One transmission link and on-island solution	No	**Demand:** Could provide for demand through transmission link but unclear whether a low carbon, on-island solution of adequate scale is technically available to support as back up. **Security:** Uncertain if a low carbon on-island solution could provide back up for significant periods if transmission link was out of service or in fault. **Technical readiness:** transmission link would be technically ready however it is unclear whether a low carbon, on-island solution of adequate scale is technically available. **Short-term needs:** Could not be developed quickly to cover immediate network risk and would have significant costs. **P2 compliance:** Unclear whether a low carbon, on-island solution of adequate scale is technically available.
10. Two transmission links	No	**Demand:** Could cater for short and long term demand. **Security:** Would provide N-1 security. **Technical readiness:** Cable can be procured and installed. **Short-term needs:** Could not be developed quickly to cover immediate network risk and would have significant costs. **P2 compliance:** Could provide compliance once in place.

Table 12: Rationale for solution feasibility

Of the four potentially feasible scenarios ('Yes' and 'Uncertain'), all have at least one distribution cable element. Therefore, installing PFE3 now does not prevent any of these options from progressing in the future, since PFW is also under consideration for replacement within RIIO-ED2. If the whole system analysis being undertaken for Orkney shows that only one distribution link is required, SHEPD will not replace PFW.

7.3 Options comparison tables

Further to the decision to progress a distribution link to replace PFE2, SHEPD assessed three cable sizes: 400mm^2 (32MVA), 500mm^2 (35.5MVA) and 630mm^2 (c.40MVA). The rationale for selecting these cable sizes for assessment was firstly that a 400mm^2 cable had only recently been installed in this location and had been deemed the most suitable installation at the time based on the data available. Since the installation of PFE2, SHEPD had undertaken the installation of a 500mm^2 subsea cable, which was fully type tested and was authorised to be used on the SHEPD distribution network. SHEPD also had revised DFES data which suggested a 400mm^2 cable may be close to capacity under normal conditions, with the approved 500mm^2 cable available for immediate order and install without delaying restoration timelines whilst providing additional capacity. SHEPD also considered if a larger capacity 630mm^2 would be suitable in this instance to maximise headroom capacity on the network.

SHEPD also gave consideration to the installation of a 66kV cable solution as part of the fault restoration, this was an option which was also considered as part of the PFE2 HVP and again was considered due to the potential increase in capacity that it could offer the network.

7.3.1 630mm^2 cable option

630mm^2 was judged to not be appropriate because, in order to release the full capacity of the cable the entire onshore network between Thurso South Grid and Scorradale, stretching across the mainland, Hoy and mainland Orkney, would need to be undergrounded. The undergrounding would be extensive and also require the replacement of all existing sections of underground cable along the route as well as the existing OHL. This would add significant cost [redacted] to release a capacity that the DFES scenarios indicate is not required by 2050, as noted in Table 13. Additionally, the majority of these assets are in good condition and are not anticipated to require asset replacement for a number of years, as detailed in Section 6.3.4.

In addition, should SHEPD have decided to proceed with the 630mm^2 cable, this could have delayed the project and subsequent fault restoration by up to 2 years. This is due to a requirement for the 630mm^2 cable to go through a full type test including an extended life test to be approved for use on the SHEPD network. A delay of this length was not acceptable given the significant network risk.

Onshore network interventions	Activities / volumes	Cost assumption	Costs	Comments
Onshore undergrounding	18.6km of undergrounding	SHEPD C1 unit rates	[redacted]	Cost may be conservative – may need larger cable size to counter peat de-rating, or imported specialist backfill to remote areas
Substation works (Scorradale)	Replacement of 2 x GM Regulators + new DVARs	SHEPD C1 unit rates for EHV Transformer	[redacted]	Regulators and DVARs are long lead specialist items and prices fluctuate regularly. These items are similar to EHV transformers.
Total cost estimate			[redacted]	

Table 13: Indicative costs of wider upgrading associated with 630mm² cable option (2020/21)

7.3.2 66kV cable option

A 66kV cable option was judged to not be appropriate in this instance for similar reasons to the 33kV 630mm² cable option. Again, in order to release the full capacity of the cable the entire onshore network between Thurso South Grid and Scorradale, stretching across the mainland, Hoy and mainland Orkney, would need to be undergrounded. The undergrounding would be extensive and also require the replacement of all existing sections of underground cable along the route as well as the existing OHL. In addition to these requirements SHEPD would also potentially require installing 33/66kV step up/down transformers at either end of the cable or change the network to operate at 66kV.

