Investment Decision Pack

NGET_A9.03 – Circuit Breakers and Bays

December 2019

As a part of the NGET Business Plan Submission

nationalgrid

nationalgrid

Engineering Justification Paper; Non-Load Related Circuit Breakers & Bays			
Asset Family	Circuit Breaker and Bay Equipment		
Primary Investment Driver	Monetised Risk (Lead Assets - CBs) and Asset Policy (Non-Lead Assets – Bays)		
Reference	A9.03		
Output Asset Types	• Circuit Breakers • Disconnectors • Earth Switches • Surge Arresters		
Cost	£263.88m		
Delivery Year(s)	2021 – 2026		
Reporting Table	C2.2a		
Outputs included in RIIO T1 Business Plan	None		
Spend Apportionment	**T1**	**T2**	**T3**
	£2.640m	£260.730m	£0.510m
Completion of RIIO-T1 schemes		£90.250m	
Development of schemes to deliver output beyond T1		£0.570m	
Total		£351.5m	

Table of Contents

1. EXECUTIVE SUMMARY

This report justifies the RIIO-T2 asset intervention plan for [redacted] circuit breakers (lead assets) and [redacted] bay assets (non-lead assets, [redacted] bay equivalent) at a total cost of £263.88m.

Circuit breakers (and the additional bay assets necessary to configure and maintain a reliable network) are the equipment required to connect and disconnect electrical circuits to control power flows and manage safety on the network. They are collectively referred to as switchgear and play a critical role in maintaining security of supply on the system.

RIIO-T1 allowances covering switchgear were set over a wide range of assets and included in situ interventions (in the same location as the existing asset) as well as more complex substation rebuilds. This paper sets out the justification for the in situ interventions for RIIO-T2 and confirms the complex RIIO-T1 projects which complete in RIIO-T2 (see Appendix A for details). For RIIO-T1 we are on track to deliver overall risk outputs, with some changes to switchgear volume due to external factors and evolving asset health, which are detailed in this report.

This RIIO-T2 plan is based on the output of the monetised risk approach for **circuit breakers**, aimed at targeting the most critical and at-risk assets that demonstrate a poor asset health, and maintaining current levels of network risk in line with stakeholder expectations. Volumes also account for our RIIO-T1 experience, where assets most at risk have been replaced, and the remaining population has not deteriorated as quickly as anticipated. Based on this approach, we will undertake fewer interventions during RIIO-T2 compared to the current price control. RIIO-T1 volumes were driven by a spike in installations in the 1960s and 1970s, resulting in a spike of assets reaching end of life. Delivery against our network risk outputs in the current period means that for circuit breakers, this spike does not continue through RIIO-T2. It does, however, drive a significant increase in activity on associated bay equipment (see below).

An overview of volume and cost variances between RIIO-T1 actuals (first 6 years) and the RIIO-T2 plan averages is outlined below. It shows the impact of the volume reduction, and a reduced cost due to the type of circuit breakers being replaced and efficiencies embedded from RIIO-T1 ('Lower cost per unit' bar).

Circuit Breaker replacement annualised spend

[redacted]

Circuit Breaker refurbishment annualised spend

[redacted]

Bay non-lead asset interventions are policy driven, targeting assets that have known issues, family type issues or reached their anticipated asset life. The refurbishment programme for bay assets which was developed during RIIO-T1 will continue during RIIO-T2 for 400kV and 275kV assets. Intervention volumes in RIIO-T2 will be more than 50% higher than RIIO-T1, driven by a spike in assets reaching end of life. Due to the volume of assets in this category, the spike in switchgear installations in the 1960s and 1970s continues to drive volumes through RIIO-T2. This is a staggered delivery profile for bays in comparison to circuit breakers, based on the criticality of the assets.

We have conducted optioneering to ensure that the mix of interventions achieves best value for customers across all asset categories. This includes full Cost Benefit Analysis (CBA) to derive a Net Present Value (NPV) estimate for each option. This analysis finds that:

- **A mixture of replacement, refurbishment and repair** is best value for circuit breakers. The expected cost for this suite of interventions is £33m in RIIO-T2.
- **A mixture of replacement and refurbishment** is best value for bays. The expected cost for this suite of interventions is £228m[1] in RIIO-T2.

Due to the range of assets, schemes and intervention types covered by this category, it is more difficult to show all the cost and volume evolutions between RIIO-T1 and RIIO-T2 in one view. However, within the detail it is shown that embedding our RIIO-T1 efficiencies into the RIIO-T2 plan, along with our value engineering approach means individual unit costs [redacted]

Circuit breaker replacement unit costs

[redacted]

Note: TNEI costs contain additional bay scope, in contrast to our value engineered approach

Circuit breaker refurbishment unit costs

[redacted]

Bay unit costs

[redacted]

Note: Shows corrected[1] RIIO-T2 unit cost for 275kV bays against the BPDT recorded unit cost. Costs shown are for a standard bay.

