Scottish & Southern Electricity Networks

RIIO-ED2 Engineering Justification Paper (EJP)

6.6kV/11kV Underground Cables

Investment Reference No: 312_SSEPD_NLR_HV_UG

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Investment Summary Table

Table 1 below provides a high level summary of the key information relevant to this Engineering Justification Paper (EJP) and the replacement of 6.6/11kV underground cables.

Table 1: Investment Summary

Name of Programme	6.6/11kV Underground Cables
Primary Investment Driver	Non-Load: Asset Condition
Investment category	312_SSEPD_NLR_HV_UG
Output type	HV_UG
Cost (£m)	45.0
Delivery Year	RIIO-ED2 (2024 – 2028)
Reporting Table	CV7b: Asset Replacement

	Licenced Area	**ED1 (£m)**	**ED2 (£m)**	**ED3+ (£m)**
Spend Apportionment	**SEPD**	-	[redacted]	-
	SHEPD	-	[redacted]	-

RIIO-ED2 Spend (£m) – 6.6kV/11kV Underground Cable

	Area	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
CV7 Asset Replacement RIIO-ED2 Spend (£m)	**SEPD**	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	SHEPD	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

RIIO-ED2 Volumes (km) – 6.6kV/11kV Underground Cable

	Area	**2024**	**2025**	**2026**	**2027**	**2028**	**Total**
CV7 Asset Replacement RIIO-ED2 Volumes (km)	**SEPD**	30	35	40	45	50	**200**
	SHEPD	17	18	19	20	21	**95**

1 Executive Summary

The Primary Investment Driver described within this Engineering Justification Paper (EJP) is the condition or health of our 6.6/11kV underground (UG) cable network. Without further intervention is this asset category during RIIO-ED2 we expect to see an increase in costly cable faults, which will significantly impact both the reliability and affordability of the distribution network for our network customers.

Our document ***Safe and Resilient (Annex 7.1)*** describes our approach to determine the Non-Load baseline for capital expenditure. This encompasses capital investment to address assets in poor health deemed to be at or near their “end of life”.

RIIO ED1 fault trends demonstrate that increasing proportions of the 6.6/11kV UG cable network are deteriorating in condition as the network ages. The age of the 6.6/11kV UG cable network means that the fault trends are expected to continue to increase without additional investment. Based on current trends, it is also possible that the average fault costs when responding to a cable fault continues to increase as the condition of each circuit continues to degrade over time.

Due to the large volumes of 6.6/11kV UG cable that are approaching end of life, a steady and sustained overlay programme will be required over the next two to three decades. This will become increasingly important as the transition to Net Zero and the electrification and heat and transport accelerates. A robust and healthy cable network will be a key enabler of a Net Zero world.

As a result, we are proposing the replacement of **200km** “end of life” 6.6/11kV UG cable in the Southern Electric Power Distribution PLC (SEPD) licence area during RIIO-ED2 and a further **95km** in Scottish Hydro Electric Power Distribution PLC (SHEPD).

This volume represents an increase in the 6.6/11kV UG cable overlay volumes when compared to RIIO-ED1. This is primarily a result of the ageing 6.6/11kV cable network and the associated fault trends observed during ED1. The total cost to deliver the proposed volumes during RIIO-ED2 is **£45.04m**

Cost Benefit Analysis (CBA) alongside analysis of historic fault trends have been undertaken to prove the need and cost effectiveness of the volumes proposed within this EJP. This analysis indicates that a steady ramp up in volumes will be required through RIIO-ED2 and into RIIO-ED3 to maintain the performance of our 6.6/11kV UG cable network.

Whilst the primary driver for this investment is the condition of our 6.6/11kV UG network, we also intend to maximise benefits associated with this investment for our network customers by adopting larger diameter cable as standard (240mm^2 or 300mm^2) during cable overlays. This marginal incremental investment will protect the network against future load growth and will enable the ongoing electrification of the energy system, a key enabler of Net Zero.

Since the health of a cable is reflected in the frequency of disruptive cable faults, the proposed overlay volumes will result in reduction in the number of cable faults that impact our network customers and the costs associated with responding to these faults when compared against no addition intervention.

Importantly, our CBA analysis has shown that a large increase in 6.6/11kV UG cable overlay volumes can be justified when comparing our current fault OPEX costs to the likely overlay cost, far higher than the volumes we are proposing in this EJP which have been capped due to our current deliverability limit. Our CBA assessment has shown that up to **581km (SEPD)** and **609km (SHEPD)** of 6.6/11kV UG cable overlay could be justified during RIIO-ED2 if there were resources available to deliver this.

2 Introduction

This Engineering Justification Paper (EJP) describes our proposed non-load related investment plan for the 6.6/11kV UG cable asset category during RIIO-ED2. The Primary Investment Driver described within this EJP is the health or condition of our 6.6/11kV UG cable network. This is reflected in the UG cable faults and the resulting network outages faced by our network customers.

Section 3 of this EJP provides useful background information on our 6.6/11kV UG cable network and explains the importance of this asset category for our electricity distribution network and our network customers. Since the UG cable network is largely inaccessible for routine inspection, it is challenging to directly determine the condition of each circuit. For this reason, it is necessary to consider fault trend data in order to determine the likely condition of our UG cable network and to determine where our circuits are approaching end of life.

Consequently, fault analysis is presented in Section 3 to determine the current condition of this asset category. In addition, to further understand the requirement to replace our 6.6/11kV UG cable, asset age profiling has been conducted, which provides useful insight into overall volumes of cable that will need to be overlaid (i.e. replaced) in RIIO-ED2 and in upcoming price controls

Section 4 of the EJP then describes the primary and secondary investment drivers for this asset category and the corresponding areas of the Business Plan Data Tables (BPDTs) which are used to capture the costs required to address these drivers for investment.

Section 5 describes our stakeholder engagement activities which have informed our proposed intervention strategy for our UG cable network during RIIO-ED2.

Section 6 then details the intervention options that will be available to us during RIIO-ED2 to address the primary and secondary investment drivers. The advantages and disadvantages of each intervention option is described in this section along with a conclusion on which we intend to take forward for RIIO-ED2.

Section 7 provides the results of our detailed analysis and the resulting cable overlay volumes that we are proposing for RIIO-ED2. This includes fault trend analysis alongside a review of the age profile of our UG cable network and the intervention volumes that each would indicate is necessary. We also provide a description of the CBA that has been developed to justify the proposed volumes and quantify the number of qualifying circuits for our 6.6/11kV UG cable overlay programme. Finally, the deliverability and the cost efficiency of the of the proposed volumes are discussed within this section of the EJP.

Section 8 provides a brief conclusion to this EJP and summarises the key findings of our assessment of the intervention requirement during RIIO-ED2 on our 6.6/11kV UG cable network. This is followed by an Acronym table and an Appendix of the relevant polices and standards that should be considered alongside this EJP.

3 Background Information

This section of the report provides useful background information which has been used to inform the non-load related investment strategy for the 6.6/11kV UG cable asset category. This includes a description of the assets under consideration, the relevant SSEN and industry policies, and the approach used to identify those that require intervention during RIIO-ED2.

3.1 6.6/11kV Underground Cable

There are a number of different types of solid cables in operation; Paper Insulated Lead Covered Cable (PILC), Paper Insulated Corrugated Aluminium Sheath Cable (PICAS), Cross-Linked Polyethylene Cable (XLPE). Cable capacity and diameter varies according to the demand associated with the local HV network.

Management of such a large and diverse asset base spread across a large geographical area is extremely challenging particularly when a large percentage of the asset category was installed many decades ago.

Table 2 below shows the quantity of 6.6/11kV UG cable assets in both SEPD and SHEPD as of 2019.

Table 2: SSEN 6.6/11kV UG Cables by Type in 2019

	SHEPD			SEPD		
Asset Type	**km**	**# Circuits**	**Average Age**	**km**	**# Circuits**	**Average Age**
6.6/11kV UG cable	5,450	1,669	32 years	17,105	3,383	41 years

The failure of a 6.6/11kV UG cable is likely to lead to an outage for the network customers it feeds depending on the connectivity and automation of the surrounding network. As such, it is critical that we maintain the condition of this asset category to prevent a reduction in the quality of service for customers and to maintain the safety of our staff and the public.

Preventing the end-of-life failure of these cables will also avoid costly reactive replacement, which can be significantly more expensive than the cost associated with planned proactive replacement before failure.

The policies, manuals and standards and operational restrictions that govern the management of 6.6/11kV UG cable are listed within Appendix 1.

3.2 6.6/11kV UG Cable Age Profile

Figure 1 and Figure 2 show the Age Profiles of our 6.6/11kV UG cable for both SEPD and SHEPD. These show the total length of cable (km) installed within both licence areas during each decade.

This data is ***provided for information purposes only*** and cannot be used in isolation to justify any investment in the asset category. However, there is a close correlation between asset age and the health of each circuit, so this data is useful to review alongside historic fault rates.

These Age Profiles also demonstrate the variance in the rate at which the network was built over time. This variance can result in sudden step changes in the volume of cable that must be overlayed from one price control to the next, particularly if a specific cable type installed in any given decade begins to show increasing trends of failure.