This would add significant cost ([redacted]) to release the full capacity of the asset. Similarly to the 630mm² 33kV cable, should SHEPD have chosen to proceed with the 630mm² cable, this would have delayed the project and subsequent fault restoration by up to 2 years. This is due to a requirement for the cable to go through a full type test including an extended life test to be approved for use on the SHEPD distribution network. A delay of this length was not acceptable given the significant network risk we were carrying while being reliant on the old PFE1 cable (which had already faulted) and the ageing PFW cable. Our analysis showed high risk of fault which needed to be mitigated as soon as possible. Therefore the 66kV option was not taken through to the CBA. A 66kV option is something that SHEPD will continue to consider as part of wider whole system analysis and future projects which may require the additional capacity which 66kV could offer.

7.3.3 400mm² and 500mm² cable options

CBAs were conducted to compare the 400mm² and 500mm² cables under the 2021 CT and LW scenarios. As noted previously, our analysis assumed no export on Orkney, which is rare given the wind and tidal generation already connected. Our analysis indicated that a 500mm² cable with max capacity of 35.5MVA was the most economic and efficient size for the new PFE cable.

Table 14 sets out the size and capacity characteristics of the core options assessed in the context of the 2021 DFES.

Option	Cable size		Max capacity	Current max demand*	Lowest 2050 max demand*	Highest 2050 max demand*
	PFE	PFW				
Current	400mm	300mm	62 MVA	34.4MW (~6MW minimum demand)	59.44MW (Consumer Transformation)	60.99MW (Leading the Way)
1	400mm	400mm	64MVA			
2	400mm	500mm	67.5MVA			
3	500mm	500mm	71MVA			

Table 14: Summary of cable options

Table 15 sets out a description of the assessed options and key advantages and disadvantages.

Options	Description	Advantages	Disadvantages
1. 400mm^2	Replace the existing PFE2 400mm^2 cable in its entirety with a new 400mm^2 cable.	Would be cheapest option. Meets immediate network requirements. Is type test approved. SHEPD has installed before.	Would be close to capacity under normal conditions following PFW intervention. Would not provide long term N-1 capability on its own.
2. 500mm^2	Replace the existing PFE2 400mm^2 cable with a new 500mm^2 cable.	Provides additional headroom over the 400mm^2 cable. Meets immediate requirements. Is type test approved. SHEPD has installed before.	Slightly more expensive than 400mm^2 option, [redacted]. Reduced bending radius versus 400mm^2 makes installation slightly more challenging. Would not provide long term N-1 capability on its own.
3. 630mm^2	Replace the existing PFE2 400mm^2 cable with a new 630mm^2 cable.	Would have a greater capacity than both other options.	More expensive than both other options. Has no type test for SHEPD. Would delay project by up to 2 years. Would be most expensive option. Full network requires undergrounding with new underground cable to release future capacity. Increases cable handling issues and makes installation more challenging with reduced bending

Options	Description	Advantages	Disadvantages
			radius. Would not provide long term N-1 capability on its own.

Table 15: Summary of investment options

Table 16 details the estimated costs of core option components.

Options	Volumes	Costs	Total costs
1. 400mm^2	Submarine cable installation	[redacted]	[redacted]
	400mm^2 Submarine Cable	[redacted]	
	Other costs	[redacted]	
	Future OHL temp uprating	[redacted]	
2. 500mm^2	Submarine cable installation	[redacted]	[redacted]
	500mm^2 Submarine Cable	[redacted]	
	Other costs	[redacted]	
	Future OHL temp uprating	[redacted]	
3. 630mm^2	Submarine cable installation	[redacted]	[redacted]
	630mm^2 Submarine Cable	[redacted]	
	Other costs	[redacted]	
	Onshore cabling works	[redacted]	

NOTES: The 'Future OHL temp uprating works' and 'Onshore cabling works' capture onshore works connecting both PFE and PFW which would be required to release the capacity on the onshore network to match that of the cables. The works included for Options 1 and 2 are planned to be completed under LRE by end RIIO-ED2 per our original Business Plan. For Option 3, the share of onshore cabling works to connect PFE only is estimated to cost [redacted], as noted in Section 7.3.1 and Table 13 (the value above also includes cabling for PFW at around [redacted]). While these works are required to release the cable capacity, they would not be part of a HOWSUM funding request as they fall under our LRE programme and are not included in 'Total costs'.

