Scottish & Southern Electricity Networks

RIIO-ED2 Engineering Justification Paper (EJP)

132kV Circuit Breakers (SEPD)

- *132kV CB (Air Insulated Busbars) (OD) (GM)*

Investment Reference No: 307/SSEPD/NLR/132kV SWGR

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Investment Summary Table

Table 1 provides a high level summary of the key information relevant to this Engineering Justification Paper (EJP) and the management of our 132kV Circuit Breaker assets with the breakdown of the spend in Appendix 2.

Table 1: Investment Summary

Engineering Justification Paper Non-Load				
Name of Programme	132kV Circuit Breakers			
Primary Investment Driver	Non-Load - Reliability			
Investment reference	307_SSEPD_NLR_132kV_SWGR			
Output reference	• 132kV CB (Air Insulated Busbars)(OD) (GM)			
Cost	[redacted]			
Delivery year	RIIO-ED2			
Reporting Table	CV7: Asset Replacement			
Outputs included in RIIO-ED1 Business Plan	No			
Spend apportionment	**(£m)**	**ED1**	**ED2**	**ED3+**
	SHEPD	-	0	-
	SEPD	-	[redacted]	-

1 Executive Summary

Our proposed investment for 132kV circuit breaker assets will deliver improved network reliability through the replacement of **16** "end of life" AIB Outdoor (OD) Ground Mounted (GM) circuit breakers in the SEPD licence area. This investment is required to meet our 'Delivering a safe, resilient and responsive network' Business Plan priority.

The primary driver for this category is the condition or health of each asset. For 132kV circuit breakers the investment works have been identified using a Condition Based Risk Management (CBRM) tool, developed using the Common Network Asset Indices Methodology (CNAIM). Further information can be found in our document: ***Safe and Resilient (Annex 7.1).***

Without intervention in this asset category, we can expect that a number of 132kV circuit breaker defects will rise which would impact directly on network reliability, customer satisfaction and the safety of the public and our staff. In addition to the key primary driver (condition), there are a number of secondary drivers such as the quality of supply, future load growth and network automation that will also impact on the programme of intervention works proposed.

For 132kV Circuit breakers there were five options put forward for consideration in this EJP:

- Option 1: Do Minimum
- Option 2: Enhanced Inspection, Maintenance, and Monitoring
- Option 3: Refurbishment
- Option 4: Retrofit
- Option 5: Replacement

These proposed interventions have been considered in detail in this paper. The outcome from this found that the only viable option is the full replacement of 132kV circuit breaker assets.

The cost to deliver the preferred solution is [redacted] and the works are planned to be completed throughout the ED2 regulatory period.

The benefit of these works revolves around the reduction of risk of failure of these assets, which are integral in the operation of our network. These replacements are intended to maximise the capacity and availability for all network customers.

2 Introduction

This Engineering Justification Paper (EJP) describes our proposed non-load related investment plan for the 132 kV Switchgear asset category during RIIO-ED2.

The primary driver considered within this paper is the condition of each circuit breaker as measured through our inspection and maintenance regimes and our Condition Based Risk Management (CBRM) models which align with Ofgem's Common Network Asset Indices Methodology (CNAIM).

The paper initially (Section 3) provides a discussion on the primary and secondary investment drivers for these assets: the main driver being the poor health and condition of the asset. This is followed by high-level background information for this asset category; explanation of the importance of this asset for our electricity distribution network and our network customers; and motivation for ensuring our 132kV Circuit Breakers are in good health over the course of RIIO-ED2 and beyond. Section 3.3 introduces the CBRM tool and the health and criticality relationship which is used in determining the particular 132kV Circuit breaker assets for investment.

Section 4 describes the key learnings from our stakeholder engagement activities and its relevance to the management of 132kV circuit breakers assets.

A table of intervention options for the 132kV circuit breaker options is presented in Section 5 with additional sections providing greater detail on each option to indicate whether the option is taken forwards or not.

A detailed analysis (Section 6) describes the cost and volumes arising from the preferred intervention options. The results of a sensitivity analysis are also provided for circuit breakers to show the impact on both cost and volumes if a higher or lower tolerance for risk (probability and consequence of failure) was chosen as our RIIO-ED2 strategy.

Section 6 also describes how we have established the cost efficiency of the plan with reference to the unit costs that have been chosen, and the deliverability of the plan with respect to our ability to replace the volume of circuit breakers indicated within this paper during RIIO-ED2 for the cost allowance requested.

The conclusion, which summarises the EJP and its recommendations, is provided in Section 7.

The Appendices start from Section 8 with a Table of Acronyms, followed by Appendices covering: the Summary of the Cost and Volumes; an explanation of Dead Tank and Live Tank circuit breakers; and a list of relevant 132kV internal standards and policies.

3 Background Information

This section of the report provides additional background information which has been used to inform the non-load related investment strategy for 132kV Circuit Breaker assets. This includes a description of the assets under consideration, the relevant SSEN and industry policies, and the approach used to identify those that will require replacement during RIIO-ED2.

3.1 Investment Drivers and Associated CV Tables

This section outlines in further detail the investment drivers for the proposed interventions of our 132kV Circuit Breaker assets **for non-load related purposes** during RIIO-ED2 for the following asset categories:

- 132kV CB (Air Insulated Busbars) (OD) (GM)

This primarily relates to the Health and Criticality of each asset as tracked by our Condition Based Risk Management (CBRM) system. A key part of the CBRM calculation of Asset Health is the presence of certain defects within the switchgear assets. Routine inspection and maintenance and will identify the following:

- **Defects** - These are captured during routine inspection and maintenance or through general network operations. Defects can include compound leaks, control cubicle (small wiring, auxiliary wiring etc.), defective isolating contacts, defective gaskets, low oil level, oil sight glass, partial discharge, reducing SF_6 gas pressure, etc. The data is assessed separately from the CBRM scoring and should be considered alongside the asset risk scores.
- **Condition** – Condition data is captured during routine inspection and maintenance and uploaded for inclusion within CBRM modelling of asset Health, Criticality, and Risk. This condition data can include trip times, condition of contacts, internal housings etc.
- **SF_6 gas** – SF_6 is as an alternative insulating medium to oil, where if the gas pressure falls too low the circuit breaker loses its ability to extinguish an arc leading to a disruptive failure. SF_6 gas pressure is monitored regularly and may require top-up from time to time.
- **Partial Discharge** – Primary switchgear assets should be free of any signs of partial discharge (PD). If detected, partial discharge would indicate that the asset is a strong candidate for refurbishment or replacement. Increasing levels of PD can eventually lead to disruptive failure with serious safety implications.
- **Mechanism performance –** This related to the reduction in the performance of the operating mechanism of each circuit breaker over time. This metric is measured by recording both the trip time and the ease of operation of the circuit breaker. A gradual reduction in the performance of the operating mechanism will indicate that additional attention is required.
- **External Connections –** The busbar connections and switchgear bushings can deteriorate over time. This can lead to overheating and disruptive failure if not addressed.

3.1.1 Primary Investment Drivers

Table 2 lists the data that may be used to inform whether an individual 132kV Circuit Breaker asset requires investment for non-load related purposes. As seen in the table, this data is often captured by CBRM and is used to calculate the risk score for each asset. However, occasionally the data list is used in addition to the CBRM to determine if the asset requires non-load related investment due to other primary drivers.

Table 2: Primary data relevant to condition lead investment into 132kV Circuit Breakers

Category	Factor included within CBRM
Basic Asset Parameters	Asset age
	Expected lifetime
Measured Condition	Partial discharge measurements
	Ductor tests
	Infrared test
	Oil and gas tests
	Temperature readings (Thermal Imaging)
	Trip tests (closure times)
Observed Condition	Switchgear external condition
	Oil leaks and gas pressure
	Thermographic assessment
	Switchgear internal condition & operation
	Indoor environment
	Support structures
	Air Systems
	Cable boxes condition
Location Factor	Distance from coast
	Altitude
	Environment (Indoor or outdoor)
	Corrosion category index
Duty Factor	Number of operations

Corresponding Ofgem CV Tables

The primary investment drivers described above correlate to the following Cost and Volumes (CV) tables within the RIIO-ED2 Business Plan Data Tables (BPDTs):

- **CV7 – Asset Replacement:** The replacement of network assets due to their health and criticality of each asset as defined by the CBRM policy.