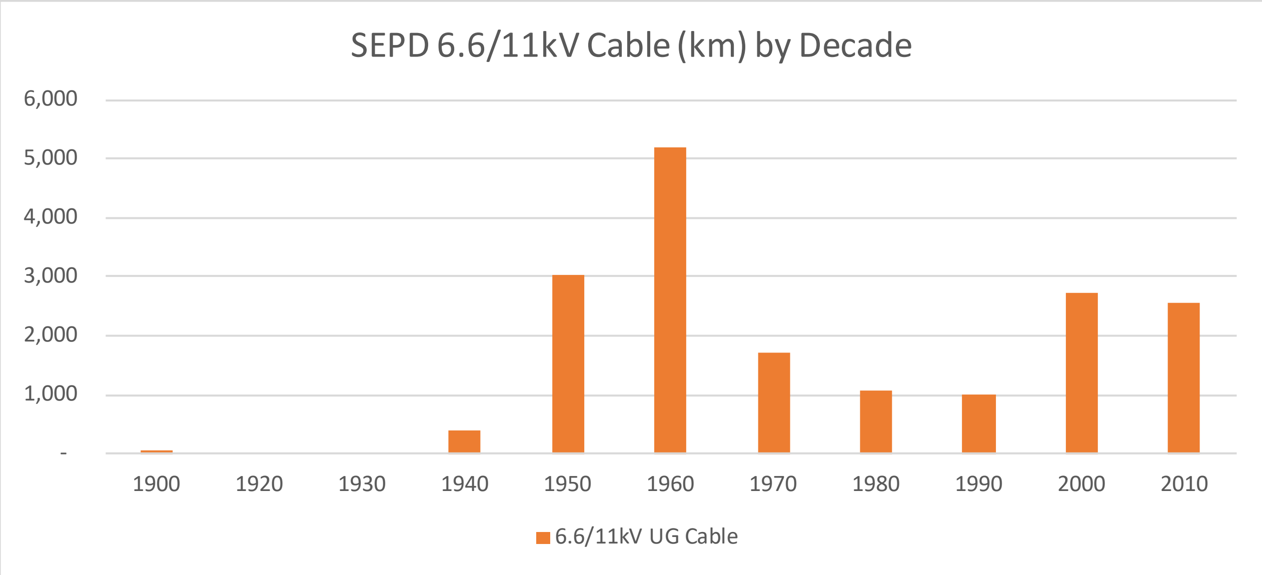

Figure 1: Age Profile for 6.6/11kV UG Cable – SEPD

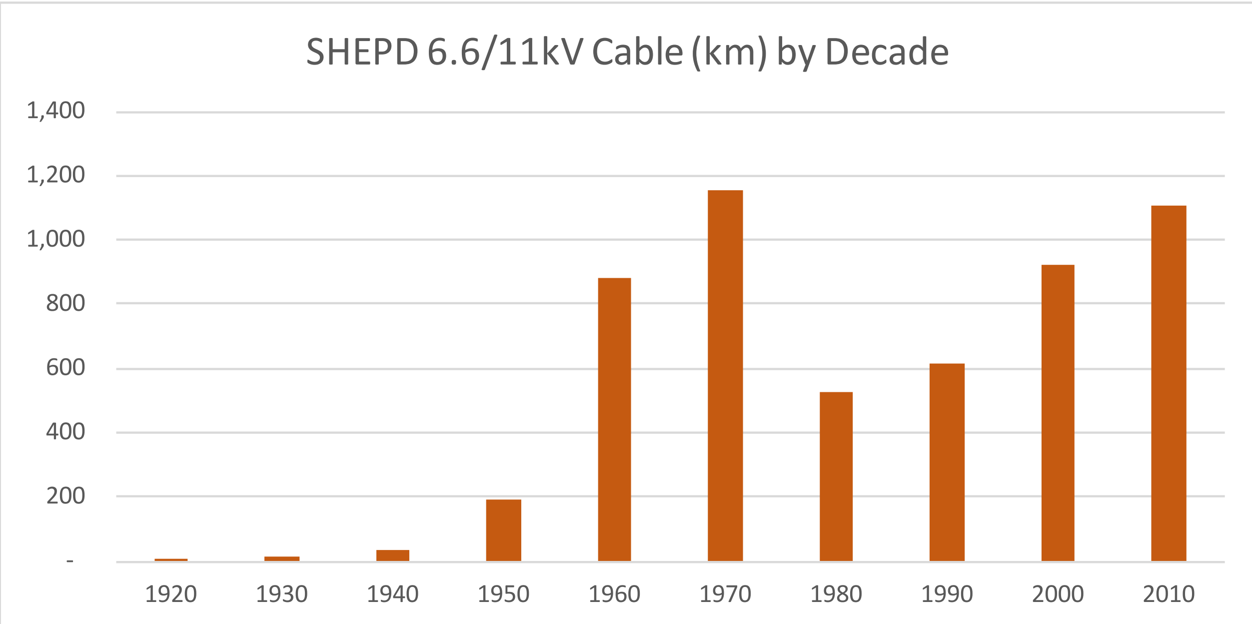

Figure 2: Age Profile for 6.6/11kV UG Cable – SHEPD

3.3 Historic Fault Trends

As discussed, the health or condition of our 6.6/11kV UG cable network is reflected in the number of cable faults we see each year. It is difficult to directly measure the condition of our UG cable as we do with other assets like Transformers as they are buried under the ground. As such, analysis of fault trends is a crucial tool used to determine in a cable circuit requires intervention.

These cable faults can be very disruptive for our network customers and can directly lead to unplanned outages which impacts our Interruptions Incentive Scheme (IIS) performance.

The following subsections show the number of faults we have experienced between 2015 and 2021 across both our own distribution licenced areas.

3.3.1 SEPD Cable Fault Trends

Figure 3 shows that the number of faults recorded in SEPD attributed to 6.6/11kV UG cables. Over this period the number of faults has increased from 2016 to 2021. This indicates that the condition of our UG cable circuits in SEPD in reducing despite the overlay volumes undertaken during RIIO ED1.

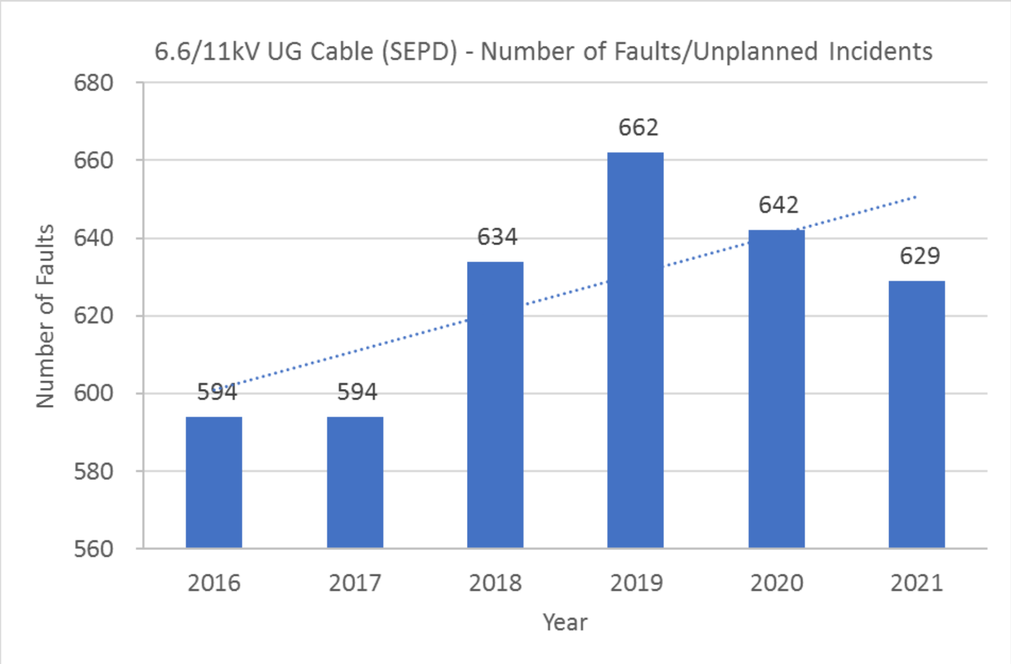

Figure 3: Number of faults recorded on 6.6/11kV UG cables SEPD

Figure 4 shows the average intervention cost per cable fault between 2014 and 2021. As illustrated the cost to respond to a cable fault is steadily increasing over time as our UG cable asset base continues to age. This data demonstrates the need to reduce the number of cable faults as the cost to respond to these faults reactively is increasing year upon year.

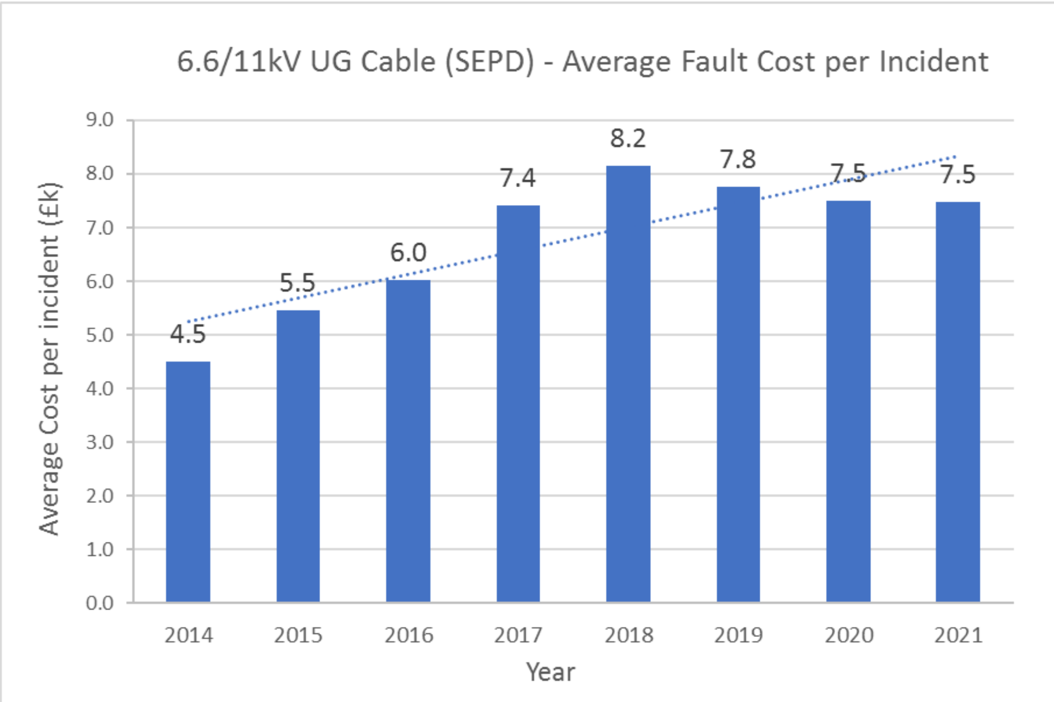

Figure 4: Average Intervention Cost per Fault Incident (£k) for 6.6/11kV UG cables SEPD

In addition, Figure 5 also shows the average fault intervention cost from 2014 to 2021. We have then extrapolated these results out to 2030 to show how the cost may continue to increase at a linear rate if significant investment is not undertaken to prevent further ageing and degradation of this asset category.

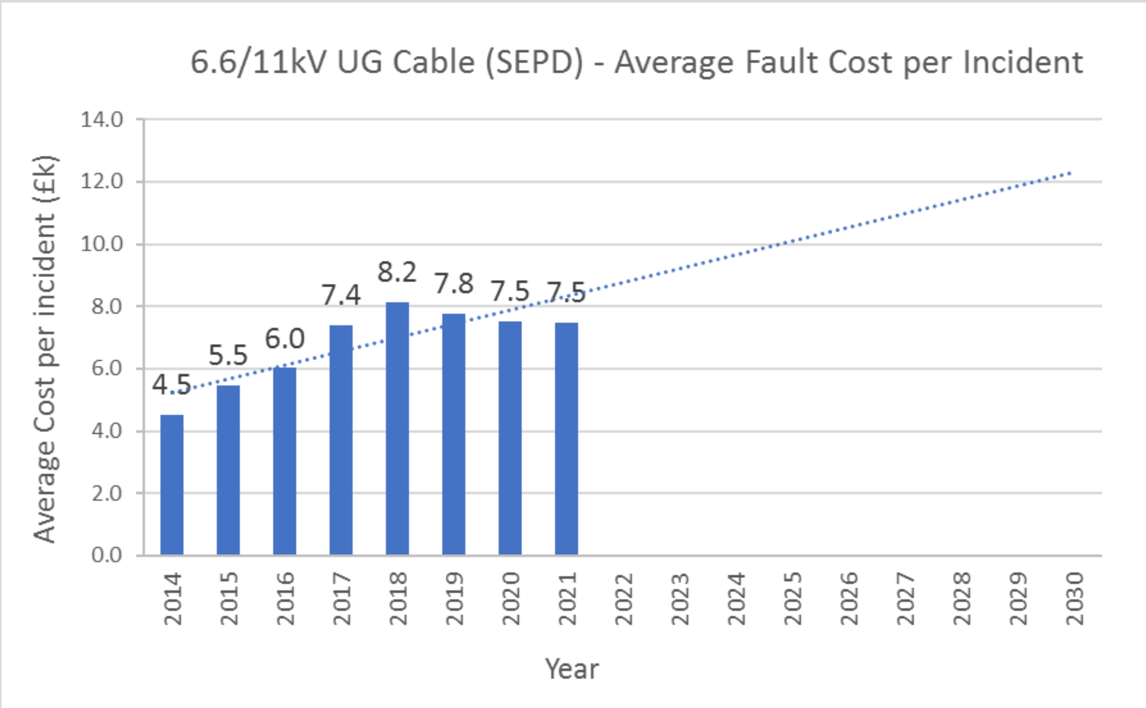

Figure 5: Average Cost per Fault Incident for 6.6/11kV UG Cables SEPD

Linear and exponential trend lines for the fault intervention costs indicate the longer-term trends that can be expected under current network status.

It is noted that the large volumes of cable installed in the 1950's and 1960's (refer to 3.2 for further details) that are anticipated to enter end of life within a relatively short duration will likely produce an upward pressure on the historic trend lines, further increasing fault levels and the associated costs of intervention.

3.3.2 SHEPD Cable Fault Trends

Compared to the obvious increasing trend seen in SEPD, the SHEPD trendline is reducing, with significant movement up and down between the years.