Table 16: Options cost comparison table

8 Detailed Option Analysis

8.1 Option 1: Do nothing

This is a theoretical option whereby SHEPD could have continued to operate the network with only the PFW cable in service and utilise KPS to provide diesel generation when demand exceeded the network ratings. SHEPD could also have reconnected and run the old PFE1 cable. Given the age and condition of the PFE1 cable this was not a realistic option as it was likely it would fail and not be able to return to operation.

Under the do-nothing options there would be a significant risk to security of supply as there would be no N-1 contingency to cover network demands, should the PFW also fail. This would also have made the Orkney network non-compliant with ER P2.

Generation export on Orkney would also have been significantly affected with only one circuit available for export.

This option was not a credible solution for the short, medium or long term needs of the island group. Nor was it an acceptable position for SHEPD in providing a secure and resilient network.

8.2 Option 2: Flexible solution or curtailment

SHEPD could have implemented a flexible solution by contracting with service providers on the islands to provide services as and when the network required, either under normal conditions or in the event of a failure of the PFW cable.

Although in theory this could have been a possible solution, the nature of the majority of generation on Orkney (wind and tidal) means these services would be intermittent and cannot currently be relied upon to provide supplies on demand without further development of storage solutions of material scale. Flexibility solutions tend to offer the bridging of small capacities for short timescales (2 to 3 hours) on a few occasions a year. The availability of third parties to provide for the significant level of demand required on Orkney, for a prolonged period of time, was unclear at the time and could have taken a significant length of time to develop.

This would have risked security of supply issues for customers whilst also maintaining a reduced export capability for the island group with only a single cable remaining in service for the foreseeable future.

Orkney network generation is already subject to a number of constraints associated with the Orkney ANM scheme and the implementation of this option would only have further exacerbated this issue, potentially leaving the island with no export route should the PFW cable have failed.

This was not deemed to be a credible solution at the time of identifying the PFE2 replacement, but will be assessed to understand its role as part of a future whole system solution, and has been reflected in SHEPD's future options analysis plans.

8.3 Option 3: Replacement of PFE2 with a new 400mm^2 subsea distribution cable

This option considers the replacement of the existing 33kV 400mm^2 cable in its entirety on a like-for-like basis.

SHEPD assessed reinstalling a new 33kV 400mm^2 Cu XLPE DWA 32MVA subsea cable between Murkle Bay on mainland Scotland and Rackwick Bay on Hoy. This option would have maintained the 32MVA rating of the PFE2 cable. This option would have required the installation of a shunt reactor at Thurso South Grid to protect the associated circuit breaker from the capacitive charging current seen on the entire circuit between Thurso and Scorradale.

The 150mm^2 Cu 50oc OHL on mainland Scotland and Hoy would require to be uprated to 70oc rating to release the full capacity of the cable in the future. This option would provide short to medium term security of supply for the islands in conjunction with the PFW circuit. The rating of the circuit would be close to capacity in 2050 under the 2021 LW DFES and future investment in PFW/O-H South and O-H Centre cables, to match the sizing of the new 400mm^2 PFE3 cable, under normal operating conditions.

Additional investment would have been required in the future to provide full N-1 capability out to 2050.

This cable was already fully approved for use on the SHEPD distribution network and could be implemented immediately with no delays to restoration programme.

It was anticipated to deliver this option the total cost would have been circa [redacted] in 2020/21 prices.

This option was progressed to the CBA stage.

8.4 Option 4: Replacement of PFE2 with a new 500mm^2 subsea distribution cable

This option considers the replacement of the existing 33kV 400mm^2 cable on a similar basis, but with a new larger capacity 33kV 500mm^2 Cu XLPE DWA subsea cable.

SHEPD assessed installing a new 33kV 500mm^2 Cu XLPE DWA 35.5MVA subsea cable between Murkle Bay on mainland Scotland and Rackwick Bay on Hoy. This option would increase the existing 32MVA rating of the PFE2 cable by 3.5MVA for an estimated increase cost of circa [redacted]. This option required the installation of a shunt reactor at Thurso South Grid to protect the associated circuit breaker from the capacitive charging current seen on the entire circuit between Thurso and Scorradale.