---

[1] The NGET Board has put in place a robust and independently verified assurance process to support the creation of NGET's RIIO-T2 Business Plan. The execution of this assurance process has identified an error that has led to the overstatement of the cost forecasts for asset health works required for one specific asset category, namely 275kV Bay refurbishment, by an amount of £33.8m over the 5-year period covered by the business plan. The root cause of the error has been identified and confirmed by the assurance process as being isolated and specific to this asset category. Due to the timing of the error being identified it has not been possible to correct it in all constituent parts of this business plan prior to the start of the necessary printing process associated with the submission of the final business plan.

2. INTRODUCTION

This chapter provides background information on the equipment covered by this paper and how they are categorised for analysis.

The equipment required to connect and disconnect electrical circuits to control power flows and manage safety on the network is collectively known as switchgear. There are two main types: air-insulated switchgear (AIS) and gas-insulated switchgear (GIS)

The term ‘switchgear’ includes the following equipment:

- **Circuit breakers** are mechanically operated, electrical switching devices, capable of connecting and disconnecting full load current during normal operation and under faults. In addition, circuit-breakers are specified to be capable of breaking the capacitive charging currents associated with cables and overhead lines. For certain applications, such as capacitor banks and shunt reactors, additional duty-specific requirements and testing may also be specified.
- **Disconnectors** are designed to operate at no load or very light load. They are used to configure the operational network and they physically disconnect equipment from the rest of the system so that it may be worked upon providing a visible safety indication for personnel working on assets.
- **Earth switches** are required to connect isolated equipment to earth potential and maintain a low-resistance current path with the intention of discharging any stored charge which may still be present post-isolation and creating a safe working environment for personnel.
- **Surge arresters** are installed to limit over-voltages (e.g. lightning and switching surges) absorbing and diverting the excessive current to earth to protect assets from damage and improve system availability.

In line with our asset management policies and current industry standards, our switchgear population can be classified into two main categories:

- Lead assets - Circuit Breakers
- Non-Lead assets - Bay assets (Disconnectors, Earth Switches & Surge arresters)

RIIO-T1 allowances covering switchgear were set over a wide range of assets and included in situ interventions (in the same location as the existing asset) as well as more complex site rationalisation projects. These more complex projects include additional scope e.g. cost of land purchase, planning process, complex design interfaces and staged construction for circuit transfers. This paper sets out the justification for the in situ interventions for RIIO-T2 and confirms the complex RIIO-T1 projects which complete in RIIO-T2 (see Appendix A for details).

3. PERFORMANCE IN RIIO-T1

RIIO-T1 allowances covering switchgear were set over a wide range of assets, and included in situ interventions (in the same location as the existing asset) as well as more complex substation rebuilds. Below, in Section 3.1, we briefly present analysis of how we have performed against the relevant allowances in terms of cost and volume for circuit breakers and bays in RIIO-T1. In Section 3.2 we discuss RIIO-T1 volumes for in situ interventions for circuit breakers and bays.

3.1 Overview - Performance of Wider Portfolio

Table 1 below displays the total volumes (and associated cost) forecast to be delivered until the end of RIIO-T1 for the wider switchgear portfolio versus allowances (all in £m, 18/19 prices). RIIO-T2 volumes for the switchgear categories justified in this report are set out in Section 4.

Table 1: RIIO-T1 performance; combined circuit-breaker replacements and refurbishments

Switchgear portfolio	T1 Allowances	T1 Actuals	T1 Forecast	T1 (all years)	Annual average	Annual avg (first 6 years)
Total cost (£m)	1335	657	295	952	119	110
Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Our 8-year switchgear delivery plan remains on track with the significant step-up in delivery volumes as forecast from 2015/16 onward. The RRP19 spend forecast for switchgear over RIIO-T1 is £952m; this is £382m less than allowances of £1,335m. We are on track to deliver overall risk outputs, with some changes to switchgear volume due to external factors and evolving asset health, which are detailed below.

Table 2 sets out how the £382m net saving against RIIO-T1 allowances will be achieved:

Table 2: Switchgear attributable savings/increases

Area	Net Saving (£m)	Detail
Efficiency	331	**Targeted bay replacement and refurbishment (£158m reduction).** Adopting a targeted replacement or targeted refurbishment approach on all bay replacements and refurbishments has resulted in cost savings. **Extended in-house switchgear refurbishment capability (£54m reduction).** Based on further cost benefit analysis, we have extended the range of refurbishment and reconditioning intervention techniques that are carried out in our Switchgear Refurbishment Centre. **Identifying design efficiencies (£43m reduction).** Through working closely with our suppliers, we have developed new interface engineering to install replacement circuit breakers into existing bays.