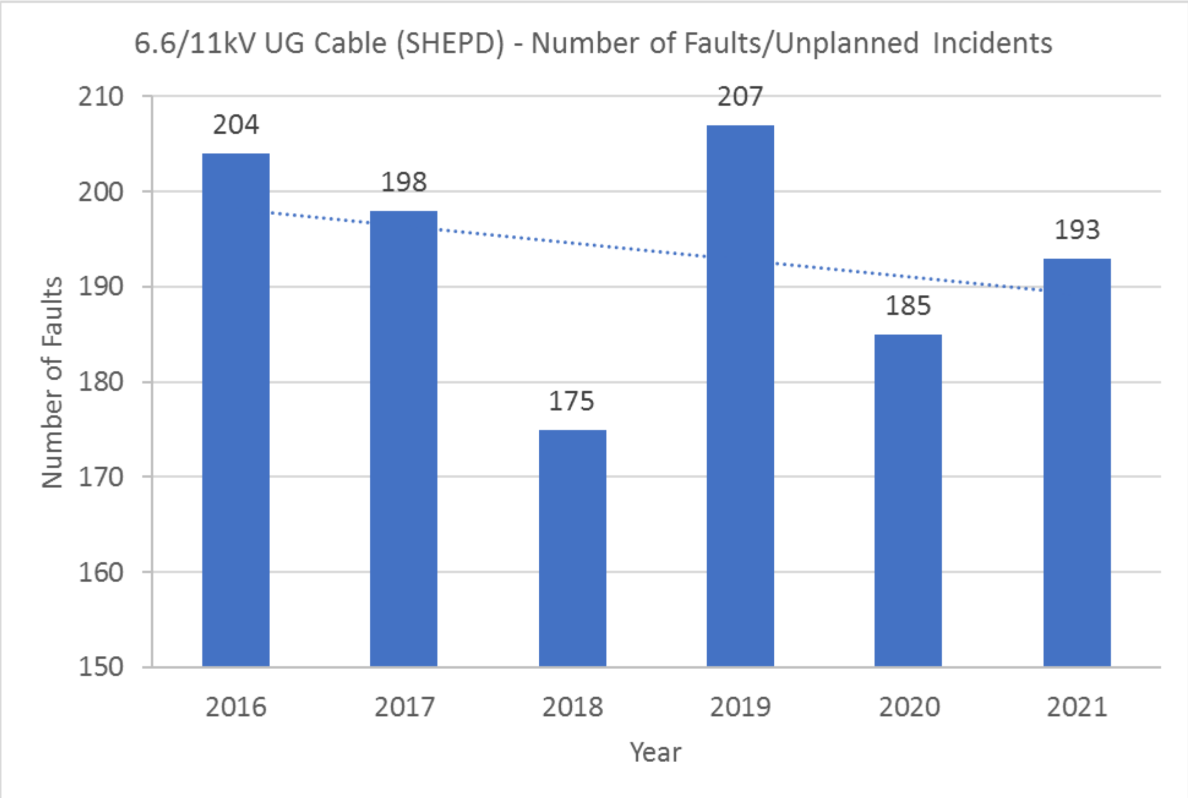

Figure 6: Number of faults recorded on 6.6/11kV UG cables SHEPD

The average intervention cost per cable fault for SHEPD is shown in figure 7. As with SEPD, there is an upwards trend in this cost; it has more than doubled from 2014 to 2021, despite the frequency of incidents remaining relatively stable.

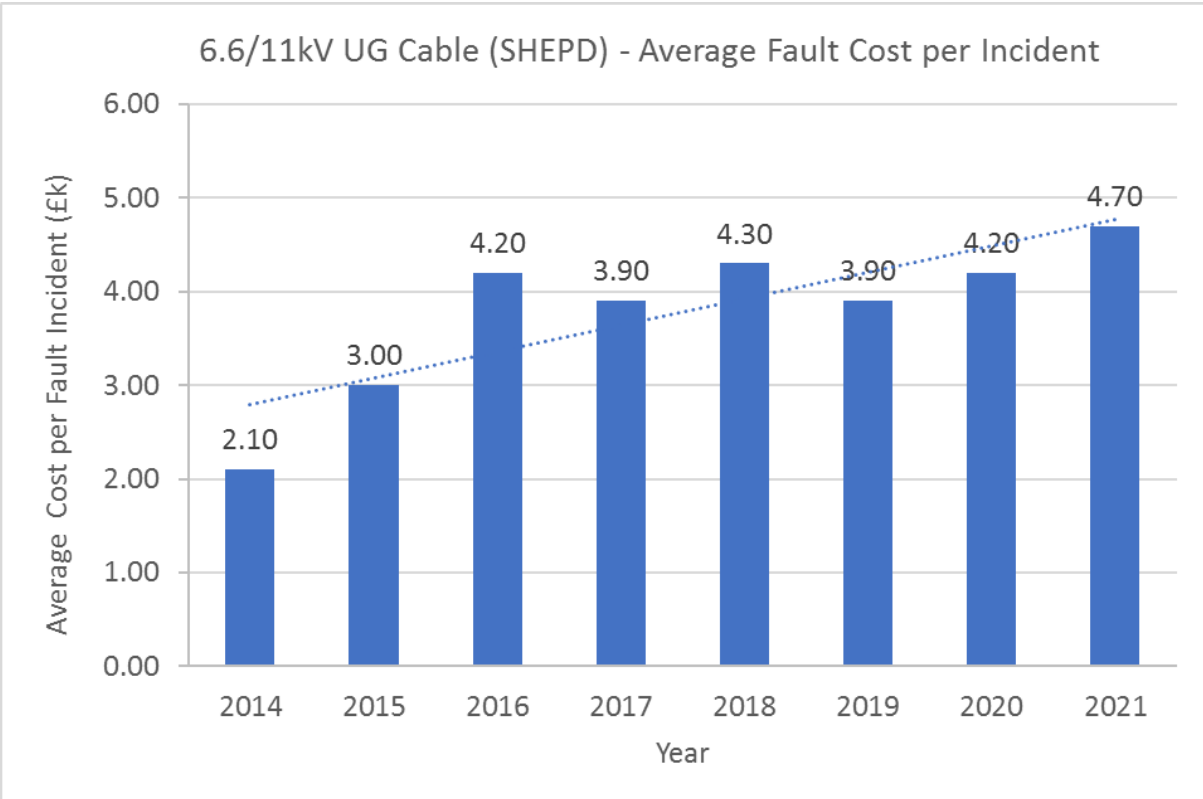

Figure 7: Average Cost per Fault Incident (£k) for 6.6/11kV UG cables SHEPD

Figure 8 also shows the average fault intervention cost for 6.6/11kV cable in SHEPD. The graph shows the potential future cost associated with responding to 6.6/11kV UG cable faults if the current trend continues at a linear rate. The fault intervention cost per km associated with the SHEPD 6.6/11kV UG cables are lower than for SEPD but still show signs of increasing over time.

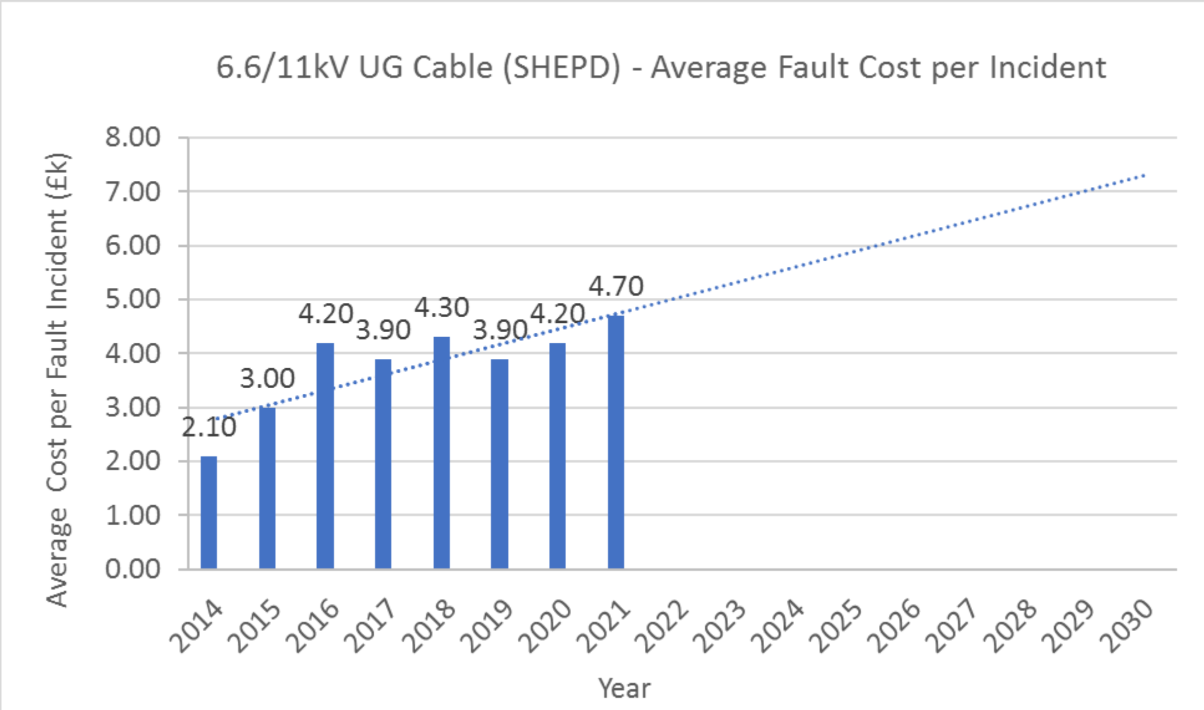

Figure 8: Average Cost per Fault Incident for 6.6/11kV UG Cables SHEPD

4 Introduction to the Investment Under Consideration

This section of the EJP provides an introduction to the investment under consideration, including a description of the asset category itself and the primary and secondary investment drivers that lead to the need to invest in this asset category.

4.1 Introduction to the Asset Category

High voltage (HV) includes all voltage levels above 1,000 volts but less than 22kV. This includes 6.6/11kV UG cables. The 6.6/11kV distribution system comprises overhead lines, UG cables and the substations used to transform voltages from the 6.6/11kV system to the higher and lower voltages.

On the SHEPD distribution network, the volume of 6.6/11kV UG cable is 5,450km, versus 21,489km of overhead lines. The cable proportion is therefore significant, comprising 20% of the overall 6.6/11kV circuits in SHEPD.

In SEPD there are 17,105 km of 6.6/11kV UG cable, which are of various types, age, design and condition. There are 13,140km of HV overhead line, and so UG cables comprises 57% of the overall 6.6/11kV circuits.

The primary investment drivers for this asset category is the condition or health on our UG cable circuits. The health of the UG cable network is reflected in network performance and fault rates. Poor performing and ageing cable assets can reduce the quality of service for network customers and lead to both safety and environmental consequences of failure if not managed effectively.

Whilst cable failures are not as frequent as OHL failures, when they do occur, they can take longer to repair than OHL failures and therefore lead to reduced network resilience for prolonged periods of time. The cost of intervention is also higher given that disruptive excavation of roads and public walkways is often required to repair a cable fault. During this repair time, there is also a possibility of a second fault leading to a wider scale network outage.

4.2 Primary Investment Drivers

As previously discussed, the primary investment driver considered within this EJP is the condition or health of our 6.6/11kV UG cable network. Maintaining the health of this asset category is important when looking to improve the number of outages experienced by our network customers.

The health of the UG cable network will also be a critical enabler of the transition to Net Zero, as the electrification of heat and transport accelerates. The importance of this asset category will only increase as the energy system is decarbonised.

When a cable fails, we record the cause of each failure to better understand the failure mechanisms of our network assets. This is also the case with our UG cables, where we record the cause of the fault and categorise this into a primary or secondary drivers.

The Primary drivers are fault causes that are directly related to the condition of the cable whereas secondary drivers encompass fault causes that are likely to decrease the condition of the cable e.g. through damage to the cable or the need to joint the cable which introduces a new weak point in the circuit. The failure mechanism that fall into these categories are listed in Table 3 below:

Table 3: Primary and Secondary causes of UG cable Faults

Primary (condition related) Drivers of UG cable Fault	Secondary Drivers of UG cable Fault
Condensation	Accidental Contact, Damage or Interference
Corrosion (e.g. Bi-Metal Contact)	Weather related faults (flooding, freezing etc)
Deterioration due to Ageing or Wear	Fire not due to faults
Faulty Installation or Construction	Ground subsidence
Faulty Manufacturing, Design, Assembly, Materials	Metal theft
Premature Insulation Failure	Tree (roots) related faults
Transient faults	Farm and Domestic Animals
	Vermin, Wild Animals, Insects

Figure 10 shows the proportion of 6.6/11kV UG cable faults on the SEPD network that are attributed to the primary and secondary causes and to other causes, as well as showing the proportion attributed to unknown causes. Figure 11 shows the same for SHEPD.

It is clear that the primary cause of cable faults are the condition related failure mechanisms (primary causes). These account for over 77% of recorded faults on UG cables between 2015-19 in SEPD and over 80% in SHEPD. This demonstrates the need to ensure our UG cable network remains healthy during RIIO-ED2 and beyond.