The 150mm^2 Cu OHL on mainland Scotland and Hoy would require to be uprated to 70oc rating to release the capacity of the cable in the future. This option would provide short to medium term security of supply for the islands in conjunction with the PFW circuit. The rating of the circuit would have additional headroom capacity in 2050 under the 2021 LW DFES and future investment on PFW/O-H South and O-H Centre cables, to match the sizing of the new 500mm^2 PFE3 cable, under normal operating conditions.

Additional investment would have been required in the future to provide full N-1 capability out to 2050.

This cable was already fully approved for use on the SHEPD distribution network and could be implemented immediately with no delays to restoration programme.

It was anticipated to deliver this option the total cost would be circa [redacted] in 2020/21 prices.

This option was progressed to the CBA stage.

8.5 Option 5: Replacement of PFE2 with a new 630mm^2 subsea distribution cable

This option considers the replacement of the existing 33kV 400mm^2 cable on a similar basis but with a new larger capacity 33kV 630mm^2 Cu XLPE DWA subsea cable.

SHEPD assessed installing a new 33kV 630mm^2 Cu XLPE DWA 40MVA (assumed) subsea cable between Murkle Bay on mainland Scotland and Rackwick Bay on Hoy. This option would increase the

current 32MVA rating of the PFE2 cable by circa 8MVA for an estimated increase cost of circa [redacted] over the 500mm^2 option. This option required the installation of a shunt reactor at Thurso South Grid to protect the associated circuit breaker from the capacitive charging current seen on the entire circuit between Thurso and Scorradale.

The entire electrical network of OHL and underground cables between Thurso South Grid on mainland Scotland and Scorradale S/S on Mainland Orkney would require to be reinforced / overlaid with new underground cable to release the capacity of this cable in the future, at significant cost. This option would have provided short to medium term security of supply for the islands in conjunction with the PFW circuit. The rating of the circuit would have additional headroom capacity over the 400 and 500mm^2 options in 2050 under the 2021 LW DFES and future investment on PFW/O-H South and O-H Centre cables, to match the sizing of the new 630mm^2 PFE3 cable, under normal operating conditions.

Additional investment would still have been required in the future to provide full N-1 capability out to 2050 for the Orkney Islands.

This cable is not currently approved for use on SHEPD distribution network and would be subject to passing a full Type Test including an extended life test. This will delay the fault restoration and project programme by up to two years. Therefore this solution cannot be implemented immediately. This will result in additional network risk, reduced generation output and increased reliance on diesel.

It was anticipated to deliver this option the total cost would be circa [redacted] in 2020/21 prices, excluding wider work to release onshore capacity.

This option was not progressed to the CBA stage due to the immediate requirement to restore security of supply, and given that the additional capacity potential of the cable was not indicated as being required under the DFES forecast. SHEPD could not accept the network risk associated with the programme delays of this option. There was also no guarantee that the cable would pass a Type test upon completion of manufacturing.

8.6 Options summary table

Table 17 sets out the estimated costs of each of the shortlisted solutions, based on the outturn costs for PFE3.

		CBA total results	C0 costs (£)				
			2023/24	2024/25	2025/26	2026/27	2027/28
1	Do nothing	N/A					
2	Flexible solution or curtailment	N/A					
3	400mm^2 subsea distribution cable		[redacted]				
4	500mm^2 subsea distribution cable		[redacted]				
5	630mm^2 subsea distribution cable	N/A				[redacted]	

CBA total results	C0 costs (£)				
	2023/24	2024/25	2025/26	2026/27	2027/28

NOTES: Note that additional onshore expenditure [redacted] require to release capacity of 630mm^2 solution

Table 17: Options summary - CBA and costs

The cost of the recommended option is listed in Table 18.

	Recommended Option	Investment Driver	Forecast actual costs (£m)					
			2023/24	2024/25	2025/26	2026/27	2027/28	2023/24
4	500mm^2 subsea distribution cable	M11b (CV26); R3	[redacted]	0	0	0	0	0

Table 18: Options summary – Forecast final cost

9 Cost Benefit Analysis (CBA)

This section of the report provides an overview of the expected costs for each option from the CBA undertaken and submitted to Ofgem. This represents the output of the detailed exercise undertaken to support the recommended investment strategy and that is now summarised within this EJP. This should be read in conjunction with review of Appendix 6B – Pentland Firth East 3 CBA LW and Appendix 6C – Pentland Firth East 3 CBA CT, which assess the Leading the Way and Consumer Transformation DFES respectively.