Area	Net Saving (£m)	Detail
		Contracting strategy and in-house delivery (£41m reduction). Efficiency savings of £12m are forecast through the improvement of construction contracting strategies by using tier 2 contractors for simple projects, thus avoiding tier 1 project management costs. Assessing supplier performance and capabilities enables us to ensure the most efficient delivery and construction plan is developed. In addition, we have been able to achieve an £8m reduction in cost through the bulk purchase of circuit breakers. We have also developed the capability for delivering straight- forward, non-complex in situ Circuit Breaker replacements using our internal operational resources. This reduces costs for breakers and bays leading to an avoidance of contractor costs and overheads which has resulted in savings of around £20m. **Wall bushing replacement efficiency (£50m reduction).** We have realised lower costs than initially estimated for replacement of through-wall bushings due to some bushing replacements being carried out as part of switchgear projects. Savings were realised on mobilisation, site set-up, project management and commissioning resource. In some instances, we could use grey-spares that were in good condition to replace bushings rather than purchase new bushings. **Re-assessment of projects (£21m increase).** The increase in spend in RIIO-T1 on the Littlebrook project is due to an increase in the cost of the land purchase (£10m). Increased civil works costs and planning conditions that includes ecological mitigation measures such as reptile and bird relocation have further increased costs(£11m). **Continuous review of asset health of switchgear (£6m reduction).** Continuous review of asset condition and policy information has provided an insight into emerging trends on key asset types. Scenarios have been run to understand how evolving system conditions impact the network risk targets, allowing us to adjust the required interventions. This has resulted in no longer needing to refurbish the FE Mk 2/3 hydraulic assets in RIIO-T1 but instead prioritising JW420 refurbishments. This provides a £6m forecast spend reduction.
External factors	37	**Timing change on projects (£32m reduction).** Some of the works at Wimbledon, Rugeley and Acton Lane have been re-planned due to changes in customer requirements. This has resulted in £32m spend moving out of RIIO-T1 to stay in line with these changes in customer requirements (this spend has not been requested in RIIO-T2). **Deferral of High Duty switchgear (£5m reduction).** Our RIIO-T1 Business Plan included the replacement of a volume of High Duty switchgear which was anticipated to require early replacement due to the expected number of operations. However, some of these breakers are no longer being switched as often due to changing system conditions. This means that 67 breakers no longer require replacement in RIIO-T1, resulting in approximately £5m cost reduction.
Provision in the price control settlement	14	**Review of London [redacted] (£14m reduction).** A project programme and design review has led to a reprofiling of the substation works to enable the tunnel construction activities to be advanced, as they are on the critical path.

We have embedded the efficiencies from RIIO-T1 into our switchgear plan for RIIO-T2. As this paper justifies in situ replacements, the next section describes RIIO-T1 performance specifically for these asset interventions.

3.2 Circuit Breaker and Bays - Costs and Volumes

Table 3 presents RIIO-T1 overview of cost and volume for in situ replacement and refurbishment of circuit breakers and bays. Whilst these provide useful indications, the nature of the interventions means that there will be significant spread in the cost of the individual interventions that contribute to the averages.

Table 3: RIIO-T1 performance; circuit-breakers and bays

		T1 Actuals	T1 Forecast	T1 (all years)	Annual average	Annual average (first 6 years)
Circuit breaker replacement	**Total cost (£m)**	53.5	35.6	89.1	11.1	8.9
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Circuit breaker refurbishment	**Total cost (£m)**	44.5	12.5	57	7.1	7.4
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Bays	**Total cost (£m)**	36.2	86.0	122.2	24	12.1
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Over the RIIO-T1 period, we are delivering a greater volume of refurbishment interventions than replacements. Refurbishment of Frame R, OIBR, GA10 and GA6 designs have proved to be cost effective alternatives to replacement. In the latter part of RIIO-T1 we have also reduced the cost of replacements through procurement and delivery initiatives.

For bays more volumes will be delivered in the latter years of RIIO-T1. This increased volume reflects the way we have dealt primarily with more complex switchgear in RIIO-T1, leaving availability to prioritise bay interventions going forward.

4. INVESTMENT NEED

Stakeholders told us they want NGET to maintain current levels of risk across the RIIO-T2 period. In absence of any intervention, the level of monetised risk would increase over RIIO-T2.

This chapter shows how we have arrived at a volume of interventions that meets stakeholder expectations around network risk. It covers:

- What are the high level drivers for investment during the RIIO-T2 period
- Our approach to assessing asset health for lead and non-lead assets
- What information we gather around the health of circuit breakers and bays
- How we have applied our methodologies and data to identify RIIO-T2 interventions

As with other chapters we present our analysis for circuit breakers and bays separately.

4.1 Investment Drivers

4.1.1 Circuit breakers

The majority of switchgear was installed between the late 1960s and early 1970s leading to a peak of interventions on circuit breaker assets during RIIO-T1. Figure 1 clearly indicates the high installation rates of circuit-breakers during the 1960s and 1970s and for each installed circuit-breaker, associated bay equipment will also have been installed. Due to the complexity of the circuit-breakers, interventions such as refurbishments have been planned and delivered in previous price control periods such that planned circuit-breaker interventions within the RIIO-T2 period are reduced.