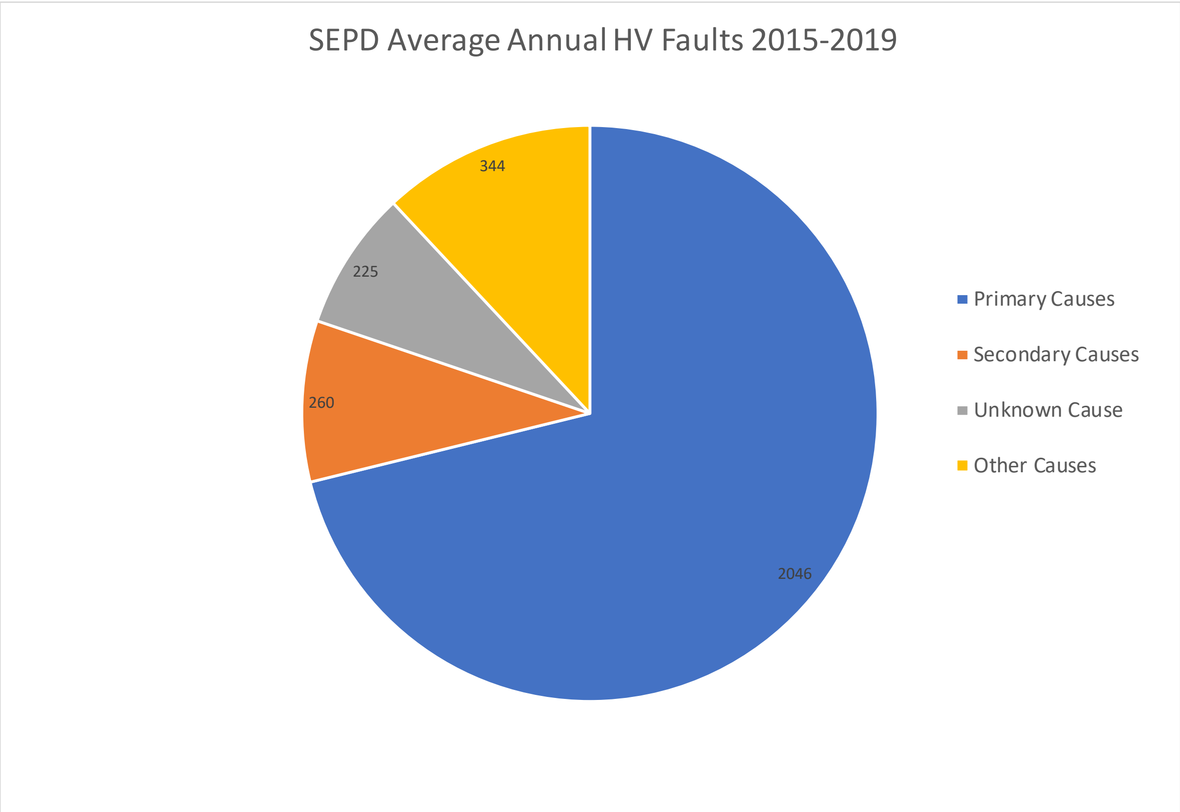

Figure 9: Proportion of SEPD HV faults attributed to primary and secondary drivers and other causes

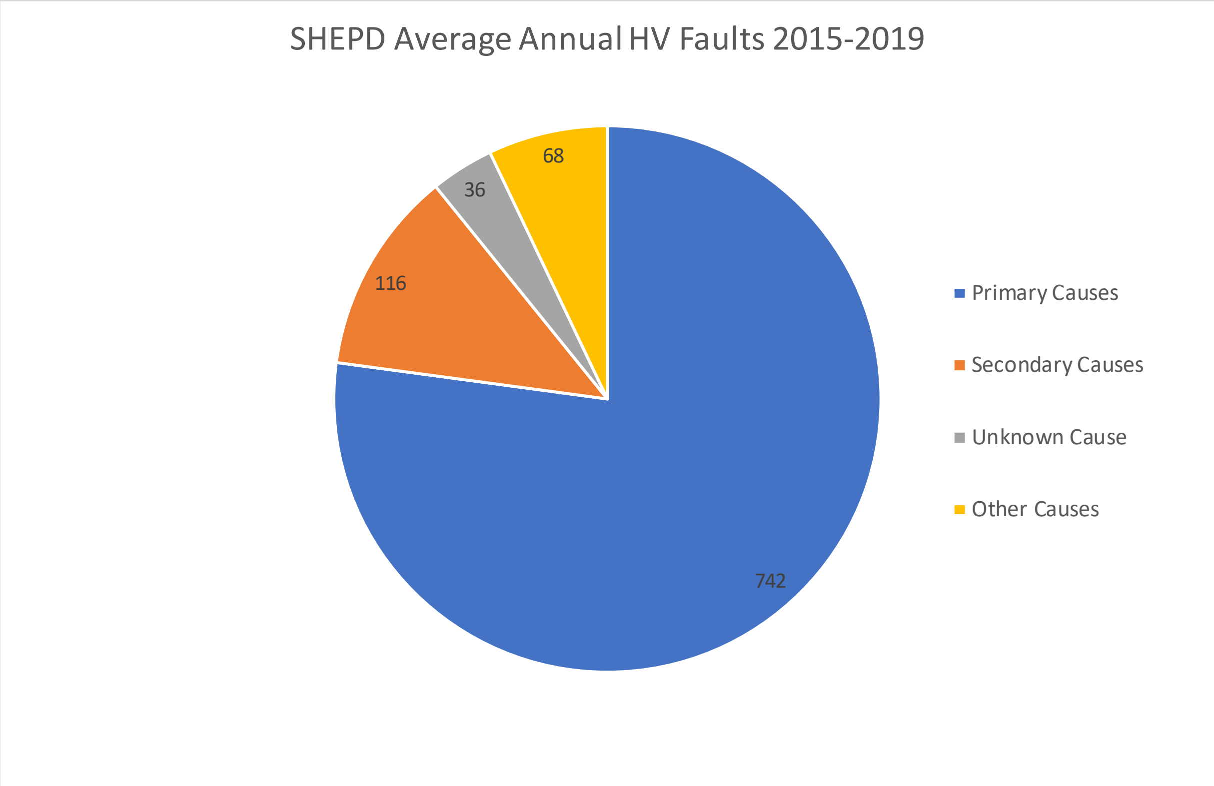

Figure 10: Proportion of SHEPD HV faults attributed to primary and secondary drivers and other causes

Corresponding Ofgem CV Tables

The costs associated with the primary investment driver (asset health or condition) accounted for within this EJP are captured with the CV7b table within the Business Plan Data Tables (BPDTs). CV7b covers the proactive replacement of non-NARMs asset categories. With respect to this EJP this includes the overlay of 6.6/11kV UG cable circuits once they are deemed to be end-of-life.

Table 4 lists the data that may be used to inform whether an individual 6.6/11kV UG cable asset requires investment for non-load related purposes. All of the data listed below is used to determine the most efficient investment option for each circuit.

Fault mapping is also a useful exercise to undertake alongside a review of the data listed below to identify fault clusters in a cable circuit (cable faults occurring close by to one another) and to identify shorter sections of a circuit where a targeted overlay can be expected to significantly improve the performance of the circuit as a whole.

Table 4: Primary data relevant to condition lead investment into 6.6/11kV UG cables.

Category	Factor
Basic Asset Parameters	Asset age
	Expected lifetime
Measured Condition	Partial discharge measurements
	Fault history
	Thermal monitoring
Location Factor	Direct Buried
	Laid in Ducts
	Laid in Tunnels
Loading	Average Loading
	Peak Loading
	Load Cycle

4.3 Secondary Investment Drivers

When making an investment in network assets it is important to carefully consider any secondary investment drivers that may influence the final investment strategy that is selected and to identify potential efficiencies or stacked benefits that can be achieved if all drivers for investment are considered alongside each other.

This includes the analysis of future network trends to ensure sustainable investment decisions are identified that represent best value for money for our network consumers and customers, whilst enabling the transition to Net Zero.

When selecting the investment option for each individual project, the following factors and secondary investment drivers are also considered to ensure the optimal solution is identified that best represents value for money for network consumers and customers:

- **Network Load Forecast**: Future network trend analysis must be carried out for each individual project to determine if sustained load growth can be expected for the cable circuit in question. If load growth can be proven with a reasonable level of confidence, a solution may be chosen which is not like-for-like, but one which can facilitate the future load growth that has been forecast. Similarly, the asset may be decommissioned if it can be demonstrated that other network assets can accommodate the forecasted network demand.
- **Network Losses**: The impact on network losses is also taken into consideration. For example, if a larger cross-sectional area cable has a lower full lifecycle cost, then this solution is considered for cable replacement, rather than simply a like for like replacement.
- **Number of Customers and Fault History:** When assessing the investment options available it is also important to consider the number and severity of network outages and the fault costs that have been incurred during previous years.

- **Protection & Telecontrol:** There may be an opportunity to lay an integrated fibre with a cable or a fibre alongside the cable as part of the cable replacement to provide functions such as differential protection or control. The existing fibre may not have this functionality but incorporating this new functionality could enable smart girds functions or increased new generation to be connected to the network, for example.

The secondary investment drivers that influence this EJP and the investment options include quality of service, future load growth, and network automation. These secondary drivers correlate to the following additional CV tables within the BPDT. Careful consideration of the secondary investment drivers can create benefits in these areas without the need for separate investment.

- **CV26 – Faults:** This table captures the costs associated with responding to cable faults. As previously discussed, our cable related fault costs have been rising over RIIO ED1 so any investment which can mitigate this rising trend could be very valuable.
- **CV2 –Secondary Reinforcement:** These tables capture investment that is required during RIIO-ED2 because of load growth across the network. Informed investment decisions in CV7b when dealing with an end-of-life circuit can also satisfy the future loads growth to prevent unnecessary future investment in the same circuits.
- **CV15 – Quality of Supply:** The replacement, refurbishment, or retrofit of network assets specifically to improve customer quality of service. This can include investment in network automation to improve IIS performance and undergrounding of overhead lines where relevant.

5 Stakeholder Engagement

In preparation for our RIIO-ED2 business plan development several stakeholder engagement exercises have been undertaken to better understand what will be important to our network customers during RIIO-ED2 and to ensure the views of our stakeholders are reflected in the cost and volumes we are proposing for each asset category in line with our ***Enhanced Engagement (Chapter 3)***.

Below is a summary of the key outcomes from this engagement from some of our critical stakeholders. The summary below provides details of our stakeholder feedback on our document ***Safe and Resilient (Annex 7.1)*** and their views on the importance of improving network reliability.

Consumer Feedback

- 88% of stakeholders in SEPD and 72% in SHEPD either agreed or strongly agreed with our asset management proposal to target assets with the highest probability of failure for ED2.
- 71% consumers thought it was very important that we are committed to reliability, which was the second highest priority for them (after affordability).
- In terms of reliability, domestic and SME customers' top priorities were 'Restoring the electricity supply as quickly as possible in the event of a power cut' (particularly for those aged 65+ or in vulnerable situations) and 'Keeping my power on with minimal power cuts'.

Local Authority and Government

- Stakeholders strongly urged us to strike a balance between maintain a reliable network by simply fixing older assets now and replacing assets (at a higher cost now) so that the network is ready for future use.
- We need to ensure reliability and disruptions are minimised, suggesting proactive actions such as providing generators during bad weather and new technologies to 'master' the network.
- Resilience partnerships are a good start for mitigating issues.

Community Energy Groups and Interest Groups

- Both old and new communities need to be resilient and must ensure the transition does not leave people behind.
- We need to think about current and future populations in areas now in order to plan its investments most effectively.

Summary of Findings

A wide range of stakeholders confirmed that they strongly support our proposed approach of prioritising assets with a higher probability and consequence of failure as described within our document ***Safe and Resilient (Annex 7.1)***. In addition, stakeholders also highlighted that network reliability was a high priority, greater than sustainability but below value for money.

Stakeholders communicated that reliability is expected as they depend on electricity for so many things in everyday life, and this is increasing, for example, with more households working from home and the electrification of heating and transport. These expectations and views validate Ofgem's IIS targets and Guaranteed Standards, so on this basis we have set our ambition to meet these levels of network performance.

6 Summary of Options Considered

This section of the report sets out the investment options that we have considered when addressing 6.6/11kV UG cables that are in poor health or condition.

As described below, a holistic approach is taken to ensure that investment options that are both least regret and represent best value for money for our customers are identified. The investment options described below range from minimum investment based solely on reactive works as required to full replacement of complete circuits; the use of potentially new, innovative alternatives and the potential use of flexibility is also considered.

By analysing all the primary and secondary investment drivers in a coordinated manner for each individual project, we can arrive at the optimal investment decision that avoids unnecessary spend and lowers the risk of future stranding of network assets.

6.1 Summary of Investment Options

Table 5 below provides a high-level summary of the investment options that we have considered, along with the advantages and disadvantages associated with each. A more detailed description of each option is then provided within the proceeding sub-sections.