9.1 CBA of investment options

The decision to progress with the new cable is supported by CBA analysis. As part of the CBA analysis, SHEPD assessed the merits of waiting until a full whole system assessment for Orkney was complete before taking a decision to replace. The CBA and wider options assessment demonstrated that replacement now was a no-regret option, since the probability of a fault on PFE1 was very high and the costs of maintaining supplies on Orkney through diesel generation, until the whole system study was complete, would be extremely high. It was determined that the cable could be installed ahead of the full whole system analysis being completed and could be factored into the arrangements without being detrimental to the wider assessment or the future whole system solution itself.

Of the two options which were progressed to the CBA stage, these considered the replacement of the existing PFE2 cable with either a 400mm^2 or a 500mm^2 cable. As part of the CBA analysis we looked at the wider possible future investment and cable arrangement looking at the four cables which supply Orkney, considering various scenarios of these cables being 400mm^2 or 500mm^2. Therefore, capital expenditure was included as part of the CBA with these associated assets, namely replacement of PFE, PFW, O-H Centre and O-H South.

The CBA looking at the cable sizing considered the following four scenarios under both 2021 LW and CT DFES.

- Scenario 1 - 400mm² PFE and 400mm² PFW. 400mm² O-H Centre, 400mm² O-H South
- Scenario 2 - 400mm² PFE and 500mm² PFW. 400mm² O-H Centre & 500mm² O-H South
- Scenario 3 - 500mm² PFE and 500mm² PFW. 400mm² O-H Centre & 500mm² O-H South
- Scenario 4 - 500mm² PFE and 500mm² PFW. 500mm² O-H Centre & 500mm² O-H South

Table 19 shows the total capex element associated with each of the cable sections for each of the scenarios which was used within both the LW and CT CBAs. Please note the capex element was based on an estimated view.

CBA Scenario	Cable Circuit CAPEX Cost £m (2023/24 prices)				£m (2023/24)
	PFE	PFW	O-H Centre	O-H South	Total
Scenario 1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Scenario 2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Scenario 3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Scenario 4	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 19: **Total CAPEX associated with each CBA scenario**

Table 20, Table 21, Table 22 and Table 23 show how the capex for each element was assumed to be spread across financial years under each scenario. The capex costs were the same under all four scenarios within both the LW and CT DFES CBAs and hence the tables can be considered for both sets of CBA results.

Scenario 1	Circuit CAPEX Cost £m (2023/24 prices)				
	23/24	24/25	25/26	26/27	27/28
PFE	[redacted]	0	0	0	0
PFW	0	0	0	[redacted]	0
O-H Centre	0	0	0	[redacted]	0
O-H South	0	0	0	[redacted]	0

Table 20: Scenario 1 Assumed Spread of CAPEX per Financial Year

Scenario 2	Circuit CAPEX Cost £m (2023/24 prices)				
	23/24	**24/25**	**25/26**	**26/27**	**27/28**
PFE	[redacted]	0	0	0	0
PFW	0	0	0	[redacted]	0
O-H Centre	0	0	0	[redacted]	0
O-H South	0	0	0	[redacted]	0

Table 21: Scenario 2 Assumed Spread of CAPEX per Financial Year.

Scenario 3	Circuit CAPEX Cost £m (2023/24 prices)				
	23/24	**24/25**	**25/26**	**26/27**	**27/28**
PFE	[redacted]	0	0	0	0
PFW	0	0	0	[redacted]	0
O-H Centre	0	0	0	[redacted]	0
O-H South	0	0	0	[redacted]	0

Table 22: Scenario 3 Assumed Spread of CAPEX per Financial Year

Scenario 4	Circuit CAPEX Cost £m (2023/24 prices)				
	23/24	**24/25**	**25/26**	**26/27**	**27/28**
PFE	[redacted]	0	0	0	0
PFW	0	0	0	[redacted]	0
O-H Centre	0	0	0	[redacted]	0
O-H South	0	0	0	[redacted]	0

Table 23: Scenario 4 Assumed Spread of CAPEX per Financial Year

9.2 CBA results

As part of the optioneering exercise, a number of CBAs were produced utilising the Ofgem standard template.