The costs and volumes associated with each CV table and the corresponding asset category depend upon the investment strategy and options that are chosen for each primary and secondary investment driver.

3.1.2 Secondary investment drivers and associated CV tables

Whilst this investment pack is intended to inform the management of 132kV Circuit Breakers for non-load related purposes, the investment options described within this EJP are also coordinated with several secondary investment drivers that may influence the final investment option that is selected for each 132kV Circuit Breaker project.

It is important to ensure that these secondary investment drivers are also considered carefully alongside the primary drivers to identify potential efficiencies and to prevent double counting within our RIIO-ED2 business plans.

This includes the analysis of future network trends to ensure sustainable investment decision are identified which represent best value for money for our network consumers and customers, whilst enabling the transition to net zero. Our Distribution Future Energy Scenarios (DFES) describe how these may influence the investment options that are taken forward.

The secondary investment drivers which influence this EJP and the investment options that are chosen include quality of supply, future load growth, and network automation. These secondary drivers correlate to the following additional CV tables within the BPDT:

> **CV15 – Quality of Supply:** The replacement, refurbishment, or retrofit of network assets specifically to improve customer quality of supply. This can include investment in network automation to improve IIS performance.

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 which best represents value for money for network consumers and customers:

- **Inability to Secure Spare Components:** Certain models of 132kV Circuit Breaker are no longer supported by the equipment manufacturer due to their age. This can lead to difficulties in securing spare components to repair broken or poorly performing assets. Consequently, 132kV circuit breaker may require replacement when repair, refurbishment, or retrofit is not viable for this reason.
- **Number of Customers and Network Outages:** When assessing the investment options available it is also important to consider the number of consumers and customers associated with the circuit breaker and the number of network outages and IIS penalties that have been incurred during previous years. This will inform the criticality of the asset and inform the most appropriate investment solution.
- **Network Load Forecast**: Future network trend analysis must also be carried out for each individual project to determine if sustained load growth can be expected for the substation that is associated with the 132kV circuit breaker in question. If load growth can be proven with a high 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, though in the case of 132kV assets this action is extremely unlikely.

3.2 132kV Circuit Breakers

This EJP focusses on the RIIO-ED2 investment in 132kV Air Insulated Busbar connected Circuit Breakers (outdoor). Figure 1 shows an example of a typical 132kV Circuit Breaker found on our distribution network: the environment in which they sit tends to be in outdoor substations with metal fencing.

Figure 1 – Example replaced 132kV CB - AIB (OD) at Amersham Main Old Oil (Left) New SF6 (Right)[1]

Circuit breakers are designed to interrupt fault conditions. These conditions are detected by relays which monitor the connected circuit for elevated currents (fault current). If the fault current is seen for a specified time the circuit breaker uses a mechanical system to open contacts which disconnects the conductors, thereby protecting all connected equipment.

In High Voltage applications the design of these assets becomes more complex as the arcing produced during the operation gets higher as the voltage increases. If this is done in air the distance between contacts would need to be substantial which is why in most cases alternative insulating mediums are used to quench the arc. An arc provides a path for current to travel between conductors, the use of these mediums minimises the impact of arcing, maximising the speed and effectiveness at which the circuit breaker operates.

There are a variety of insulating mediums used in circuit breaker applications, but the most commonly used for 132kV equipment is Sulphur Hexafluoride (SF_6). Due to the dependence on this gas to act as an effective arc quenching medium it is important that a sufficient volume of gas remains present in the breaker. A common failure mode of SF_6 insulated breakers is the deterioration of the gaskets and seals used to contain the gas within the equipment which can escalate the need to carry out top ups. This is monitored and scrutinised by us as a separate factor as part of our document: ***Environmental Action Plan (Annex 13.1)*** to justify replacement due to the detrimental effect of SF_6 on the environment (9/SSEPD/ENV/SF6). This driver however is not considered within this EJP.

132kV AIB (OD) Circuit Breakers are available as live-tank or dead-tank designs. Dead-tank designs put the interrupter in a grounded metal enclosure. Live-tank circuit breakers consist of an interrupter chamber that is

[1] KUS Power Engineering, 'Case Studies' Amersham Main 132kV Circuit Breaker Changes. https://kus.co.uk/case-studies/amersham-main-132kV-circuit-breaker-changes/ [Last accessed 21/9/2021]

mounted on insulators and is at line potential. Our strategy for replacements is to select like for like or the most similar model available at the time of replacement.

In distribution networks, circuit breakers are situated on either end of a circuit. In other applications they can be used between a generator and transformer for fast protection. In all scenarios their purpose is to protect connected equipment, and in turn any staff or the public, during fault conditions.

The failure of a 132kV Circuit Breaker (depending on the failure mode) is likely to have a significant impact on the network. The most detrimental is when a circuit breaker fails to open. The impact of this fault puts the connected equipment in danger of failure due to exposure of excess current levels beyond their operational expectation. This is generally remedied by activating a breaker higher up in the distribution network which increases the number of effected consumers. This has an exponential cost implication, but it also increases the risk of fatality and major injury to staff.

As such, it is critical that we maintain the condition of this asset category to prevent a reduction in the quality of supply for customers and to maintain the safety of our circuit breakers and connected equipment for our staff and the public.

Preventing the end-of-life failure of these circuit breakers also avoids costly reactive replacements which can be significantly more expensive than the cost associated with planned proactive replacement before failure.

As the Health of each Circuit Breaker deteriorates over time the Probability of Failure (PoF) increases. To prevent unwanted failures before they happen and to avoid costly reactive replacement of failed breakers, we calculate a Health Score for each asset. This allows us to proactively intervene at a lower cost before the total Risk of Failure (Probability of Failure x Consequence of Failure) becomes intolerable for network customers.

There are up to 26 different unique models of 132kV Circuit Breakers connected to our distribution network, each with their own unique characteristics, challenges and inspection and maintenance requirements. 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 up to 30 years ago.

Table 3 shows the quantity of 132kV Circuit Breaker assets (Air Insulated-OD-GM) in SEPD.

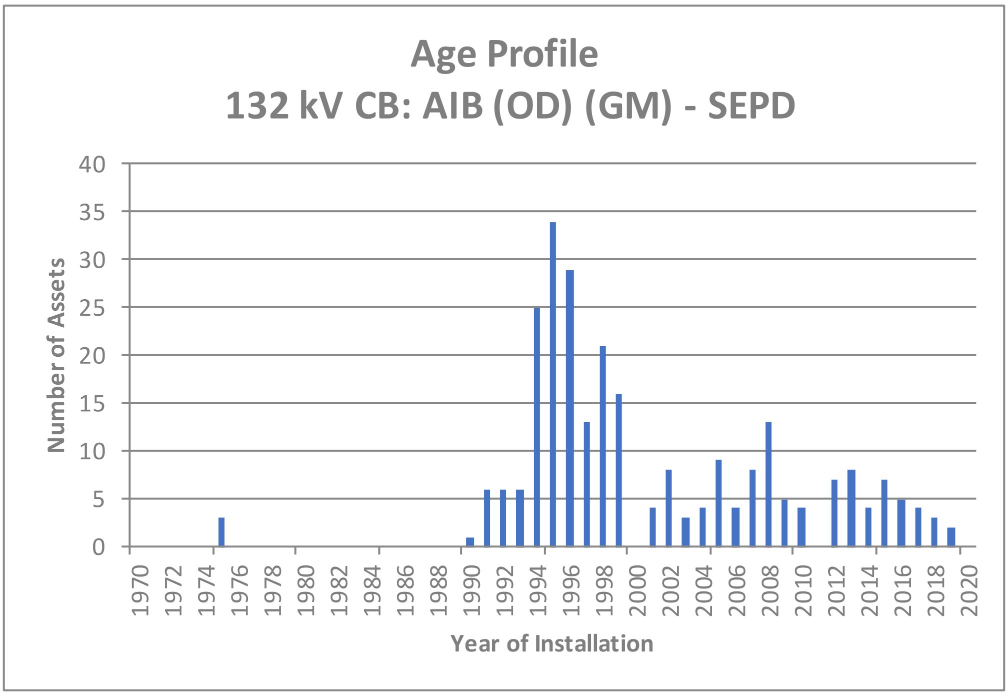
Table 3: SEPD total population of 132kV Circuit Breaker