Table 5: Summary of 6.6/11kV UG Cable Investment Options

Option	Description	Advantages	Disadvantages	Result
1. Reactive Replacement of Faulted Cable Section	Post-fault replacement of cable section with like for like section.	Allows the cable to be repaired and returned to service quickly without the need for extensive replacement works.	A temporary solution which is triggered by a circuit outage and potential disruption to customers. Introduces additional joints to the cable circuit which increase the likelihood of future faults.	To be undertaken during fault repair and captured in CV26.
2. Circuit Rationalisation	It is possible that when the original circuit has come to the end of its life a replacement circuit may not be required. In this case the original circuit is disconnected, and the cable is left in the ground.	CAPEX may be reduced, as less expenditure is required.	Capacity will be lost from the network, potentially restricting future network usage.	To be considered during RIIO-ED2 but is not an option that is considered as part of this EJP.
3. Enhanced Monitoring	Enhanced monitoring to better understand the condition of our UG cable network. This valuable data can inform the optimal time to intervene upon an ageing circuit.	May be cost effective for certain cable types and circuits which are showing signs of ageing or supply a large number of customers. Can prevent the early overlay of healthy circuits or circuits that would be better deferred till later years.	Given the high volume of circuits it will be extremely expensive to deploy monitoring across all of our 6.6/11kV UG cable circuits.	Projects are underway to determine the most cost-effective way to monitor GB DNO cable networks. Option not taken forward currently.
4. Proactive Replacement of Section	Proactive replacement of cable section rather than the whole circuit. This may be carried out due to condition, monitoring information, or fault history etc. Fault location analysis can be used to identify fault clusters and sections that would benefit from a targeted overlay.	Significantly lower cost than the full replacement of the circuit. Can substantially reduce the number of faults on the circuits with problem sections. Can significantly reduce the number of joints in sections of a circuit with a high number of historic faults.	Less beneficial on UG cable circuits with historic faults that are spread evenly across the whole circuit. Does not improve the condition of the whole circuit which may continue to degrade to the state of the replaced section.	**To be taken forward during RIIO-ED2 within CV7b**

5. Replacement of Complete Cable Circuit with Larger Diameter Cable	Replacement of the entire circuit with a larger diameter 6.6/11kV UG cable. The cost of the cable material only represents a relatively small proportion of the total cost of overlay. Using a cable with a larger diameter than the original cable can protect again future load growth and reduce network losses at little incremental cost.	An entirely new UG cable circuit will minimise future faults and maximise the reliability of the circuit for our network customers. A larger cable cross sectional area will reduce electrical losses, reducing both carbon emissions and consumer energy bills. A larger cable cross sectional area will also protect against future load growth without the need for additional investment.	High upfront CAPEX cost to overlay an entire circuit. Can be very expensive and disruptive in urban areas, requiring extensive road works and traffic management. A larger cable cross sectional area slightly increases the CAPEX of the cable. This may not be cost effective on lowly loaded circuits that are unlikely to see future load growth.	**To be taken forward during RIIO-ED2 within CV7b**
6. Replacement with Innovative Low Loss cable technology	Deployment of novel and innovative cable technologies when overlaying a HV UG cable that is in poor health or condition, which can improve both electrical losses and the voltage drop along the length of the circuit.	May lead to a reduction in electrical losses, reducing both carbon emissions and consumer energy bills. Can enabler longer UG cable circuits due to better voltage drop performance.	Likely to have a higher cable CAPEX due to novel technology. An unproven business case not widely deployed or tested in the field with lower Technology Readiness Level (TRL).	New cable technologies to be monitored during RIIO-ED2. Not currently built into RIIO-ED2 business plans.

6.2 Option 1: Reactive Replacement of Faulted Cable Section

If a cable fails during operation our faults team respond as quickly as possible to locate and repair the fault to minimise the disruption to our network customers whether there is an outage associated with the cable fault or not. Once the fault is located the ground around the fault is excavated to expose the failed cable. The cable is then cut back on either side of the point of failure, whether that is due to a fault on the cable itself or a failed historic joint, and new section of cable is jointed in to replace this section. This requires two joints to install the new section of cable.

Whilst this allows us to return the circuit to operation as quickly as possible it does not address the underlying cause of the fault if the rest of the circuit is also in bad health or condition. It also introduced two new joints to the circuit which are weak points and can increase the likelihood of future faults.

The cost and volumes associated with this activity are captured within the CV26 Faults table within Ofgem's BPDT pack. As such, this option does not impact the volumes presented within this EJP with records the proactive CV7b asset replacement activity planned for RIIO-ED2.

6.3 Option 2: Circuit Rationalisation

By analysing the surrounding network and considering the change in network loading that can be expected over the ED2 period, we can identify if there is a long term need for a cable that has reached the end of its useful life or that requires repairing.

If there is no sustained need for the cable due to low network loading or changes in the network configuration, decommissioning can be considered, particularly if there is spare capacity available on other local circuits that can be utilised. It may also be possible to reduce the size of the cable; for example, replace the existing cable with a lower cross-sectional area cable.

Network analysis would be needed to perform contingency analysis to ensure that the cable is not required under any potential scenario. This option should only be pursued if the future scenarios are clearly showing that the capacity will not be needed, with the implications of the uptake of Low Carbon Technologies (LCTs) accounted for. It is not anticipated that significant volumes of cable will qualify for removal / rationalisation during ED2.

If this option is chosen, the existing poor health or condition cable will be de-energised and disconnected from the network. It is not common for the cable to be remove from the ground after it is disconnected as there is little need for it to be removed and this would be expensive.

6.4 Option 3: Enhanced Monitoring

For some assets, it may be adequate to undertake additional operational activities to further manage the risk associated with each asset. In the case of 6.6/11kV UG cables, there are possibilities for enhanced monitoring, depending on the type of cable and the potential for retrofitting monitoring equipment, or carrying out increased routing testing with the cable in situ.

Partial discharge provides the main opportunity to detect insulation defects. On-line partial discharge monitoring can be used to provide continuous measurements, which gives increased information regarding degradation or deterioration of the insulation. Cable accessories for new cables are particularly important to monitor as these are more prone to problems due to installation and operational stress. This type of enhanced monitoring would fall under the CV30 (inspection) data table.

However, it can be difficult to carry out these measurements in situ once the cable has been installed. For new cable circuits, methods of monitoring the cable during the cable's lifetime should be established as part of the project. Additionally, it is likely that this option is too expensive to roll out across the entire network and it may only be practical to deploy new monitoring on existing cables on a case-by-case basis. Cables can be prioritised if they are showing the early signs of ageing or are considered high criticality due to high customer numbers etc.

A key component of our Visibility Strategy is the visibility of the health of our network, this is expected to come from monitoring devices that have pre-fault detection capability. We are currently trialling devices which provide warning of imminent faults (pre-fault) and will incorporate this into our internal and potentially external systems, allowing proactive management of our networks and improved customer service through rapid fault repair and customer communications. Within our Digitalisation Strategy we have described how Data Partnerships will allow third parties under restricted access to utilise data gathered from our monitoring and provide new service such as the pre-fault detection described above. Furthermore, we are currently running an innovation called DFA which intends to monitor the networks from the primary looking for faults on the 6.6/11kV network.

As such, we are not currently in a position to build this option into our RIIO-ED2 business plans. However, during RIIO-ED2 we will continue to develop our monitoring strategy for our 6.6/11kV UG cable network and assess the learnings from our innovation projects so that we can identify if enhanced monitoring becomes a cost-effective solution during the price control period.

6.5 Option 4: Proactive Replacement of Section

Proactive replacement of our UG cable is also an important investment option undertaken when a cable or circuit is deemed to be in poor health or condition and the on-going fault repair costs are unacceptable; therefore, not representing value for money for our customers.

Often, rather than replacing an entire UG circuit, a smaller section of the circuit is overlayed. This option is chosen when a problem section of a wider circuit has been identified and a targeted investment is cost effective and is expected to significantly reduce the number of future faults on that circuit.

To do this, historical fault data can be plotted to identify the location of each fault and the proximity of these faults to one another. Clusters or closely located faults indicates that the condition of the circuit has degraded faster in one section of the cable than others. In these situations, a targeted overlay can significantly improve the performance of the circuit at a much lower cost than full circuit overlay.

This option will be undertaken during RIIO-ED2 and the volumes associated with this will be captured in CV7b (Asset Replacement Non-NARM).

6.6 Option 5: Replacement of Complete Cable Circuit

If historic fault analysis indicates that the entire circuit is degrading and reaching end-of-life condition, it may be necessary to overlay the entire circuit with a new cable. This intervention can be very expensive depending upon the length of the circuit and its environment (e.g. urban vs rural). As such, cost benefit analysis must be undertaken on a circuit-by-circuit basis to ensure the costs associated with a full overlay are justified against the expected reduction in cable faults on that circuit and the fault OPEX required to respond to these.

Whilst overlaying the end-of-life circuit we intend to deploy a larger cross-sectional area cable as standard. Before doing so we will ensure that each circuit has a sustained need as per Option 2. If there is continued loading on the circuits in question, then 240mm^2 or 300mm^2 cable will be used to overlay the end-of-life cable.

A larger cross-sectional area reducing the electrical losses associated with distribution power to our network customers. This provides both financial (a reduction in consumer energy bills) and carbon benefits (the CO2e associated with the lost energy). A larger cross-sectional area also protects the network against future load growth and prevents the need for additional investment before the end of the useful life of the replacement cable. It will also act to enabler the transition to Net Zero and the electrification of both heat and transport.

As with Option 4, this option will be undertaken during RIIO-ED2 and the volumes associated with this will be captured in CV7b (Asset Replacement Non-NARM).

6.7 Option 6: Replacement with Innovative Low Loss Cable

If full replacement of the entire UG cable circuit is deemed to be the most cost-effective option, then alternative cable technology can be considered. There are several novel cable technologies in development that promise improved cable performance when compared to the business as usual (BaU) solutions.

For example, technology is in development which offers a significant reduction is electrical losses when compared to the current technology. Others claim improvement in the voltage drop along the length of the cable allowing us to build longer cable feeders without the need for additional substations and wider reinforcement.

However, the precise cost and performance of this technology is not fully understood and as such is not ready for full BaU deployment. As such, this option has not been included in the baseline of the RIIO-ED2 business plan. However, we will continue to monitor advancements during RIIO-ED2 and may take the decision to deploy any new cable technologies is a proven business case is identified.

6.8 Investment Options Taken Forward

To summarise, we intend to take forward Option 1, Option 4, and Option 5 during RIIO-ED2. The costs associated with Option 1 (reactive replacement of faulted cable) will be captured during ED2 within the CV26 Faults table in the BPDT pack. Meanwhile, the costs and volumes associated with Options 4 & 5 are captured within CV7b Asset Replacement. These costs and volumes are presented in section 7.4 of this EJP. Option 2 (circuit rationalisation) we be considered during RIIO-ED2 but due to the nature of this option there are no corresponding volumes at this stage.

After consideration, we have not chosen to take forward Option 3 and Option 6. However, we will continue to assess the business case for these options during RIIO-ED2 and they will be reconsidered if a more proven business case becomes clearer.

7 Detailed Analysis

This section of the report provides further detail on the investment strategy that we have chosen for 6.6/11kV UG cable assets for RIIO-ED2. This includes details of the CBA analysis that has been undertaken to justify our RIIO-ED2 proposal and the final costs and volumes that have been selected against each investment option.

7.1 Age Based Replacement Schedule

Although there are guidelines available for normal expected lifetime of our EHV and 132kV cables under CNAIM v2.1, the methodology does not provide guidance on the normal expected lifetime of our 6.6/11kV UG cables. This is understood to be partly due to the limited availability of condition data and published analysis.

Figure 12 and Figure 13 show the replacement schedules that correspond to the age of the 6.6/11kV UG cables on the SEPD and SHEPD networks and the expected average lifespan. This is based on an average lifespan on 75 years.

As illustrated, if age were to be used alone to determine and justify our RIIO-ED2 volumes up to 915km (SEPD) and 108km (SHEPD) of cable overlay would be required by 2030. This is significantly higher than the volumes we are proposing within this EJP as shown in section 7.4.