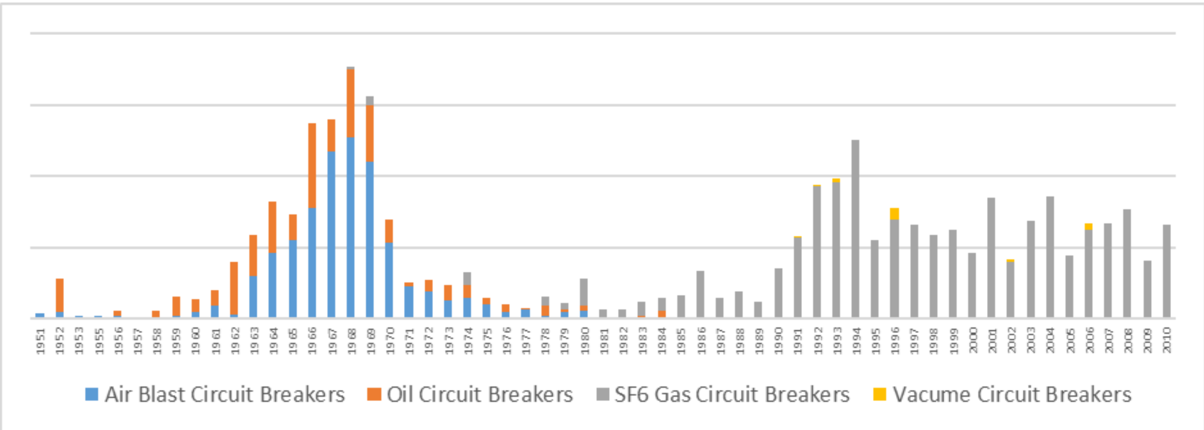

Figure 1: Circuit breaker installation profile

4.1.2 Bays

The intervention policy is defined in PS(T) EPS 12.06 Switchgear Replacement and Refurbishment. The intervention volume is determined on asset age. This is then allocated to the respective regulatory period.

Evidence indicates that many of these assets have deteriorated to a point requiring intervention. The condition and scope of this deterioration was confirmed during RIIO-T1 through assets sent to the refurbishment centres. Based on this information these assets have been selected and prioritised for RIIO-T2 based on a combination of pollution factors and service duration.

Within the bay, the circuit breaker is responsible for safely interrupting system fault current. The remaining bay equipment; disconnectors, earth switches, instrument transformers (subject to separate JR - A9.05) and surge arresters provide functions that only need to withstand the fault duty. While many of the circuit breakers have been replaced in situ, the balance of plant in the bay has not. The volume is determined by the number of non-lead assets which have reached or exceed their anticipated asset life. Generally, failure in service is destructive, impacting safety and security of supply, especially faults on the main busbar which can cause more extensive damage to the busbar section and longer-term outage while the repairs are carried out.

These assets are low cost, high volume in relation to circuit breakers and transformers. While NGET aims to sweat assets where prudent, it is necessary to have a programme of intervention to ensure we maintain network reliability and do not build up a backlog volume of ageing assets, which could disproportionally impact on network reliability if they start failing in service. Bay non- lead switchgear is fundamentally mechanical equipment, with moving parts, springs and contacts exposed to the atmosphere. Ageing and corrosion of the assemblies (e.g. see contacts in Figure 2 below) leads to end of life factors, necessitating either refurbishment or replacement.

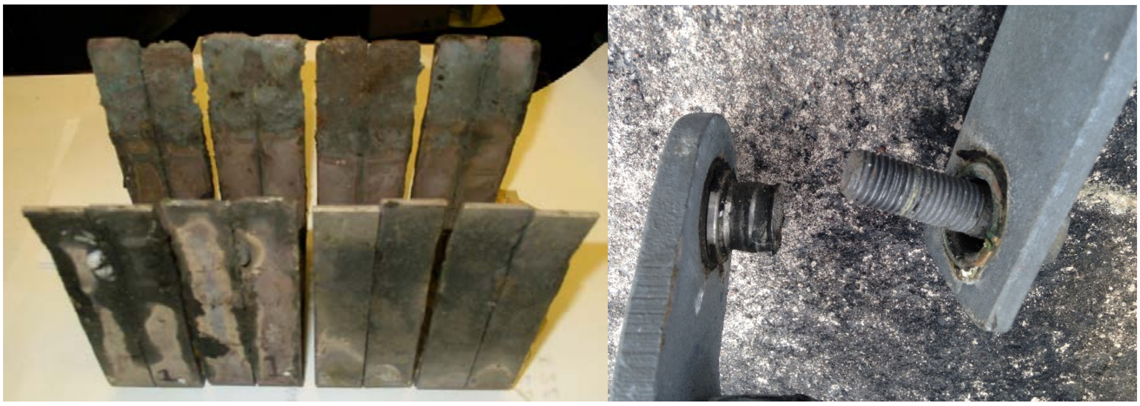

Figure 2: Example of disconnector contact corrosion and a broken drive linkage

Intervention on disconnectors, earth switches and surge arresters is policy driven and have not changed from RIIO-T1. It is necessary to ensure that the non-lead assets within a bay are in a suitable condition to support the Circuit Breaker for its asset life and ensure the safe and reliable operation of the transmission system whilst maintaining same level of network risk as at the beginning of RIIO-T1.

There is a total of [redacted] non-lead switchgear assets. For every circuit breaker bay, there are on average [redacted] disconnectors and [redacted] earth switches, plus there are the busbar systems and their respective devices. Many of the disconnectors and earth switches were installed in the 1960s and 70s, so consequently there is a large percentage of the population beyond 50 years old requiring an intervention (see Figure 3 below). Compared to the circuit breakers themselves, historically, the level of intervention upon the simpler bay equipment of the same age has been much less. This bay equipment is now reaching an age where asset deterioration is apparent and major intervention is required to ensure continued reliable operation.