	SEPD
132kV Circuit Breaker	**No. of Units**
132kV CB (Air Insulated Busbars) (OD) (GM)	262

Figure 2 shows the Age Profile for the asset category included within this EJP for SEPD. This shows the number of assets installed during each calendar year with a large number of assets installed 20-30 years ago and roughly five to ten assets installed each year since. This age profile is provided for information purposes only and cannot be used in isolation to justify any investment in the asset category.

Our CBRM policy calculates a Health and Criticality score which informs more clearly the investment required each year. However, there is a close correlation between age and asset health. Furthermore, these Age Profiles demonstrate the variance in the age of assets remaining on the network. This variance can result in sudden increases or decreases in future investment to manage these historic ageing assets.

Figure 2: Age Profile for 132kV Air insulated Busbar Circuit Breakers (OD) (GM) - SEPD



3.3 Condition Based Risk Management (CBRM)

We introduced our Condition Based Risk Management (CBRM) system in 2014 following the RIIO-ED1 Business Plan submission. However, since August 2017, we switched over fully to maximise utilisation of the Common Network Assets Indices Methodology (CNAIM) modelling for all asset classifications applicable for the RIIO-ED1 requirements with the data inputs outlined in the Information Gathering Plan (IGP).

The RIIO-ED2 Business Plan submission has been based on the latest version of the industry standard CNAIM v2.1 which was approved for use in RIIO-ED2 by Ofgem in April 2021. The supporting data used in the modelling of this submission is based on the reported position of our asset condition for RIIO-ED1 Year 6 at the end of March 2021, and subsequently reported to Ofgem in the summer of 2021.

The full details of the Energy Network Association's NARMs Electricity Distribution Working Group (NEDWG) publication on CNAIM v2.1 is available on Ofgem's website. For further detail on our RIIO-ED2 NARMS strategy please see ***Safe and Resilient (Annex 7.1).***

The output from CBRM has been used to inform the intervention criteria utilising our internal Network Asset Indices Methodology (NAIM) on how the assets are selected for prioritised investment. This is based on the assets relative position in the standard CNAIM reporting Risk Index matrix as illustrated by Table 4 below, which shows the value of Monetised Risk attributed to each asset according to its attributed Health and Criticality within each cell, providing a reference risk value in £. However, consideration is given to the specific Health Score within the selection criteria for a more granular consideration than purely consideration of the wider Monetised Risk (HI/CI) classification only.

The specific Health Score Intervention Criteria we have established for this asset category has been developed within a number of internal workshops with our subject matter expert with the objective of finding the optimal balance of risk between proactive and reactive asset intervention. This approach has also been tested and ratified through targeted stakeholder engagement and intends to maximise both the reliability and importantly the affordability of the network for our customers.

A fuller understanding of our NAIM and how the specific Health Score Intervention Criteria for each specific asset category was reached is available in our ***Safe and Resilient (Annex 7.1)*** within section 8 and the associated referenced technical guidance document TG-NET-ENG-026 (NAIM).

Table 4: 132kV CB AIB OD GM Risk Index Matrix

		Health Index				
Criticality Index		HI1	HI2	HI3	HI4	HI5
	C1	23,566	110,482	220,049	326,517	458,053
	C2	33,666	157,832	314,355	466,452	654,361
	C3	50,499	236,748	471,533	699,679	981,542
	C4	84,165	394,580	785,888	1,166,131	1,635,903

The specific selection criteria for each asset classification is detailed more specifically later in this EJP in identifying the volume of the specific asset classification requiring intervention. (Section 6).

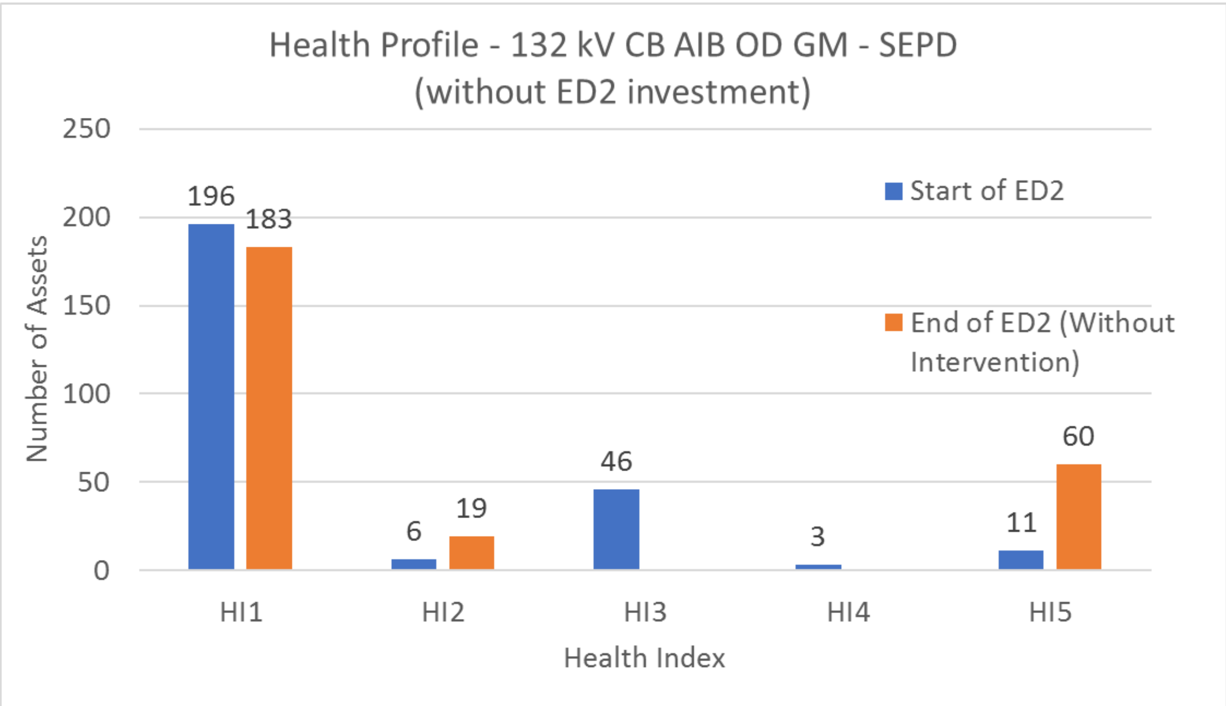
3.3.1 Health Index

The Health Index is a key output of the CBRM policy. This measure provides a view on the condition of the asset relative to its Normal Expected Life. For 132kV Circuit Breakers the Normal Expected Lifetime is as follows:

- 132kV CB (Air Insulated Busbars) (OD) – 50 years

Figure 3 shows the current Health Profile for SEPD 132kV Air Insulated Busbar Circuit Breakers (OD) (GM) and also the Health Profile by the end of ED2 where investment in these assets is limited to that expected to be completed in the remainder of ED1. As evident in the Figure, although most of the assets are HI1, there are a large number of HI3 assets which will provide a sharp increase in the quantity of HI5 assets without investment.