- First CBA - Repair / Replace
- Second CBA - Repair / Replace / Cut and Recover
- Third CBA - Cable Sizing (4 CBAs produced considering 2020 and 2021 LW and CT DFES scenarios)

The first of these CBAs were around the option to repair or replace the PFE2 cable. Following extensive review, as described above, SHEPD deemed the repair option to be unacceptable on the basis that it may present a considerable risk of future failure. SHEPD therefore concluded a replacement cable would be required. An opportunity was then taken to review the size/capacity of the new installation whilst being mindful that a quick solution was required to restore security of supply to the islands. This then considered the 400mm^2 / 500mm^2 and 630mm^2 cable sizes, with 630mm^2 being discounted prior to the Third CBA analysis. This was done in conjunction with the long list, whole system optioneering highlighting this approach would not limit future whole system considerations to be taken forwards in ED2.

The most pertinent CBA results relate to the Third CBA – Cable sizing. The results of this analysis and the output NPVs can be seen in Table 24 and Table 25 below. 2021 DFES were the latest available at the time and the most appropriate to consider within the analysis. Under both LW and CT it was confirmed that in all scenarios the new PFE3 cable should be a 500mm^2 Cu XLPE DWA cable.

Options	NPV after 10 years (£m)	NPV after 45 years (£m)
400mm^2 PFE and 400mm^2 PFW. 400mm^2 O-H Centre, 400mm^2 O-H South	(24.75)	(47.24)
400mm^2 PFE and 500mm PFW. 400mm O-H Centre & 500mm O-H South	(24.73)	(46.98)
500mm PFE and 500mm^2 PFW. 400mm^2 O-H Centre & 500mm^2 O-H South	(24.64)	(46.66)
500mm^2 PFE and 500mm^2 PFW. 500mm^2 O-H Centre & 500mm^2 O-H South	(24.64)	(46.62)

Table 24: Comparison of CBA results for Leading the Way 2021 DFES

Options	NPV after 10 years (£m)	NPV after 45 years (£m)
400mm^2 PFE and 400mm^2 PFW. 400mm^2 O-H Centre, 400mm^2 O-H South	(24.75)	(47.24)
400mm^2 PFE and 500mm^2 PFW. 400mm^2 O-H Centre & 500mm^2 O-H South	(24.70)	(46.96)

Options	NPV after 10 years (£m)	NPV after 45 years (£m)
500mm² PFE and 500mm² PFW. 400mm² O-H Centre & 500mm² O-H South	(24.66)	(46.71)
500mm² PFE and 500mm² PFW. 500mm O-H Centre & 500mm² O-H South	(24.65)	(46.6)

Table 25: Comparison of CBA results for Consumer Transformation 2021 DFES

10 Deliverability and Risk

The project was considered to be deliverable given SHEPD had installed a cable in this location in 2020. Previous survey data and consents requirements were known and in some cases still in place from the previous installation. In order to facilitate a new cable, some short sections of the PFE2 cable had to be removed as they sat in the optimal cable route.

SHEPD aimed to reduce contractual and customer risk by taking an EPCI contracting approach – ensuring one contractor took responsibility for the full project, ensuring increased oversight and reducing the potential for dispute. This was primarily to ensure a future scenario where, should the cable fail in the first few years of operation when failure risk is high, there would be a single contractual reference point for remediation. This would increase quality oversight and avoid defensive arguments between manufacturer and installer preventing resolution from a SHEPD perspective.

This project has now been delivered.

10.1 Procurement and commercial strategy

10.1.1 Contracting approach

The EPCI is an Engineer, Procure Construct and Install contract. This is where one contractor takes full responsibility for delivering all aspects of the project. This is in contrast to the SDI contracts we have used in the past where one contractor constructs the cable and another contractor installs it.

The EPCI contract makes one party responsible for quality and in the event of a fault simplifies any defect resolution process, reducing the risk to customers caused by running the network in an abnormal fashion for an extended period as well as time, resource and expense involved in pursuing legal claims. Following the first round of tenders, the average project price for PFE3 was [redacted]. [redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

In September 2022 our analysis indicated that, taking account of these cost increases, an [redacted] for PFE3 would cost around [redacted].

We note that in the Transmission business, EPCI contracts are standard practice for high value projects; however, we have sought to assess the level of risk which an EPCI contract mitigates for customers vs the additional cost:

- Additional cost of EPCI: [redacted]
- Risk mitigated: [redacted]
- Strengthened control/management by a single contractor improving quality and reducing scope for disputes.