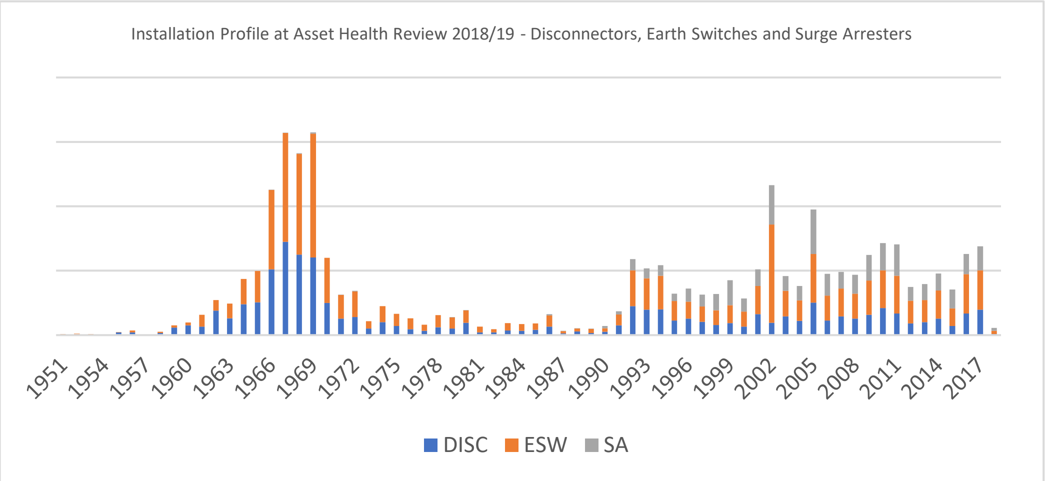

Figure 3: Installation profile, non-lead assets

4.2 Approach to establishing intervention need

In RIIO-T1, for lead assets (such as circuit breakers) we moved to a replacement priority based on the monetised risk methodology in which we combined System, Safety and Environmental Criticality with the Asset condition. In determining switchgear interventions, we have considered:

Asset Condition – current condition of the network assets, the reliability of the network assets, and the predicted rate of deterioration in the condition of the network assets. This is relevant to assessing the present and future ability of the switchgear to perform their function

Network Risk - the overall level of risk to the reliability of transmission system arising from the condition of the switchgear

Network Performance- technical performance of the switchgear that have a direct impact on the reliability and cost of services provided

For non-lead assets (such as bays), which are not subject to the monetised risk methodology, our approach was based on our Asset Health Indices (AHI) where asset age & condition are the key parameters.

Below we provide more detail around these methodologies.

To identify and prioritise assets in need of intervention we apply an assessment of failure *likelihood* and then the impact that any failure may have on the electricity system, the safety of people and the environment. This impact is described as the *criticality* or *consequence* of an asset, should it fail in service. This principle is consistent across the approaches for lead and non-lead assets evident in our business plans.

For lead assets (such as circuit breakers), failure likelihood is expressed as a probability up to 100% (or 1). For non-lead assets (e.g. bays), a proxy for probability of failure is used in the form of a scoring system - the Asset Health Index (AHI). This scoring system places assets into discrete bands of ‘1’ to ‘4’, and was used for all lead assets for RIIO-T1. It was combined in a matrix with an asset criticality score, again banded from 1 to 4 to arrive at ‘Replacement Priorities’. The management of the volumes of assets in each replacement priority band was the basis for the capital plan submitted for RIIO-T1 and one of the Network Output Measures in Special Licence Condition 2M.

The new approach developed for lead assets forms the basis of the Network Asset Risk Metric (NARM), and achieves a greater level of maturity than the Asset Health Index and Criticality approach that preceded it. This is because:

1. A simple probability of failure for each asset provides for a greater resolution of asset risk of failure. The low number of discrete bands employed by the AHI and Criticality approach produces a lower resolution measure and doesn’t allow for prioritisation within those bands

2. By monetising the consequences of asset failures, it is possible to measure whole network risk and enable decision making between different asset classes. The AHI and Criticality approach outputs volumes of asset ‘Replacement Priorities’. It does not define a monetised impact of this risk and there is no equivalency between asset types (e.g. a number of circuit breakers in Replacement Priority ‘1’ is equal to some volume of overhead line conductor in the same or different replacement priority bands). This impedes any network-wide measure of risk and plan optimisation across asset classes.

The two approaches are summarised in Table 4.