Figure 3: Health Profile for 132kV Air Insulated Busbar Circuit Breakers (OD) (GM) - (SEPD)

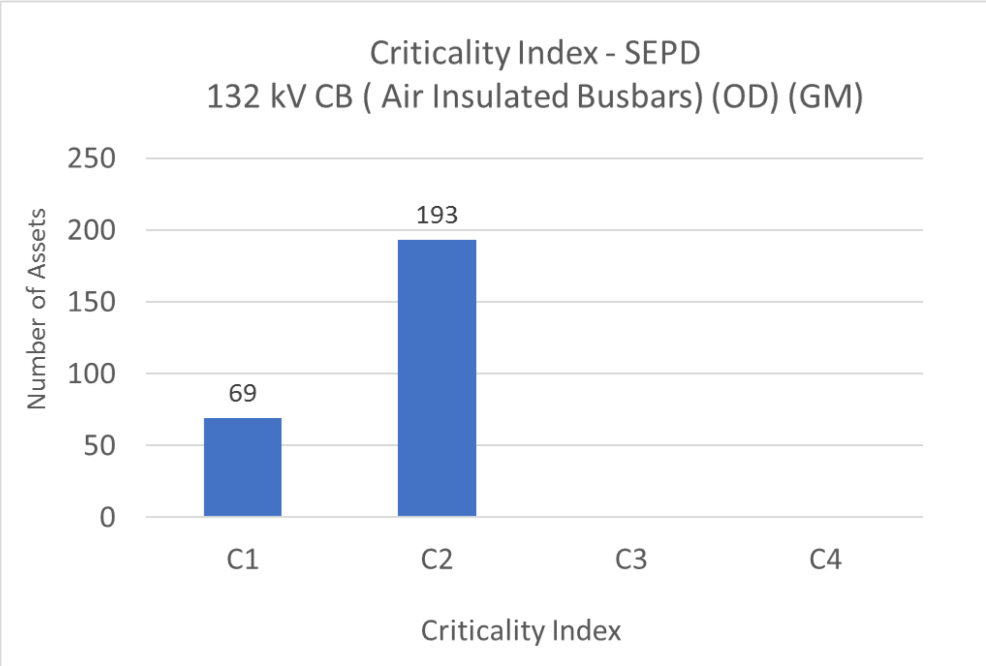


3.3.2 Criticality Index

The Criticality Index is used to prioritise the replacement, refurbishment, or maintenance of network assets based upon the impact they are likely to have should they fail. High criticality assets should be replaced ahead of low criticality assets to protect network customers. An Index between C1 to C4 is assigned to each asset, where C1 is the least critical. It is assumed that the criticality of each asset will remain constant from the beginning to the end of RIIO-ED2, as the consequence of failure is unlikely to change without a significant change in the characteristics of the network (for example, the number of customers connected to each asset).

Figure 4 shows the current SEPD Criticality Profiles for the particular 132 kV Circuit Breaker. As illustrated, all the assets are distributed between C1 and C2 showing that the network does not have any highly critical assets in this particular category.

Figure 4: Criticality Profile for 132kV Air Insulated Busbar Circuit Breakers (OD) (GM) - SEPD

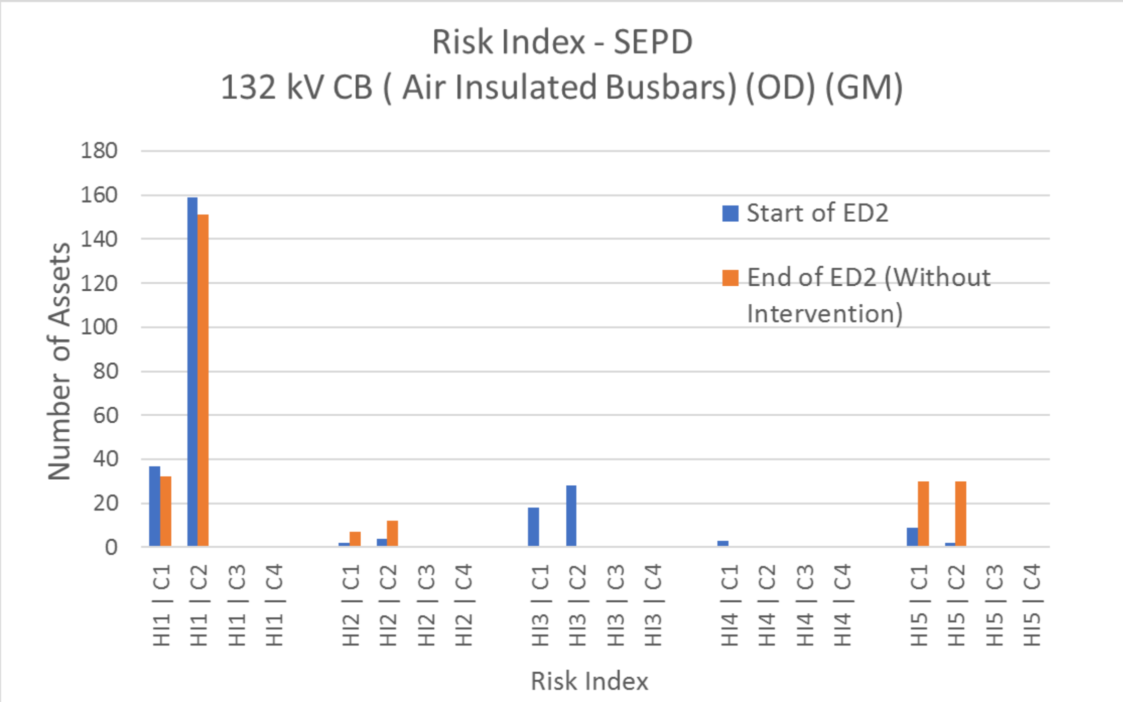


3.3.3 Total Risk Score

Figure 5 shows the Risk Profile associated with 132kV Circuit Breaker assets within SEPD currently and the projection for the end of RIIO-ED2 with any additional network investment limited to that expected for the remainder of ED1.

As seen, by the end of RIIO-ED2 there is a reduction in HI3 assets and an increase in the HI5 assets across both C1 and C2 criticality scores.

Figure 5: Risk Profile for 132kV Air Insulated CB (OD) (GM) - SEPD



4 Stakeholder Engagement

In preparation for our RIIO-ED2 business plans, several stakeholder engagement exercises have been undertaken to understand more clearly 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 Stakeholders' ***Enhanced Engagement Strategy (Chapter 3)***.

The details from some of our critical stakeholders' feedback on our Asset Management Strategy and their views on the importance of improving network reliability is presented:

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

- In maintaining a reliable network, stakeholders strongly urged us to strike a balance between simply fixing older assets and replacing assets (at a higher cost) 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 improve our control of 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 - must ensure the transition does not leave people behind.
- We need to think now about current and future populations in areas in order to plan our 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 likelihood of failure as part of the asset management strategy. 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 an expectation, as they depend on electricity for so many aspects 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.

5 Summary of Options Considered

This section of the report sets out the investment options that are considered when managing 132kV Circuit Breaker assets. A holistic approach is taken to ensure investment options which is least regrets and represents the best value for money for network customers.

The investment options range from no additional investment (Do Minimum) to the full replacement of each circuit breaker. 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 which avoids unnecessary spend and risks the future stranding of network assets.

5.1 Summary of Options

Table 5 provides a high-level summary of the **five** investment options under consideration along with the advantages and disadvantages associated with each. A more detailed description of each option is then provided within the following sub-sections.