On the basis of these considerations, in addition to assessing the potential for failure (PoF) in the first 5 years and how this would be minimised by increased contractual cohesion, we are satisfied that the EPCI contract is justified and provides additional security for customers and is the appropriate choice of contract type for a large project of this nature [redacted].

10.2 Deliverability strategy

Our RIIO-ED2 Business Plan Deliverability Strategy (Annex 16.1) describes our approach to evidencing the deliverability of our overall plan as a package, and its individual components. Testing of our EJPs has prioritised assessment of efficiency and capacity, and this has ensured that we can demonstrate a credible plan to move from SHEPD's RIIO-ED1 performance to our target RIIO-ED2 efficiency.

We have also demonstrated that SHEPD's in house and contractor options can, or will through investment or managed change, provide the capacity and skills at the right time, in the right locations. This assessment has been part of the regular assessment of our EJPs, IDPs and BPDTs. For the investment proposed under our subsea cable related EJPs, we have been developing our RIIO-ED2 Commercial & Deliverability Strategy and engaging with our supply chain to ensure we can deliver the solutions proposed, while identifying and managing the risks presented by the complex and challenging nature of the projects.

The delivery programme for all subsea cables in RIIO-ED2 is being determined through detailed planning and engagement with marine installation contractors and cable procurement opportunities. In addition, early stakeholder engagement will significantly de-risk project schedules and deliver value.

For more on our approach to Deliverability please see the HOWSUM Core Narrative document.

10.3 PFE3 delivery

An EPCI (Engineering, Procurement, Construction and Installation) contract was awarded in November 2022 to the principal contractor for design, route surveys, supply and installation of the submarine cable system. The principal contractor started onshore construction and offshore construction and cable lay works in June 2023. The submarine cable lay was completed in July 2023, and was subsequently buried, protected, stabilised and tested. Onshore construction also included decommissioning of the PFE2 cable in the intertidal areas.

SHEPD standards and circuit studies specified the requirement for a 5 MVAr 33kV Shunt Reactor located at Thurso Grid South to reduce the charging current of the relevant circuit to within acceptable limits. The Shunt Reactor scope was managed by SHEPD, with a contractor supplying the Shunt Reactor and another managing the civils and electrical works at Thurso South Substation.

The execution of all submarine cable and shunt reactor works completed in September 2023 ready for the outage and commissioning works. On completion of these works the temporary overhead lines were dismantled by the SHEPD's Regional team.

The Shunt Reactor Factory Acceptance test was completed successfully and witnessed by SHEPD. The Shunt Reactor was delivered to site and installed at Thurso South Substation. Site acceptance testing was completed and picked up a number of snag items to be rectified. Civil and electrical works were completed at Thurso South in advance of the outage planned to allow for energisation.

The PFE replacement submarine cable and shunt reactor at Thurso South were both energised in September ahead of the baseline programme. All commissioning works were successfully completed including protection checks and upgrades at Thurso South and Scorradale, jointing of the submarine cable to the onshore network, and testing prior to energisation. All key delivery works are set out at Table 26.

Key activities	Approximate dates
• Mobilise for Murkle Bay site set-up	21 Jun 2023
• Mobilise for Rackwick Bay site set-up	28 Jun 2023
• Mobilise PLGR Vessel	22 Jun 2023
• Mobilise MPV and load rock-bags	28 June and 01 July
• Cable pull-in, lay and complete pull-in	04 July to 15 July 12
• Mobilise TSV	02 July
• Cable Load-in at Nigg	16 July to 19 July 23
• Shunt Reactor delivered at Thurso	31 July 23
• Submarine cable jointed and CIS installed	28 Aug 23
• Submarine cable buried and stabilised	28 Aug 23
• Shunt reactor civil and elec. works completed	08 Sep 23
• Outage to energise cable and Reactor	18 Sep to 30 Sep 23

Table 26: PFE3 delivery dates

11 Outlook to 2050

The option which has been progressed by SHEPD in this instance will be a key enabler as part of a future whole system solution for the Orkney Island Network.

Future whole system analysis will be conducted in 2024 looking at the longer picture out to 2050, ahead of the January 2025 HOWSUM reopener window. The further whole system analysis will look at further solutions which build upon this initial investment which will be fit for purpose for 2050 and beyond.