Table 4: Summary of two approaches

Approach	Likelihood of Asset Failure	Consequence of Asset Failure	Risk is a function of Likelihood of an event and its consequence
Asset Health Index and Criticality	Scores assets according to their health. AHI1 to AHI4	Each asset is scored according to its system, safety and environment impact should the asset fail. The maximum score is used.	A Replacement Priority is output based on a matrix of AHI and Criticality score. Poor health assets in highly critical locations are identified for intervention over good health assets in locations with a low criticality.
Monetised Risk	Each asset has a probability of failure. This probability is arrived at by use of an 'End of Life Modifier' (EoL). This is a score that maps an asset to a place on a probability of failure plot. An asset is assigned an 'equivalent age' determined by its place on the probability of failure plot.	For each asset failure event, there is a probability some other event will occur. These events have safety, system and environmental consequences that are monetised.	The probability of failure of an asset multiplied by the probability of an event with a monetised consequence produces the monetised risk of asset failure. As the same currency is used to define the consequences of asset failure, a whole network measure of risk is enabled as well as prioritisation between different assets.

The rise in monetised risk is governed by an asset's probability of failure plot. The magnitude of the risk at any given point in time is a function of the probability of failure (variable) and the probability of an event with a monetised consequence (fixed).

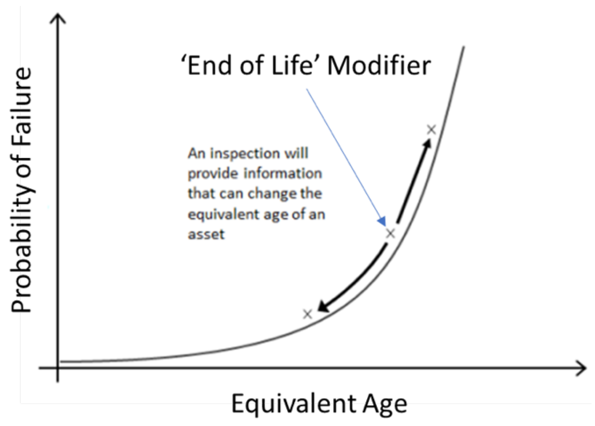

Figure 4: End of life modifier (EoL) overview

Our method will continue to develop so that a greater number of assets contribute to a monetised measure of risk and enable enhanced optimisation of business plans. Both assessment approaches may be employed in the transition to a monetised risk methodology, translating for example, Asset Health Indices into its equivalent measure, an 'End of Life Modifier' (EoL) and vice versa. The simple, discrete bounds of the AHI are useful in providing qualitative meaning to a continuous scoring system.

4.3 How we Monitor Asset Health

4.3.1 Circuit breakers

Circuit breaker EoL modifiers/scores are primarily driven by the age model due to deterioration of materials and mechanism wear – the expected probability of failure for an asset given the operational history of its wider family. Higher probability of failure scores are also driven by SF_6 loss, with a number of mid to end of life circuit breakers suffering from loss of this greenhouse gas. There are a relatively small number of circuit breaker assets that are high duty, typically voltage control circuits.

Table 5 summarises the end of life scoring approach for circuit breakers based on the types of data employed and the various factors that make up an assessment.

Table 5: EoL assessment drivers, circuit breakers

EoL Assessment Factor / EoL Assessment Input	Age	Ops	Interrupter	SF_6	Family
Asset Inventory Data	Asset type/ install date/ refurbished/reconditioned date	Mechanism Type	Interrupter Type	Installed SF_6 Inventory	Asset type
Performance Data	NA			SF_6 Top-up Records	Failure Records
Operational Duty Data	NA	Circuit Break Ops Counters Records	Fault Current Database	NA	

Circuit Breakers are inspected on the following frequencies:

Table 6: Circuit breaker inspection frequency

Inspection Type	Frequency
Statutory inspection (pressure regulations)	3 yearly
RFI and Thermography	3 Months
Basic Maintenance	6 Years
Major Maintenance	9 Years
Op Test	Yearly
Mechanism - Basic	6 years
Mechanism - Major	9 years

4.3.2 Bays

The Asset Health assessment for Bay equipment is age driven. The specific life limiting factors for each asset are as follows:

Disconnectors (age):

- linked to the duty on current carrying components, such as the male and female contacts and the associated busbar
- the drive mechanisms
- control systems.

Earth Switches (age):

- Similar issues to the disconnector - key components impacted by age are the electrical contacts
- main moving components.

Surge arresters (age):

- Surge arresters were a latter addition to the network during the 1990s and early 2000s. These were primarily retrofitted to SGT HV and LV terminals.
- These are hermetically sealed devices which rely upon the active part being within a dry, pollution free environment. Deterioration of the atmospheric seals is their key life limiting factor (approximately 20 years).
- The volume is essentially determined by age of the asset and loss of dry air tightness.

This identification of interventions based on age is borne out by evidence. During RIIO-T1, the deterioration of these assets was confirmed through assets sent to the refurbishment centres. Based on this information these assets have been selected and prioritised for RIIO-T2 based on a combination of pollution factors and service duration.

4.4 RIIO-T2 Intervention Volumes

4.4.1 Circuit breakers

Stakeholders told us they want NGET to maintain current levels of risk across the RIIO-T2 period. In absence of any intervention, the level of monetised risk would increase over RIIO-T2 (see Figure 5 below).