Table 5: Summary of 132kV Circuit Breaker Investment Options

Option	Description	Advantages	Disadvantages	Result
1. Do Minimum	Continuation of the normal inspection and maintenance activities associated with 132 kV Circuit Breakers. Reactive replacement of Circuit Breakers following failure.	No additional CAPEX spend.	No improvement in asset Health. Increased risk of asset failure.	Not Considered.
2. Enhanced Inspection, Maintenance, and Monitoring	Enhanced inspection and maintenance to improve asset condition or slow the rate of ageing. Additional monitoring to better understand performance and health of the breaker.	Improved understanding of asset Health. Potential to prevent premature replacement of breaker. Can defer investment over short periods of time.	Additional maintenance resource required. Not effective for mechanical wear. Increase is part of OPEX portion of Cost and Volumes.	Not Considered.
3. Refurbishment	Refurbishment of the AIB circuit breaker operating mechanism.	No need for additional switch room. No civil costs.	Limited support from OEMs. Often costly when compared with other options. May require additional type testing.	Not Considered.
4. Retrofit	For AIB circuit breakers replacement of the entire CB mechanism with a new unit.	No cabling or jointing costs. Lower cost than full replacement of a switchboard.	Only considered if solution is low risk (tried and tested).	Not Considered.
5. Replacement (Baseline)	Like for like replacement of Air Insulated Busbar circuit breakers with equivalent technology. According to the latest CBA Guidance published by Ofgem this option is considered baseline as it is currently BaU for Air insulated Busbar assets.	Replacement of individual circuit breakers is possible rather than an entire switchboard.	Requires continued use of additional space. Exposed to weather so lower life expectancy Safety and security risk due to potential trespass. Outdoor structures and busbar may need to be replaced if in poor condition.	Considered.

5.2 Option 1: Do-Minimum

In this option a decision is made to accept the risk associated with each circuit breaker asset in its current condition without any additional CAPEX or OPEX investment. However, the normal annual inspection and maintenance activities required for 132kV circuit breakers continue as normal as per the relevant policies.

Whilst this option avoids additional CAPEX investment, it does not improve the condition of the circuit breaker in question. For end-of-life assets this option is likely to lead to asset failure which can have both safety, environmental and financial consequences and a reduction in the quality of supply for network customers.

For this reason, during RIIO-ED2 the do-minimum option is limited to assets which remain below the Health Score criteria described within our asset management policies. All other assets will require additional investment to manage the risk of asset failure within acceptable levels.

5.3 Option 2: Enhanced Inspection, Maintenance, and Monitoring

Option 2 recommends undertaking additional operational activities to further manage the risk associated with each asset. In the case of 132kV Circuit Breakers there are two approaches that can be considered within Option 2. These are:

1. **Enhanced Monitoring**: To understand more clearly the performance of the asset under consideration, enhanced monitoring can be installed to track key parameters associated with the operation of the circuit breakers. This can include the deployment of fixed monitoring for partial discharge or equipment to track the closure time of each circuit breaker during trip testing. The data that is collected from the monitoring equipment is then reviewed by the business to identify any trends that would indicate that additional invention through CBRM.
2. **Enhanced Inspection & Maintenance** To improve the management of the risk of asset failure, enhanced inspection and maintenance can also be carried out to slow the rate at which the asset deteriorates and to prevent increasing CB closure times etc. The cost of this additional inspection and maintenance strategy should be balanced against the additional lifetime that can be attributed to this increased OPEX investment and the deferment in the future replacement of the asset. This option is most successful when the underlying cause is inadequate lubricant rather than mechanical wear.

This option is usually a cost-effective option over short periods of time when compared with the replacement option. However, it can also increase the strain on maintenance resources and is not effective if the primary investment driver is mechanical wear.

For 132kV Circuit Breakers this option would only be relevant for volumes of assets with no condition information. Since all assets are known to hold condition-based drivers this option has not been considered.

5.4 Option 3: Refurbishment

Option 3 considers the refurbishment of the 132kV circuit breakers in question. The refurbishment of individual circuit breakers would require bespoke support from the OEM and the provision of spare components. The need for this OEM support will often reduce the cost competitiveness of this option, particularly for a temporary extension of the lifetime of the asset when compared with a full replacement.

Therefore, the cost of a refurbishment and the expected increase in the condition of the asset and its remaining useful lifetime should be balanced against the deferment of the full replacement of the switchgear which may still be required later on.

In this instance refurbishment of circuit breakers has not been considered. This is based on the alignment of support by OEM's. Where OEM components remain available it is more effective to replace the asset due to its size, complexity and the fact that a replacement can be catered for much more easily considering that the volumes posed are all outdoor. Where OEM support is not available, for similar reasons, a retrofit option of a new asset is the preferred approach. This standpoint is the BaU strategy currently utilised by SEPD.

5.5 Option 4: Retrofit

Because the full volume of 132kV Circuit Breakers are AIB connected and located outdoors retrofit is an option if a like for like circuit breaker is no longer available due to obsolescence. For this asset class the retrofit option includes the supply of a brand-new circuit breaker of similar design which is fitted in place of the existing unit. In most cases minor supporting works are required to ensure connections and mounting points are located correctly to accommodate the new unit.

Because the asset is new and there is no detrimental effect on the asset's potential life this option has been removed for consideration in a CBA and the volumes have been attributed to the Replacement option (discussed).

5.6 Option 5: Replacement

The replacement options for 132kV AIB Circuit Breakers is:

- **Outdoor Air Insulated Busbar Solution** – This option uses outdoor circuit breakers which in some cases allows the existing outdoor busbars to be reused if in good condition and the support structures are also safe and secure. This solution is significantly cheaper than Indoor Gas Insulated Busbar technology and allows individual circuit breakers to be replaced. However, it also requires a lot of outdoor space which can be restrictive and costly in urban areas. Exposure to the weather can also accelerate deterioration and increases the risk of trespass and the associated safety and security concerns.

For 132kV Circuit Breakers this option has been taken forward. This incorporates the replacement of a like for like asset or, a new asset which requires minor enabling work to complete the installation (retrofit). This option is currently the BaU strategy used by us to tackle end-of-life assets.

6 Detailed Analysis

This section of the report describes the investment strategy that we have chosen for 132kV Circuit Breakers for RIIO-ED2. This strategy has been informed by both stakeholder engagement and wider RIIO-ED2 strategies.

6.1 Our Health Score Intervention Criteria

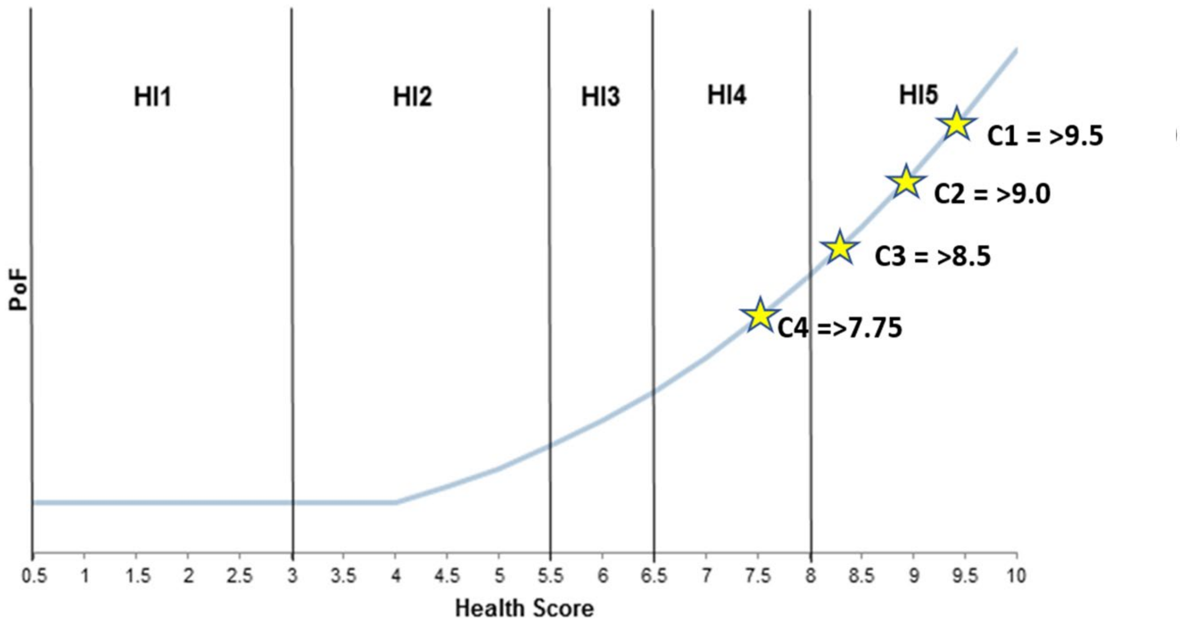
We have developed our own investment criteria for assets which are deemed to be end-of-life due to their condition. This criterion is applied against the Health and Criticality scores arising from our CBRM models to identify which assets require intervention during RIIO-ED2.