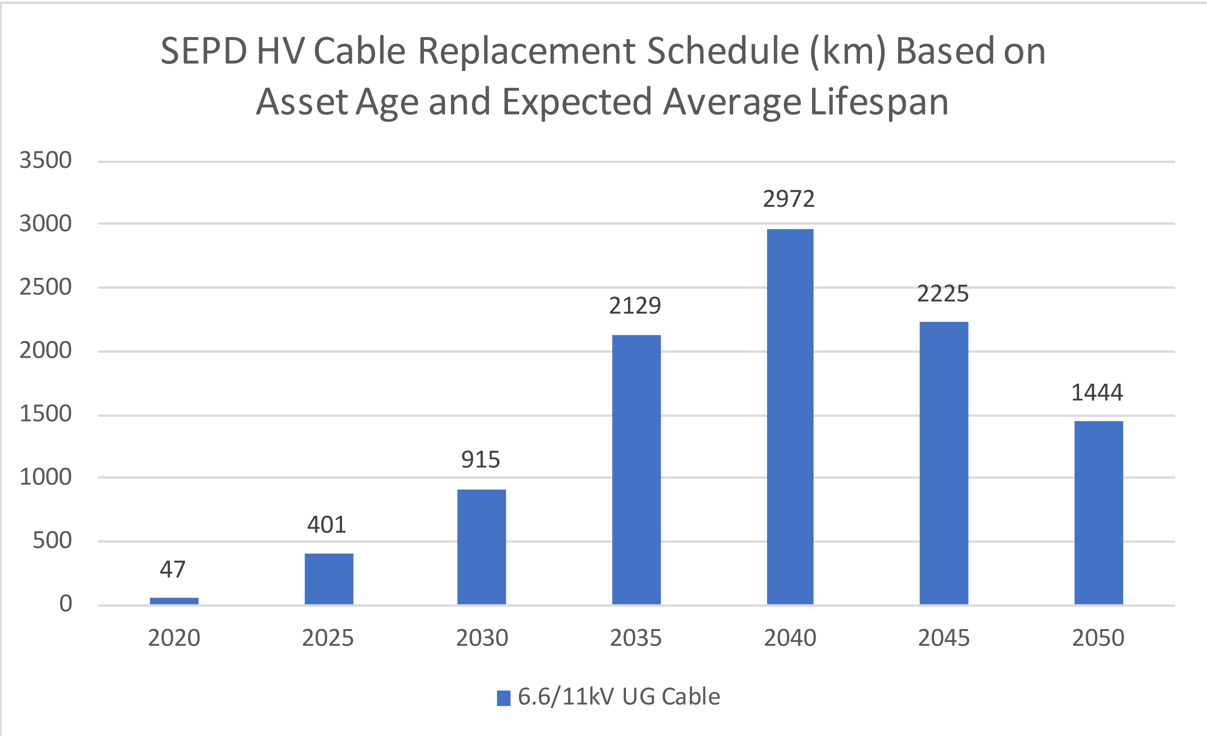

Figure 11: Replacement Schedule for 6.6/11kV UG cable by Type SEPD, Normal Expected Life: 75 years

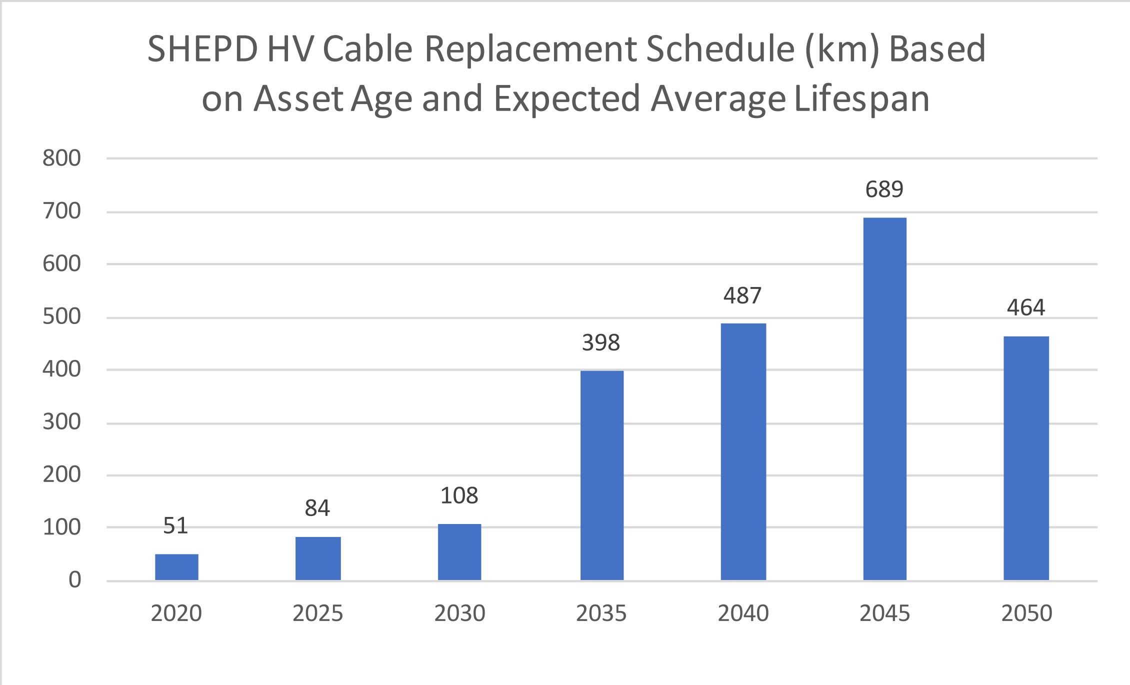

Figure 12: Replacement Schedule for 6.6/11kV UG cable by Type SHEPD, Normal Expected Life: 75 years

7.2 Illustrative Replacement Schedules

The lifetime of UG cable depends on several factors, including the quality of the manufacturing and installation, ground conditions/soil acidity, the volume of interventions, fault repairs throughout the life of the cable and the electrical and resulting thermal loading of the cable during its working life.

For these reasons it is not possible to directly link a physical cable age to its 'age related' condition; instead, an effective cable age must be determined to enable a cost effective and well scheduled overlay programme.

A good measure of the effective age of a cable is the frequency at which it faults. Where the frequency of primary faults is steadily increasing, the cable can be considered to be approaching end of life, particularly as the cost associated with responding to these faults continues to rise.

As such, we have prepared graphs to illustrate the indicative overlay schedules, these are based on:

- Proposed ED2 volumes
- A steady ramping up of resource to undertake the overlays over subsequent price control periods
- The total volume of 6.6/11kV UG cable that needs to be replaced in the next few decades

The monitoring of future fault trends will determine whether the overlay volumes need to be increased at a higher rate; it is considered unlikely that the illustrated volumes could be reduced due to life extension of the 6.6/11kV UG cables beyond the dates used in the illustrations.

7.2.1 SEPD Illustrative 6.6/11kV UG Cable Overlay Schedules

The example 6.6/11kV UG cable overlay schedules for SEPD (Figure 14 and Figure 15) are based on replacement of all 6.6/11kV UG cable (c. 10,300km) by 2050. This reflects the age of the cable and an indicative 75-year average cable life and is considered to be the date by which the vast majority of 6.6/11kV UG cable will need to be replaced.

Figure 14 illustrates a schedule based on 20km in year 1, rising to a stable run rate by 2035, which is then sustained until 2050. Figure 15 illustrates a schedule that starts with a higher rate in year 1 of 40km but delivers the same total volume by 2050. The volume delivered in year 1 mainly affects the rate of increase that will be required in subsequent years to meet the necessary final overlay volumes by 2050, with lower initial overlay volumes increasing the year-on-year rate of increase in volumes for future years. If 6.6/11kV UG cable fault rates trend at continuously higher rates, then the final disposal date may need to be brought forward from 2050, which will result in increased annual volumes than those in the illustrated example overlay schedules. As illustrated below it is critical for us to make a strong start to this overlay programme during RIIO-ED2 to minimise the bow wave of cable overlays that may be required during future price control periods. As such, we consider the volumes included within CV7b to be the minimum volumes, particularly given the increasing importance of the cable network as the energy system decarbonises to meet our collective Net Zero targets.

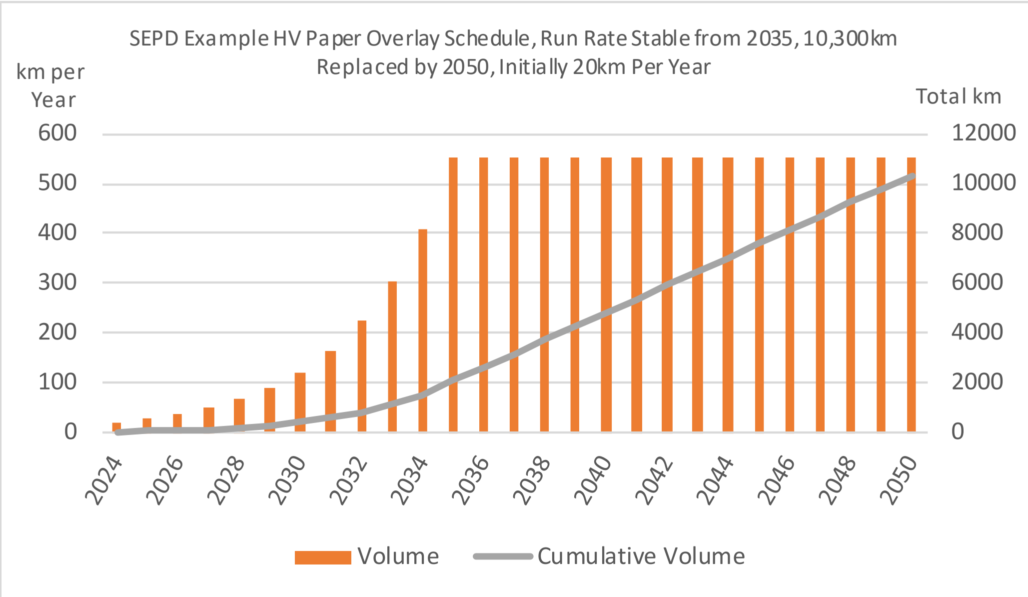

Figure 13: Example Overlay Schedule for 6.6/11kV UG Cable for SEPD, replacing all cable by 2050, starting from 20km per year, 200km Delivered During ED2

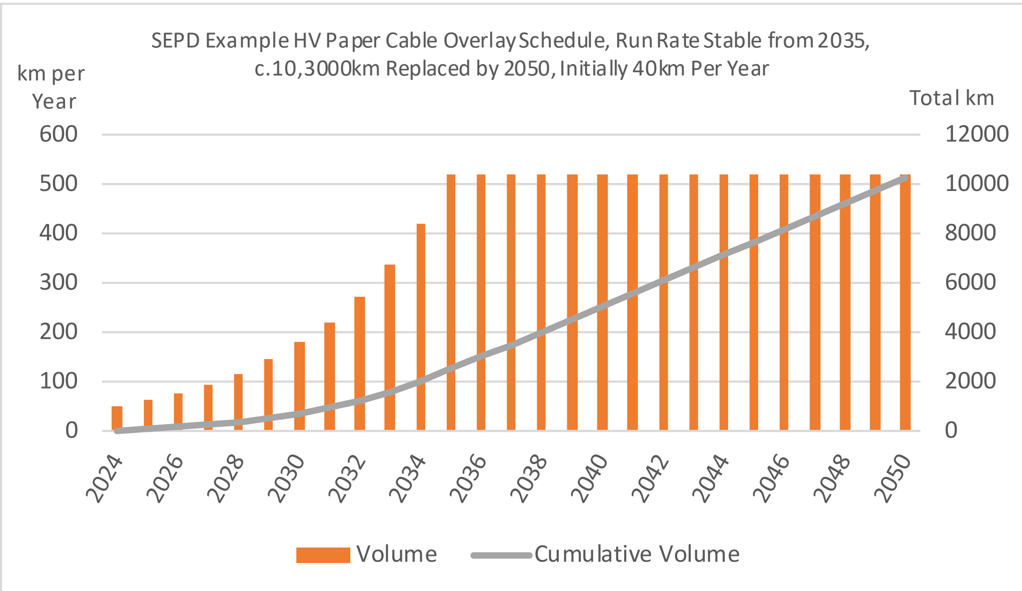

Figure 14: Example Overlay Schedule for 6.6/11kV UG Cable for SEPD, replacing all cable by 2050, Starting from 40km per Year, 400km Delivered During ED2

7.2.2 SHEPD Illustrative 6.6/11kV UG Cable Overlay Schedules

As with SEPD, the example 6.6/11kV overlay schedule for SHEPD (Figure 16 and Figure 17) is based on replacement of 6.6/11kV UG cable (c. 2,280km) by 2050. This reflects the age of the cable and an indicative 75-year average cable lifetime and is considered to be the date by which the vast majority of 6.6/11kV UG cable network of this age will need to be replaced.