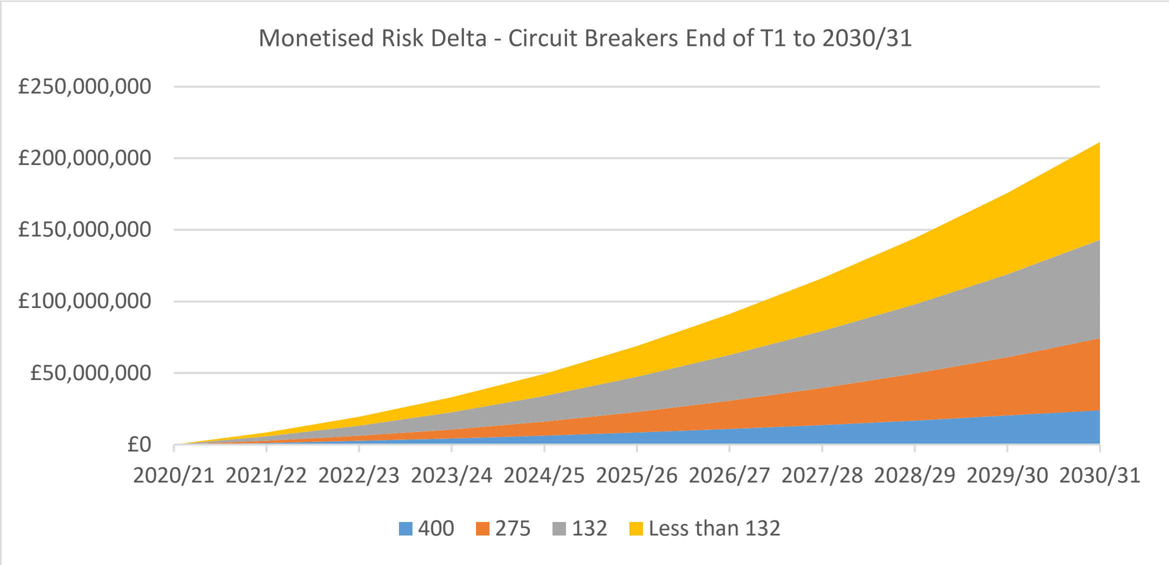

Figure 5: Unconstrained risk, circuit breakers

We have identified [redacted] circuit breaker interventions for RIIO-T2 which mitigate this risk in line with stakeholder requirements. As well as [redacted] in situ interventions justified in this paper, they also include the complex projects described in Appendix A, and switchgear replacements associated with other RIIO-T2 projects e.g. [redacted], which are justified in other papers. The list of all [redacted] investments and their contribution to risk mitigation is provided in Appendix B (split into in situ and other projects). Risk mitigation from these [redacted] interventions is set out in Table 7 for each asset subdivision, and graphically in Figure 6.

Table 7: Risk mitigation during RIIO-T2 by asset subdivision

Relevant asset subdivision (e.g. Highest Voltage for Circuit Breakers)	Risk delta (£m) @ 2025/26	Number of interventions	Risk Impact (£m) of Interventions @ 2025/26
400kV	8.4	[redacted]	5.3
275kV	14.5	[redacted]	12.4
132kV	24.5	[redacted]	23.3
<132kV	21.6	[redacted]	23.5
Monetised Risk Sub-Total	**68.9**	[redacted]	**64.5**