The Health Score as defined by the Ofgem approved Common Network Asset Indices Methodology (CNAIM) which can be correlated to a Probability of Failure (PoF). The worse the asset health the higher the PoF will be. The total Risk for network customers increases as the PoF increases with the condition of the asset.

During ED2, we do not feel it is appropriate to replace all assets that are projected to become Health Index 5 by the end of ED2. This approach would shortlist Circuit Breakers for replacement that still have multiple years of useful lifetime before likely failure and could be replaced proactively during RIIO-ED3.

As such, specific Health Score criteria has been developed based upon the Criticality (consequence of failure) of each Circuit Breaker. This is reflected in Figure 6 which shows the probability of failure rising as the health score increases along on the horizontal axis. The particular points indicated on the graph show the intervention points for different asset criticalities. The higher the criticality of the asset, for example C4, the lower the PoF which is deemed tolerable for network customers. In addition, the Figure shows the minimum Health Score for each Criticality before an intervention is considered necessary.

Figure 6: Health Score Investment : Sensitivity 1 Criteria for 132kV Circuit Breakers



This approach has been designed to maximise the lifetime of our network assets and to defer replacement for as long as possible.

If a more basis approach was taken, such as the intervention of all Circuit Breakers that become HI5 by the end of ED2, a significantly higher number of Circuit Breakers would require intervention.

6.2 Sensitivity Analysis

To arrive at the methodology discussed above in Section 6.1 a sensitivity analysis was carried out. This sensitivity analysis allows us to establish the impact on the volumes of interventions required during RIIO-ED2 when the Health Score investment criteria is adjusted.

This risk management exercise explores the impact on the volume of ED2 interventions if we were to accept more or less risk of asset failures within this asset category.

Stakeholder engagement (discussed in Section 4) has found that, during RIIO-ED2, network customers' first priority is affordability, closely followed by the reliability of the network. As such, when selecting the minimum Health Score for each Criticality banding which justifies the need for ED2 intervention, it is important that both affordability and reliability are taken into consideration.

High health scores indicate assets with poor condition. By increasing the minimum Health Score for each Criticality band, the number of shortlisted assets in the Health Score/Criticality band will reduce as fewer assets have reached the poorer condition indicated by the higher Health Score. A higher score criteria also allows us to maximise the useful lifetime of network assets and not include assets on the shortlist which have lower health scores (better condition). However, as the Health Score corresponds to the Probability of Failure (PoF) increasing these minimum values will also increase the number of costly asset failures that we will experience during ED2. A careful balance must be found between maximising the lifetime of our assets and avoiding costly failures.

For this reason, three scenarios were considered for 132kV Circuit Breakers as shown in Table 6. Each sensitivity analysis captures a different volume of assets for intervention during ED2 by altering the minimum Health Score values for each criticality. It is important to note that these values represent the Health Scores for each asset (from our CBRM models) that have been calculated as at the end of ED2.

Table 6: 132kV Circuit Breaker sensitivity analysis criteria

Criticality	**Health Score band**		
	Sensitivity 1	**Sensitivity 2**	Sensitivity 3
C1	≥ 9.50	**≥ 9.50**	≥ 9.00
C2	≥ 9.00	**≥ 9.00**	≥ 8.75
C3	≥ 8.50	**≥ 8.50**	≥ 8.25
C4	≥ 8.00	**≥ 7.75**	≥ 7.50

Sensitivity 1 investment criteria shortlists assets for intervention which will fall within the Health Index 5 band only. However, within this Health Index the more critical C4 assets are shortlisted for intervention at a lower Health Score (and lower PoF) than the C1 assets, due to C4 assets having a more significant Consequence of Failure (CoF).

For Sensitivity analysis 2, the more critical C4 assets are shortlisted for intervention at a lower Health Score (and lower PoF) than in the Sensitivity 1 analysis. This scenario shortlists those C4 assets which fall within the very end of the HI4 band (7.75) just before these assets are expected to become HI5s. This approach reduces the total risk that network customers are subjected to with these highly critical circuit breakers, whilst also attempting to maximise their useful lifetime. This is the example illustrated in Figure 6.

Sensitivity analysis 3 takes this slightly further by reducing the health score across all criticalities: thereby increasing the numbers of assets proposed for intervention. In particular, this analysis shortlists those C1 and C2 assets with an HI5 health score above 9.00 and 8.75, respectively. The effect on the volumes from each scenario can be seen in Table 7.

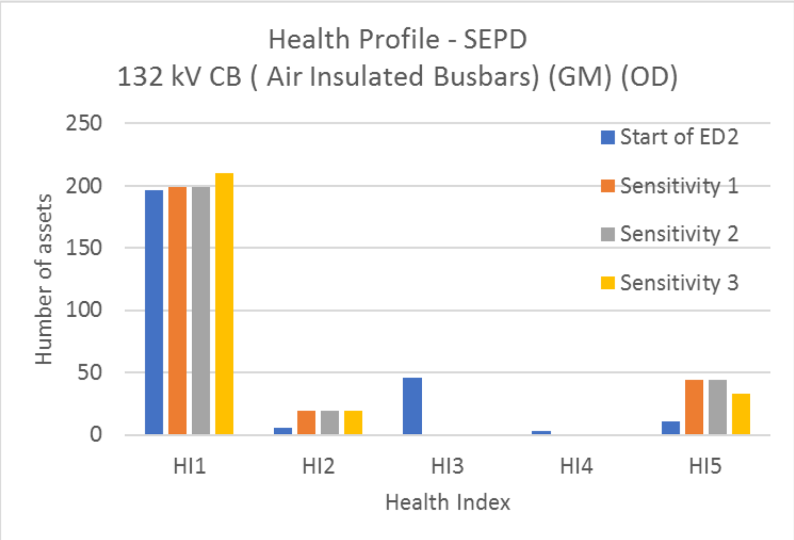
As expected, and looking back at Figure 5, the impact of the change in Sensitivity 3 is to increase the number of assets proposed for intervention on the SEPD network.

Table 7: 132kV Circuit Breakers sensitivity analysis volumes

Asset	**ED2 Volume**		
	Sensitivity 1	Sensitivity 2	Sensitivity 3
	Vol	**Vol**	Vol
132kV CB (Air Insulated Busbars) (OD)(GM) - SEPD	16	**16**	27

The impact of these volumes on overall Health Profiles at the end of ED2 can be seen in Figure 7 where the decrease in HI5 assets under Sensitivity 2 Health index criteria (Yellow) can be seen, along with the corresponding increase in HI1 assets.

Figure 7: Health Profiles of scenarios in sensitivity analysis for 132kV Circuit Breakers (SEPD)



Monetised risk (MR) was also calculated to allow comparison as part of the sensitivity analysis process, the values for each intervention scenario for 132kV Circuit Breakers are provided in Table 8. Under the Sensitivity 1 and 2 criteria, the MR increases over the ED2 period. Using the Sensitivity 3 criteria the MR increases from the start of ED2 but is less than both the MR using the Sensitivity 1 and 2 criteria: the asset health and risk improves due to the intervention on a larger number of assets.