Figure 16 illustrates a schedule based on 13km in year 1, rising to a stable run rate by 2035, which is then sustained until 2050. Figure 17 illustrates a schedule that starts with a higher rate in year 1 of 25km but delivers the same total volume by 2050.

The volume delivered in year 1 mainly affects the rate of increase that will be required in subsequent years to meet the necessary final overlay volumes by 2050, with lower initial overlay volumes increasing the year-on-year rate of increase in volumes required for future years. If 6.6/11kV UG cable fault rates trend at continuously higher rates, then the final disposal date may need to be brought forward from 2050, which will result in increased annual volumes than those in the illustrated example overlay schedules.

As with SEPD, the graphs below demonstrate the importance of a strong start during RIIO-ED2. Any reduction in the proposed 6.6/11kV UG cable overlay volumes risks a unmanageable bow wave of cable overlays and cable faults during future price control periods, to the detriment of our network customers.

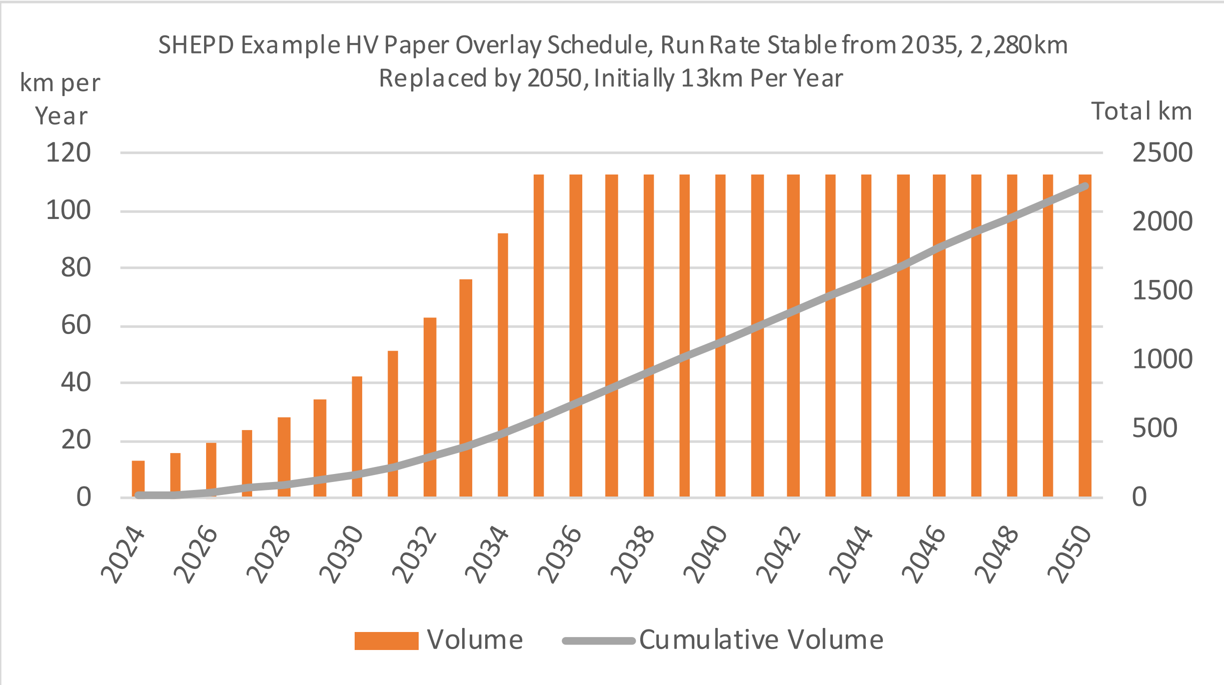

Figure 15: Example Overlay Schedule for 6.6/11kV UG Cable for SHEPD, replacing all by 2050, Starting from 13km per Year, 100km Delivered During ED2

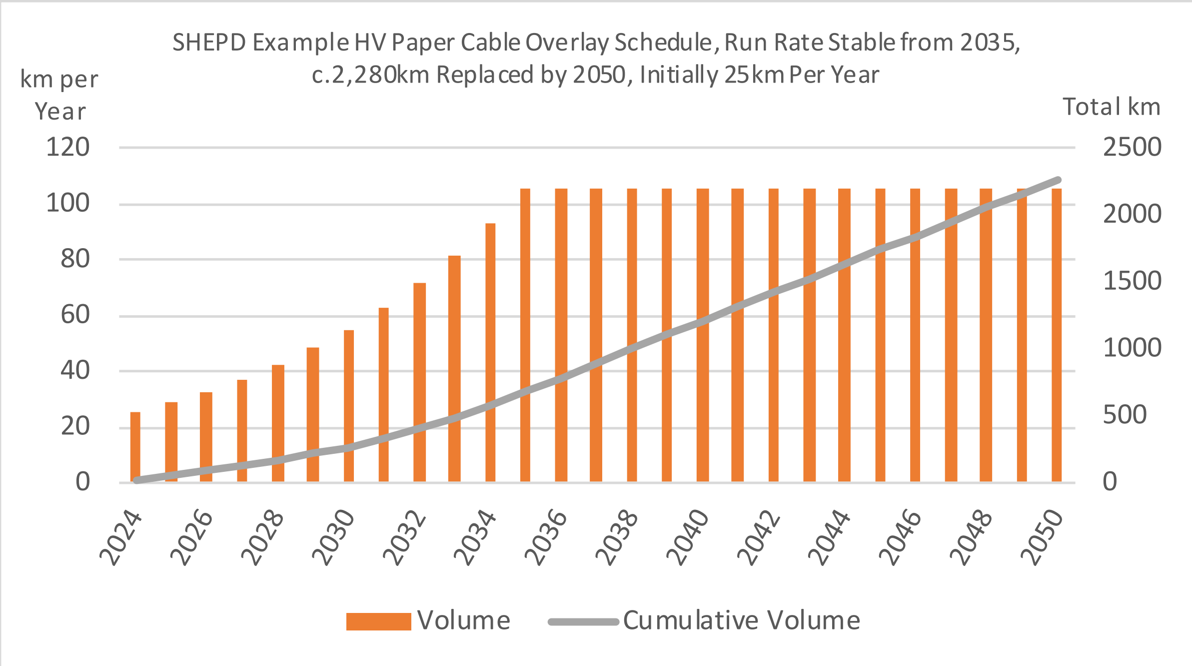

Figure 16: Example Overlay Schedule for 6.6/11kV UG cable for SHEPD, replacing all by 2050, Starting from 25km per Year, 165 km Delivered During ED2

7.3 Cost Benefit Analysis

A detailed Cost Benefit Analysis (CBA) exercise has been undertaken to support the investment strategy that is described within this EJP.

Within the CBA an analysis was undertaken on the costs and benefits associated with the ongoing management of our 6.6/11kV UG cable circuits that are faulting, which considers the increasing costs associated with maintaining these circuits in a reactive manner compared with the costs and associated savings associated with proactively overlaying the aged circuits with new 6.6/11kV cable.

7.3.1 CBA Methodology

The Ofgem CBA tool has been used to build a CBA which captures the costs and benefits associated with 6.6/11kV UG cable overlay during RIIO-ED2.

The CBA compares the cost of a typical UG cable overlay against the ongoing fault repair costs in Net Present Value (NPV) terms over a 45-year period. This is then used to identify the minimum conditions (fault rate) that justifies a typical 6.6/11kV UG cable overlay given the expected reduction is fault OPEX.

Our own **National Fault and Interruption Reporting System (NAFIRS) data**, specific to both SEPD and SHEPD, has been used to identify which of our 6.6/11kV UG cable circuits meet this minimum investment condition in terms of number of faults per year. The number of faults recorded against each circuit over the previous 5-years (2017-2021) is used to shortlist the 6.6/11kV UG cable circuits that are over and above the ‘breakeven’ point identified by the CBA.

The counterfactual does not assume however, that the existing cable can be repaired under fault conditions indefinitely. As such, the CBA explores the benefits associated with overlay during RIIO-ED2 compared to a deferred overlay in future price control periods when the circuit is assumed to reach “end of life” due to its age, condition, and number historic faults and joints. A **sensitivity is applied** within the CBA to explore the impact on justifiable volumes (Low, Medium, High) if the deferment in cable overlay is shorter or longer. This is shown in the CBA results section below.

In addition to the methodology described above, the following costs and benefits are used in the CBA to identify the 'breakeven' point between proactive overlay and ongoing reactive fault repair, and hence the total volume of cable within our licenced areas over and above this:

- **Fault Rate:** As above, the fault rate is used to identify the 'breakeven point' between proactive cable overlay and ongoing reactive fault repair. This identifies the minimum conditions that justifies an 6.6/11kV UG cable circuit overlay. This is used to identify the volume of cable on our network that meets this 'breakeven point' during RIIO-ED2.
- **Fault Costs:** The costs associated with responding to and rectifying cable faults on the 6.6/11kV UG cable network. Historic fault cost data is used to determine the on-going fault OPEX cost.
- **NAFIRS Data:** Our own NAFIRS data is used to identify the performance of our 6.6/11kV UG cable circuits over the last 5-years (2017-2021) and hence the volume of cable which is justified by the CBA for overlay during RIIO-ED2. The NAFIRS data is filtered on **condition related faults only** on our 6.6/11kV UG Mains cable to determine the relevant fault rate against each of our 6.6/11kV UG cable circuits.
- **Average Circuit Length:** This is calculated using our total 6.6/11kV UG cable network length divided by the total number of 6.6/11kV UG circuits. This calculation is undertaken separately for both SEPD and SHEPD and determines the average cable overlay cost for each 6.6/11kV UG cable circuit.
- **Replacement Cost:** The Capex associated with overlaying 6.6/11kV UG cable, based upon our CV7b unit cost and the average overlay length calculated for each 6.6/11kV UG cable circuit. Includes all associated costs such as the material cost, and the excavation and reinstatement of ground during overlay.
- **Carbon Footprint:** The embedded carbon (tonnes CO_2e) per km associated with the overlay of 6.6/11kV UG cable during both proactive overlays and during fault response.
- **Network Losses:** The reduction in losses associated with replacing smaller cross-sectional area cable with larger 300mm^2 cable during proactive cable overlays.
- **Network Reliability:** The Customer Minutes Lost (CML) and Customer Interruptions (CIs) that can be expected before and after the proposed overlay intervention. These costs are used to represent the Value of Lost Load (VoLL) for our network customers during an outage. Historic Interruption Incentive Scheme (IIS) data is used to calculate the benefits that can be attributed to an 6.6/11kV UG cable overlay within the CBA.

For a more detailed description of our 6.6/11kV UG cable methodology please see our ***Cost Benefit Analysis Process (Annex 15.8)*** document.

7.3.2 CBA Results

Table 6 shows the results for both of the CBAs we have created to justify our proposed volume of 6.6/11kV UG cable overlays during RIIO-ED2. As seen, in both cases the volume that can be justified for overlay during RIIO-ED2 is higher than the volume we have proposed in the BPDTs, where our volumes have been capped due to our current delivery capacity and resource.

The volumes listed below are also supported by the age-based replacement schedules that are described in Section 7.1. which shows the significant volume of cable that will need to be overlayed in future price control periods if we assume an average lifetime for our 6.6/11kV UG cable circuits.

The ‘volume justified (km)’ in Table 6 reflects the historic rate that our 6.6/11kV UG cable network was built and the large peak of cable volumes installed in the 1950’s and 1960’s when compared to earlier decades (see Section 3.2). This peak is of particular concern in SEPD where our age-based data shows a huge peak in the 1950’s and 1960’s, circuits that will be reaching an age of 70-80 years old during RIIO-ED2.

Table 6: SSEN 6.6/11kV UG Cable CBA Results

Licence Area	Scenario	Fault Rate	No. of 6.6/11kV circuits justified	Volume Justified (km)	Volume in BPDT (km)
SEPD	Low	0.623	110	581	200
	Medium	0.647	110	581	
	High	0.687	110	581	
SHEPD	Low	0.357	194	609	95
	Medium	0.369	194	609	
	High	0.394	194	609	

7.4 Proposed RIIO-ED2 Investment

As previously described, the primary investment driver detailed within this EJP is the condition or health of our 6.6/11kV UG cable assets as experienced within our UG cable fault performance. This correlates to the CV7b (Asset Replacement Non-NARM) data tables within Ofgem’s BPDTs. The following subsections show both the costs and volumes that we have proposed for RIIO-ED2.