12 Conclusion and Recommendation

Further to the failure of PFE2, in SHEPD's view, there was a clear, urgent need to take action to procure a replacement solution to meet security of supply for the Orkney islands. Based on the additional information gathered through further DFES analysis following the failure of PFE2, SHEPD refined its view of subsea cable requirements and its specification was determined on the basis of its ability i) to support short- and long-term demand and generation needs, and ii) to play a 'least regrets' role in future whole system solutions for the Orkney islands.

SHEPD has no defined funding for PFE3 in RIIO-ED1 or RIIO-ED2, and is therefore seeking to recover [redacted] (2020/21) under the HOWSUM reopener mechanism. The benefits associated with delivery of this project are significant and include improved asset health and reliability, contribution to security of supply and meeting demand and generation needs out to 2050. The cable will play a core and complementary role in the future Orkney whole system solution.

CV description	Asset Category	Total (£m)
M11b (CV26); R3	EHV Subsea Cable	[redacted]
	EHV Transformer (Shunt Reactor)	[redacted]
Notes	There was a requirement to install a 5MVAr shunt reactor as part of the works. There is no specific deliverable line for a reactor, but these are in effect like an EHV transformer and as such a single addition is claimed as part of the project under CV26.	

Table 27: Summary of project costs

13 References

The documents detailed in Table 28, Table 29 and Table 30 should be used in conjunction with this document.

Table 28 - Scottish and Southern Electricity Networks Documents

Reference	Title
N/A	Hebrides and Orkney Whole System UM Core Narrative
N/A	Appendix 6B – Pentland Firth East 3 CBA LW
N/A	Appendix 6C – Pentland Firth East 3 CBA CT

Table 29 – External Documents

Reference	Title
N/A	Distribution Future Energy Scenarios 2022 Results and Methodology Report, North of Scotland licence area, March 2022

Table 30 – Miscellaneous Documents

Title
None at this stage

14 Subsequent Sections

N/A

15 Revision History

No	Overview of Amendments	Previous Document	Revision	Authorisation
01	First Issue	N/A	01	D.Taylor
02				

Appendix A Definitions and Abbreviations

Acronym	Definition
ANM	Active Network Management
BAU	Business As Usual
CAPEX	Capital expenditure
CBA	Cost Benefit Analysis
CBRM	Condition Based Risk Management
CDM	Construction Design Management
CEM	Common Evaluation Methodology
CI	Criticality Index
CIS	Cable system, Installation and Service
CMZ	Constrained Management Zone
CNAIM	Common Network Assets Indices Methodology
CT	Consumer Transformation
DEG	Distributed Embedded Generation
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DSO	Distribution System Operator
DTS	Desk Top Survey
DWA	Double Galvanised Steel Wire Armour cable
EAC	Estimate At Completion
EHV	Extra high voltage
EJP	Engineering Justification Paper
EoL	End of Life
EPCI	Engineering, Procurement, Construction, and Installation contract
ER P2	Engineering Recommendation P2 Issue 8 2023
EV	Earned Value
FES	Future Energy Scenarios
GB	Great Britain
GSP	Grid Supply Point
HI	Health Index
HOWSUM	Hebrides and Orkney Whole System Uncertainty Mechanism
HVP	High Value Project Uncertainty Mechanism under RIIO-ED1 price control
HVDC	High Voltage Direct Current
KPS	Kirkwall Power Station
kV	kiloVolt

Acronym	Definition
LIRA	Line Resonance Analysis
LW	Leading the Way DFES
MPV	Multi Purpose Vessel
MVA	Mega Volt Ampere
MW	Megawatt
NPV	Net Present Value
OHL	Overhead Line
OPEX	Operating expenditure
PFE	Pentland Firth East
PFE1	Pentland Firth East 1 cable
PFE2	Pentland Firth East 2 cable
PFE3	Pentland Firth East 3 cable
PFW	Pentland Firth West
PO	Purchase Order
RIIO-ED1, 2, 3	RIIO Electricity Distribution Price Control periods 1, 2 and 3
ROV	Remotely Operated Vehicle
SBT	Science Based Target
SEPD	Southern Energy Power Distribution
SHEPD	Scottish Hydro Electric Power Distribution
SWA	Steel Wire Armoured cable
SSEN	Scottish and Southern Electricity Networks
TO	Transmission Operator
UM	Uncertainty Mechanism
XLPE	Cross-linked polyethylene cable