However, these scores were combined with all assets in the ED2 business plan and were reviewed holistically by us, resulting in a decision made to pursue **Sensitivity 2** as it represented the right balance of risk (affordability vs reliability) for the business and network customers.

Table 8: Change in Monetised Risk (MR)

Licenced Area	MR (Current)	MR (End of ED2 with proposed sensitivity analysis investment)		
		Sensitivity 1	**Sensitivity 2**	Sensitivity 3
SEPD	26,250,700	34,367,040	**34,367,040**	27,911,811

6.3 Cost Benefit Analysis

The investment options described in this EJP have not been assessed within a Cost Benefit Analysis (CBA). This is based on the information contained in the CBA guidance document published by Ofgem.

132kV Circuit breaker condition is based on NARM/CNAIM outputs. Also, these assets are restricted in their feasible options on technical grounds. The sole technically justified option tackles interventions using a replacement strategy. The single breaker replacement for AIB is considered BaU which is specified to be considered baseline by Ofgem. This is the limit of feasible options which could be compared as the guidance states we should not reflect a 'do minimum' ('run to failure') approach as this is not a practical option for a DNO to employ as a business strategy.

6.4 Proposed RIIO-ED2 Investment

As previously described, the primary investment driver associated with this EJP is the management of 132kV Circuit Breaker assets for non-load related purposes, specifically asset Health and Criticality. This correlates to the CV7 (Asset Replacement) table within Ofgem's BPDTs. The following subsections show the costs and volumes that are proposed for RIIO-ED2 for this CV table.

6.4.1 CV7 Asset Replacement

Table 9 and Table 10 show the volumes and costs associated with the replacement of the 132kV Circuit Breaker asset category for SEPD. These costs and volumes have been determined by our ***Safe and Resilient (Annex 7.1)*** asset management strategy for this asset category and the feedback we have gathered from the RIIO-ED2 stakeholder engagement activities.

Table 9: CV7 132kV Circuit Breaker Volumes for RIIO-ED2

Asset Category	Unit	2024	2025	2026	2027	2028	Total
132kV Air Insulated OD GM (SEPD)	#	2	3	3	3	5	**16**
Total	#	2	3	3	3	5	**16**

Table 10: CV7 132kV Circuit Breaker Cost for RIIO-ED2

Asset Category	Unit	2024	2025	2026	2027	2028	Total
132kV Air Insulated OD GM (SEPD)	£m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	£m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

6.1 Change in Network Health & Risk Scores

Given the investment proposed for the chosen investment strategy in CV7, Figure 8 shows the change in the Health Profiles for 132kV Circuit Breakers between now and the end of ED2 with the proposed investment set out in the table above.

As seen, there still remain a number of HI5 circuit breakers despite our proposed volumes of ED2 interventions. This demonstrates the Health Score Intervention Criteria approach we have taken when identifying the Circuit Breakers that really need intervention based upon their individual Health Score and Criticality.

As per our ***Safe and Resilient (Annex 7.1).***asset management strategy for RIIO-ED2, we have only shortlisted 132 kV Circuit Breakers for replacement when the Health Score within the Health Index 5 banding becomes so severe that the continued risk for network customers becomes intolerable and the asset must be intervened upon.

Any reduction against these volumes will risk the reliability, safety and environmental impact of the network to the detriment of our network customers.

Figure 8: Health Profile 132kV AIB CB (OD) – SEPD (Current and After intervention)

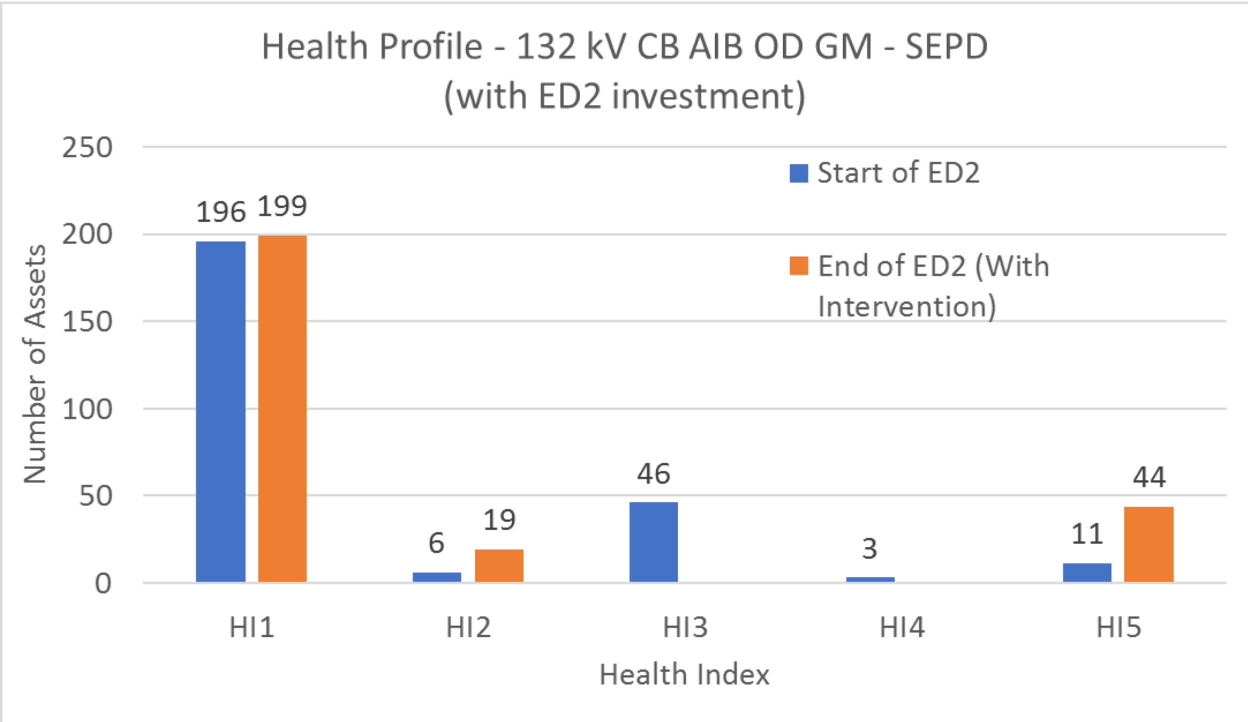


Table 11 shows the change in Monetised Risk (MR) by the end of RIIO-ED2 with and without the investment proposed within this EJP. From the table, the monetised risk increases over the ED2 period but there is a larger monetised risk without intervention.

Table 11: Change in Monetised Risk (MR)

Licenced Area	MR (Current)	MR (End of ED2 with proposed investment)	MR (End of ED2 without proposed investment)
SEPD	26,250,700	34,367,040	41,877,456

6.2 Costing Approach

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 ***Cost Efficiency Annex (15.1).***

Following on from our draft Business Plan, we have continued to develop project volumes and costs, utilising valuable stakeholder feedback. We have included developments of our Commercial Strategy within the updated project scope and delivery strategy.

This analysis has produced **RIIO-ED2 CV7a unit costs as follows:**

- 132kV AIB CB (OD) SEPD – [redacted]

6.3 RIIO-ED2 Deployment of Investment Options

Table 12 shows the volumes that have been calculated for each RIIO-ED2 strategies for each of the investment options considered for 132kV Circuit Breaker assets.

The table shows the final volumes associated with each investment option concluded from our strategic review of each strategy for 132kV Circuit Breakers and feedback from our stakeholder engagement exercises.

Table 12: SSEN Final RIIO-ED2 volumes for each investment Option

Option	Options Name	No. of Deployments (#)	RIIO-ED2 TOTEX Spend (£m)
5	Replacement	16	[redacted]

A phased roll-out of replacements for “end-of-life” 132kV circuit breakers is the preferred approach for the deployment by us. The rollout was presented in Table 9.