The results from the RIIO-ED2 CBA assessment indicate that significant volumes of 6.6/11kV UG cable overlay will result in best value for customers when considered over a 45-year NPV. This is due to the age profile of our 6.6/11kV UG cables, and the result of high cable volumes now reaching end of life. This is causing an increase in both the fault rate and a steady increase in the cost to respond to each fault.

The rising intervention costs are attributed to several factors, including the fact that it is harder and more time consuming to rectify a fault on a cable that is approaching end-of-life due to issues with rejointing old cables and the need to replace increasing lengths of cable to ensure a sound joint can be made on aged sections, when compared with newer cable.

The CBA analysis, as described in Section 7.3 indicates a volume of up to **581km (SEPD)** and **609km (SHEPD)** can be justified for overlay during RIIO-ED2 based upon the fault OPEX currently experienced on our network.

The increase from RIIO-ED1 overlay volumes is significant and has been largely triggered by high volumes of cable now at or approaching end of life, as evidenced by the ED1 fault trends combined with the asset age profiles.

We have chosen to target **200km of total 6.6/11kV UG cable overlay in SEPD** during ED2 due to current deliverability constraints, whilst developing the resource base to further step up overlay volumes during subsequent price control periods. A target of **95km of non-load based 6.6/11kV UG cable overlay has been set for SHEPD.**

7.4.1 CV7 Asset Replacement

Table 7 and table 8 show the volumes and costs associated with the replacement of the 6.6/11kV UG cable asset category for both SHEPD and SEPD during ED2. These costs and volumes have been informed by our document ***Safe and Resilient (Annex 7.1)*** for this asset category and the feedback we have gathered from the RIIO-ED2 stakeholder engagement activities.

Due to the increase in volumes for 6.6/11kV UG cable overlay when compared with RIIO ED1, deliverability of the overlay is a major consideration in the proposed volumes. A steady increase in annual volumes is proposed throughout ED2, positioning resources for an anticipated continuous increase in annual 6.6/11kV UG cable overlay volumes over ED3/ED4 price control periods, with a sustained high volume of overlay for several subsequent price control periods.

The volumes listed in Table 7 below are associated with intervention Option 4 and Option 5 as described within Section 6 of this EJP.

Table 7: CV7 6.6/11kV UG Cable Volumes for RIIO-ED2.

Asset Category	Unit	2024	2025	2026	2027	2028	Total
6.6/11kV UG Cable (SEPD)	km	30.0	35.0	40.0	45.0	50.0	**200.0**
6.6/11kV UG Cable (SHEPD)	km	17.0	18.0	19.0	20.0	21.0	**95.0**

Table 8: CV7 6.6/11kV UG Cable Costs for RIIO-ED2.

Asset Category	Unit	2024	2025	2026	2027	2028	Total
6.6/11kV UG Cable (SEPD)	£m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
6.6/11kV UG Cable (SHEPD)	£m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

7.5 Unit Costs Efficiency

Our RIIO-ED2 Business Plan costs are derived from our outturn RIIO ED1 expenditure. We have modified costs per activity, capturing and reporting those adjustments in our cost-book. By tying our costs back to reported, outturn, real life data this approach provides multiple data points on which both the Regulator and we can benchmark cost efficiency. It provides a high level of cost confidence in our Business Plan cost forecast for RIIO-ED2.

Through our benchmarking analysis, we recognised that not all Non-Load related RIIO-ED1 actual unit costs sit within the upper quartile efficiency band. Where this is the case, we have applied a catch-up efficiency to those cost categories. Further detail on our unit cost approach, cost efficiency and cost confidence for RIIO-ED2 can be found within our document ***Cost Efficiency (Annex 15.1).***

We expect that as our Business Plan continues to develop, project scopes and costs will be refined, especially with valuable stakeholder feedback on our draft proposals. In our final Business Plan submission in December our cost forecasts will contain that refinement and the changes captured within our supporting Plan documentation. Development of our Commercial Strategy is expected to drive much of this refinement.

The unit costs of 6.6/11kV UG cables for RIIO-ED2 are as per Table 9 below:

Table 9: SSEN RIIO-ED2 Unit Cost for 6.6/11kV UG Cables.

Asset	SEPD	SHEPD
6.6kV/11kV Underground Cable	[redacted]	[redacted]

7.6 Deliverability of Proposed Volumes

Between our draft and final Business Plans we have carried out a more detailed deliverability assessment of our overall plan as a package and its component investments. Using our draft Business Plan investment and phasing as a baseline we have followed our deliverability assessment methodology. We have assessed any potential delivery constraints to our plan based on:

In-house workforce capacity and skills constraints based on our planned recruitment and training profile and planned sourcing mix as well as the efficiencies we have built into our Business Plan (detailed in our documents: ***Workforce Resilience Strategy (Annex 16.3)*** and ***Cost Efficiency (Annex 15.1)***

- Assessment of the specific lead and delivery timelines for the asset classes in our planned schemes
- We have evaluated our sourcing mix where there were known delivery constraints to assess opportunities to alleviate any constraints through outsourcing

We have engaged our supply chain ***Supply Chain Strategy (Annex 16.2)*** to explore how the supply chain could support us to efficiently deliver greater volumes of work and how we could implement a range of alternative contracting strategies to deliver this

- We have also engaged with the supply chain on the delivery of work volumes that sit within Uncertainty Mechanisms to ensure we have plans in place to deliver this work if and when the need arises
- We have assessed the synergies between our planned load, non-load and environmental investments to most efficiently plan the scheduling of work and minimise disruption to consumers
- Based on our assessment of delivery constraints and potential solutions to resolve them, we have revised our investment phasing accordingly to ensure our Business Plan is deliverable, meets our consumers' needs and is most cost efficient for our consumers

Table 10 below shows a comparison of the 6.6kV/11kV UG cable replaced within the first 5 years of RIIO-ED2 compared to our proposal for RIIO-ED2. Overall, our RIIO-ED2 volumes represent a 201% increase when compared to the volumes that have been delivered in the first 5 years of RIIO ED1.

Table 10: ED1 delivered volumes (first 5 years) vs. ED2 proposed volumes.

SSEN Licenced Area	ED1 (first 5 years)	ED2 Proposed Volumes	Percentage Change
SEPD	63.5	200.0	215%
SHEPD	34.6	95.0	175%
Total	**98.1**	**295.0**	**201%**

Replacement volumes in CV7 have been phased over RIIO-ED2 to allow resources to be ramped up in later years to aid overall the deliverability of the longer-term programme. Due to the large volume of cable that will be replaced, there will be a focus on upscaling resource, which may include procuring more contractors to secure ability to deliver full volumes, whilst also expanding inhouse capability. This ramp up will continue throughout the next price control period as larger volumes will also need to be addressed in future years to maintain a healthy asset base.

8 Conclusion

The purpose of this Engineering Justification Paper (EJP) has been to describe the overarching investment strategy that we have chosen for RIIO-ED2 for the non-load related management of our 6.6/11kV UG cable network.

The primary investment driver explored within this EJP is the health or condition of our UG cable network. The condition of this asset category is closely reflected in the performance of the network and the number of faults or network outages.

We have then explored 6 investment options to address the primary and secondary non-load related drivers for investment in our 6.6/11kV UG cable network. The viability of each of these options depends upon the specifics of each cable project that requires intervention.

During RIIO-ED2, further cost benefit analysis will be undertaken on a case-by-case basis to identify which option represents best value for money for network customers and which can be considered least regret. Ongoing cost benefit analysis will also be used to prioritise the circuits that required intervention during RIIO-ED2.

The options considered within this EJP for RIIO-ED2 are listed below. Option 1 will be undertaken during fault response and the cost of this are captured in CV26. Option 2 will be explored during ED2 although there are no volumes associated with this option given that is involves de-energising cable circuit when they are no longer required. There is also no clear and proven business case currently to support Option 3 and Option 6. However, we will continue to investigate these options during RIIO ED2 and reconsider these if they begin to represent value for our network customers.

Options 4 and **Option 5** are those that have been chosen for deployment during RIIO-ED2 where cable replacement is required. The cost and volumes associated with these options are captured within the CV7b table.

- Option 1: Reactive Replacement of Faulted Cable Section
- Option 2: Circuit Rationalisation
- Option 3: Enhanced Monitoring
- **Option 4: Proactive Replacement of Section**
- **Option 5: Replacement of Complete Circuit with larger diameter cable**
- Option 6: Replacement of Complete Circuit with innovative low loss cable

The CV7b volumes associated with Options 4 & 5 are supported by a CBA that provides more detail on the benefits of undertaking overlay on circuits during RIIO-ED2. The CBA, in conjunction with circuit level fault data, has directly informed the final costs and volumes that have been calculated for RIIO-ED2 alongside the stakeholder engagement feedback.

We will be maximising the long-term benefits for our customers by ensuring that 6.6/11kV UG cable overlays will minimise operational losses, whilst also providing sufficient capacity to enable the transition Net Zero and the ongoing electrification of heat and transport.

As such, we will be assessing the whole life benefits of adopting larger diameter cable as the standard overlay size, this is likely to be $240mm^2$ or $300mm^2$.

A holistic approach is taken when selecting the most viable option for each cable project, where the primary and secondary investment drivers are assessed together within a CBA. This includes future network trend analysis and careful consideration of the financial, safety, and environmental implications of each investment.

Importantly, our CBA analysis has shown that a large increase in 6.6/11kV UG cable overlay volumes can be justified when comparing our current fault OPEX costs to the likely overlay cost, far higher than the volumes we are proposing in this EJP which have been capped due to our current deliverability limit. In fact, our CBA assessment has shown that up to **581km (SEPD)** and **609km (SHEPD)** of 6.6/11kV UG cable overlay could be justified during RIIO-ED2 if there were resources available to deliver this.

However, due to deliverability constraints, a total of **295km of 6.6/11kV UG cable** has been identified for replacement during RIIO-ED2 (200km SEPD, 95km SHEPD). This investment represents a total spend of **£45.04m** throughout RIIO-ED2.

Appendix 1: Acronym Table

Acronym	Description
BaU	Business as Usual
BPDT	Business Plan Data Table
CapEx	Capital Expenditure
CBA	Cost Benefit Analysis
CEG	Customer Engagement Group
CI	Customer Interruption
CML	Customer Minutes Lost
CMZ	Constraint Management Zone
CO_2e	Carbon Dioxide equivalent (can be suffixed by t (tonnes))
Consac	Underground Cable type, Paper insulation with Aluminium Sheath
CV	Cost and Volume
DFES	SSEN's Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DPCR5	Distribution Price Control Review for five years from 1 April 2010 to 31 March 2015
DSO	Distribution System Operator
EJP	Engineering Justification Paper
ENA	Energy Networks Association
ESQCR	Electricity, Safety, Quality and Continuity Regulations
EU	European Union
GB	Great Britain
HSE	Health and Safety Executive or Health, Safety and Environment
HV	High Voltage, Voltages > 1kV and < 22kV , in SSEN these assest are usually 6.6kV and 11kV.
IIS	Interruption Incentive Scheme
IR	Insulation Resistance
kV	Kilovolt
LCT	Low Carbon Technology
MEAV	Modern Equivalent Asset Value
NPV	Net Present Value
Ofgem	Office of Gas and Electricity Markets
OpEx	Operational Expenditure
PILC	Paper Insulated Lead Covered
RIIO	Ofgem's price control framework first implemented in 2013
RIIO-ED1	First price control for Electricity Distribution companies under the RIIO framework from April 2015 to March 2023
RIIO-ED2	Second price control for Electricity Distribution companies under the RIIO framework from April 2023 to March 2028
SEPD	Southern Electric Power Distribution PLC
SHEPD	Scottish Hydro Electric Power Distribution PLC
UG	Underground

Appendix 2: Relevant Policy, Standards, and Operational Restrictions

The policies, manuals and standards and operational restrictions which govern the management of 6.6kV/11kV UG cable are listed below in Table 11

Table 11: 6.6kV/11kV UG cables relevant documents

Policy Number	Policy Name / Description
TG-NET-NPL-010	Planning Standards for 11kV and 6.6kV Distribution Networks
TG-NET-CAB-009	Load Ratings of underground cables
TG-NET-CAB-426	11kV and 33kV Joints Selection Matrix
TG-NET-CAB-010	Electrical Constants for Underground Electricity Cables
TG-NET-CAB-426	11kV and 33kV Joints Selection Matrix
ENA EREC P2	Security of Supply
ENA EREC P29	Planning Limits for Voltage unbalance in the United Kingdom