6.4 Deliverability and Risk 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 with 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 13 shows a comparison of the 132kV Circuit Breakers replaced within the first 5 years of RIIO-ED1 compared to our proposal for RIIO-ED2. Overall, our RIIO-ED2 volumes represents a 129 % increase compared to the volumes that have been delivered in the first 5 years of RIIO-ED1. The numbers proposed were based on the assets' overall health criteria.

Table 13 - SSEN change in volume comparison for deliverability

SSEN Licenced Area	ED1 (first 5 years)	ED2 Proposed Volumes	Percentage Change
SEPD	7	16	+129 %

7 Conclusion

The purpose of this Engineering Justification Paper (EJP) has been to describe the overarching investment strategy that we intend to take during RIIO-ED2 for the non-load related management of 132kV Circuit Breaker assets, specifically *132kV Air Insulated Circuit Breaker OD GM.*

A background into the asset category under consideration has been provided including the Age Profiles for SEPD and the Health, Criticality, and Risk profiles prior to the start of ED2 and at the end of ED2 without investment. SHEPD is not considered, because SHEPD does not possess any 132kV Switchgear assets as part of their distribution network.

Section 5 outlined five investment options for the issue of dealing with poor condition assets. A holistic approach is taken when selecting the most viable option for each circuit breaker project and includes careful consideration of the financial, safety, and environmental implications of each option. In relation to the 132kV Circuit Breakers only the option 5 has been selected for deployment.

- Option 1: Do Minimum
- Option 2: Enhanced Inspection, Maintenance, and Monitoring
- Option 3: Refurbishment
- Option 4: Retrofit
- **Option 5: Replacement**

The options listed above have been assessed against RIIO-ED2 strategies as follows: Meeting Obligations, Stable Performance, and Leading Reliability. A thorough stakeholder engagement exercise was undertaken to gather feedback on each of these strategies to determine which approach should be proposed within our RIIO-ED2 business plans.

The most cost-effective investment option identified for 132kV Circuit Breakers is the proactive replacement of the existing “end-of-life” assets. This solution delivers significant financial benefits for network customers.

In total, **16 circuit breakers** have been identified for replacement during RIIO-ED2 based on the asset’s health.

This investment represents a total spend of [redacted] throughout RIIO-ED2.

8 Appendix 1 Acronym Table

Acronym	Description
AAAC	All Aluminium Alloy Conductors
ACB	Air Circuit Breaker
ACSR	Aluminium Conductor Steel Reinforced
AIB	Air Insulated Busbar connected
AVC	Auto Voltage Control
BaU	Business as Usual
BPDT	Business Plan Data Table
Cad Cu	Cadmium Copper
CapEx	Capital Expenditure
CB	Circuit Breaker
CBRM	Condition Based Risk Methodology
CBA	Cost Benefit Analysis
CCA	Chromated Copper Arsenate
CEG	Customer Engagement Group
CI	Customer Interruption
CML	Customer Minutes Lost
CMR	Continuous Maximum Rating
CMZ	Constraint Management Zone
CNAIM	(DNO) Common Network Asset Indices Methodology
CO_2e	Carbon Dioxide equivalent (can be suffixed by t (tonnes))
CoF	Consequence of Failure
Consac	Underground Cable type, Paper insulation with Aluminium Sheath
CRC	Charge Restriction Condition
CV	Cost and Volume
DFES	our Distribution Future Energy Scenarios
DGA	Dissolved Gas Analysis
DIN	Dangerous Incident Notification
DNO	Distribution Network Operator
DP	Degree of Polymerisation
DPCR5	Distribution Price Control Review for five years from 1 April 2010 to 31 March 2015
DSI	Death or Serious Injury
DSO	Distribution System Operator
DTI	Department of Trade and Industry

EHV	Extra High Voltage, Voltages > 22 kV and < 132kV , in SSEN these assets are usually 33 kV and 66 kV.
EJP	Engineering Justification Paper
ENA	Energy Networks Association
EQ	Equation
ESQCR	Electricity, Safety, Quality and Continuity Regulations
EU	European Union
FFA	Furfuraldehyde
FFC	Fluid Filled Cable
GB	Great Britain
GIB	Gas Insulated Busbar connected
GM	Ground Mounted
GRP	Glass Reinforced Plastic
HI	Health Index
HSE	Health and Safety Executive or Health, Safety and Environment
HM	Her Majesty or His Majesty
HV	High Voltage, Voltages > 1 kV and < 22 kV , in SSEN these assest are usually 6.6 kV and 11 kV.
ID	Indoor
IIS	Interruption Incentive Scheme
IR	Insulation Resistance
kV	Kilovolt
LCT	Low Carbon Technology
LV	Low Voltage, Voltages < 1 kV, in SSEN these assest are usually ~400V.
LV UGB	Low Voltage Underground Board (Link Box)
LTA	Lost Time Accident
MEAV	Modern Equivalent Asset Value
MMI	Maximum and Multiple Increment
MR	Monetised Risk
MVA	Megavolt Ampere
NaFIRS	National Fault and Interruption Reporting Scheme
NAIM	Network Asset Intervention Methodology
NARA	Network Asset Risk Annex
NARM	Network Asset Risk Metric
NAW	Network Assets Workbook
NEDeRs	National Equipment Defect Reporting Scheme
NPV	Net Present Value

OD	Outdoor
OEM	Original Equipment Manufacturer
Ofgem	Office of Gas and Electricity Markets
OHL	Overhead Line
OpEx	Operational Expenditure
PCB	Polychlorinated Biphenyls
PESC	Postsecondary Electronic Standards Council
PILC	Paper Insulated Lead Covered
PM	Pole Mounted
PoF	Probability of Failure
PVC	Polyvinyl Chloride
RIG	Regulatory Instructions and Guidance
RIIO	Ofgem's price control framework first implemented in 2013
RIIO-ED1	First price control for Electricity Distribution companies under the RIIO framework from 1 April 2015 to 31 March 2023
RIIO-ED2	Second price control for Electricity Distribution companies under the RIIO framework from 1 April 2023 to 31 March 2028
RMU	Ring Main Unit
SDI	Secondary Deliverable Intervention
SEPD	Southern Electric Power Distribution PLC
SF6	Sulphur Hexafluoride
SHEPD	Scottish Hydro Electric Power Distribution PLC
SLC	Standard Licence Condition
SOP	Suspension of Operational Practice
UGC	Under Ground Cable
VoLL	Value of Lost Load
VSL	Value of Statistical Life
WM	Wall Mounted

9 Appendix 2 Cost and Volume Summary

The breakdown of the cost and volume summary is given in Table 14 and Table 15

Table 14: CV7 132kV Circuit Breaker Cost for RIIO-ED2

Asset Category	Unit	2024	2025	2026	2027	2028	Total
132kV Air Insulated OD GM (SEPD)	£m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total	£m	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 15: CV7 132kV Circuit Breaker Volumes for RIIO-ED2

Asset Category	Unit	2024	2025	2026	2027	2028	Total
132kV Air Insulated OD GM (SEPD)	#	2	3	3	3	5	**16**
Total	#	2	3	3	3	5	**16**

1

10 Appendix 3 Relevant Policy, Standards, and Operational Restrictions

A sample of the policies, manuals, standards and operational restrictions which govern the management of 132kV Circuit Breakers is listed in Table 16.

Table 16: 132kV Circuit Breaker relevant documents

Policy Number	Policy Name / Description
SP-NET-SST-013	Circuit Breakers at 66 kV and Above
SP-PS-402	Current Transformer, Voltage Transformer, Line Trap and High Accuracy Metering Unit for 66 kV and above
TG-NET-ENG-026	Network Asset Intervention Methodology
TG-NET-SST-200	Technical Guide Primary Substation Plant Catalogue