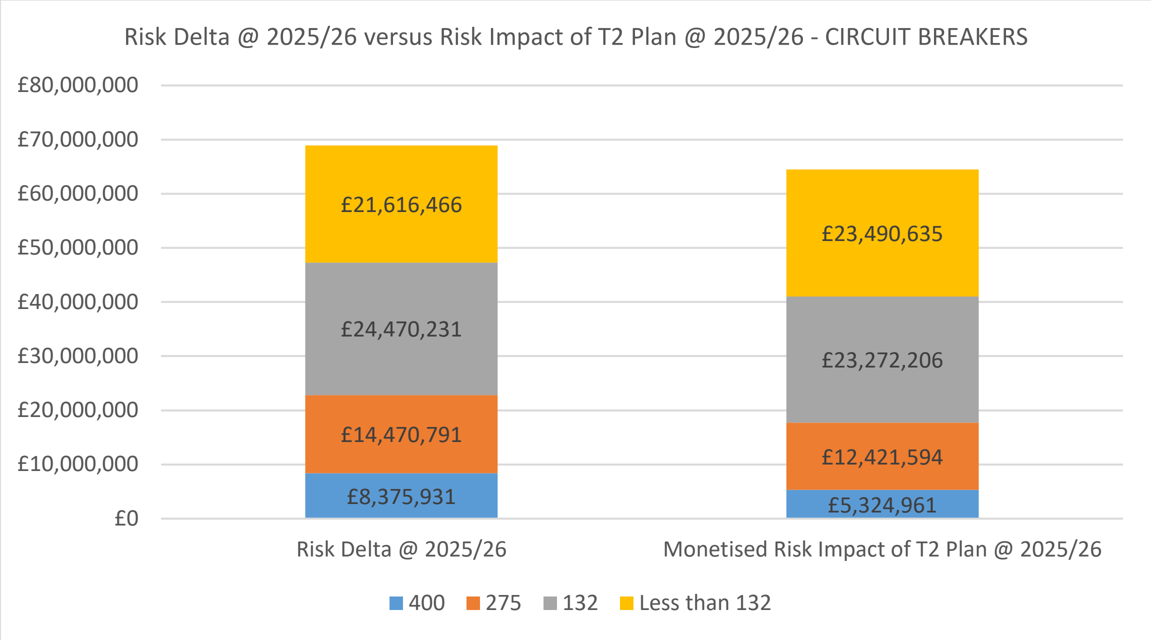

Figure 6: Risk mitigation during RIIO-T2 by asset subdivision

The risk impact of these interventions is outweighed by the increase in network risk in the order of £4.5m. The number of interventions in RIIO-T2 has been reduced to reflect the trend witnessed in RIIO-T1, where most assets at risk have been replaced and the remaining population of circuit breakers have not deteriorated as quickly as expected.

It is possible to plot the monetised risk contribution of RIIO-T2 interventions in 2025 versus their current EoL score. This has been completed for every asset (available in Appendix B) but to an enable an overview in this section, these have been categorised into bands of EoL Score (shown below in Table 8).

Table 8: EoL score brackets

EoL Score	Description
80-100	Asset is in a state where it is likely to lead to failure in the short term (5 years). Additional monitoring, operational restrictions and ad hoc component replacement is likely
60-79	Asset expected to deteriorate to an AHI 1 within 5 years. May require additional monitoring and/or ad hoc component replacement
35-59	Low level of faults or defect – some known to cause failure
0-34	Good health – no known specific or general life limiting problems.

Circuit breakers have been selected for intervention based on EoL score, i.e. most interventions are on assets with the highest EoL scores. This is illustrated in Table 9, which shows the monetised risk impact of RIIO-T2 interventions against their current EoL grouping. The impact of SF_6 leakage is also a factor for intervention in RIIO-T2.

Table 9 RIIO-T2 interventions by EoL band

EoL Band	Volume of interventions	Monetised Risk £m per asset	Total impact on monetised risk (£m)
80-100	[redacted]	[redacted]	40.8
60-79	[redacted]	[redacted]	15.9
35-59	[redacted]	[redacted]	7.8
0-34	[redacted]	[redacted]	0.0
Total	[redacted]	[redacted]	**64.5**

There are [redacted] interventions on assets that are currently within the 0-34 scoring band, implying a low probability of failure.

Xxxxx units to be replaced as part of the wider substation replacement works

- [redacted] oil circuit breaker to be disposed of ([redacted]) as the associated SGT is to be scrapped.
- A single 13kV air-blast reactor breaker ('DBG' type) that requires reconditioning ([redacted]). The asset is on a 90-year life expectancy and is 49 years of age. It requires mid-life reconditioning to meet its 90-year life expectancy. This asset requires a reduced-life, probability of failure curve to show the higher chance of failure without a reconditioning intervention.

Figure 7 below shows the monetised risk by EoL score bracket (as per Table 9 above) disaggregated into specific EoL assessment drivers that determine the probability of failure (see Table 5 above).

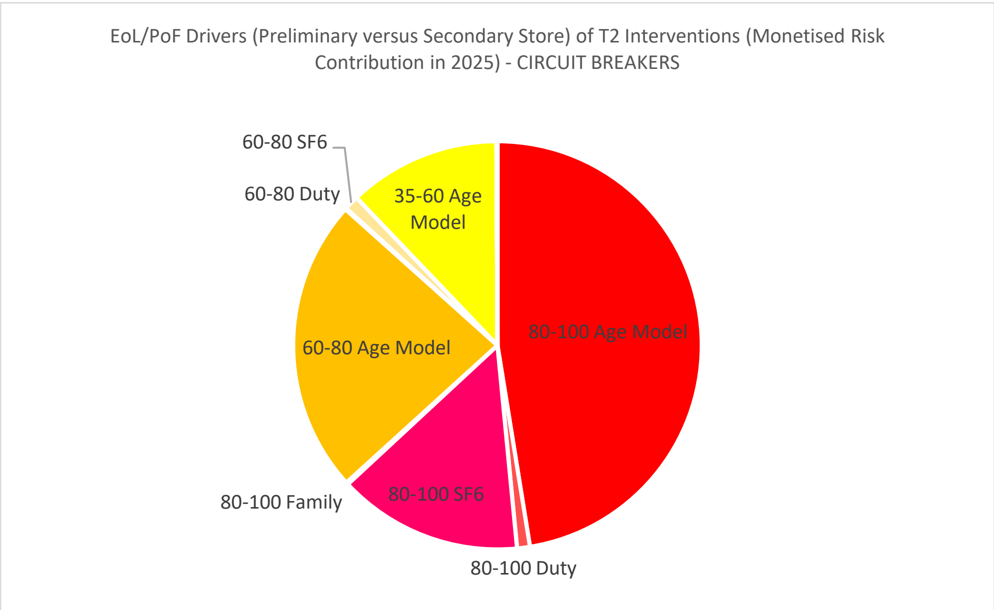

Figure 7: Monetised risk reduction, by EoL score bracket and assessment driver

4.4.2 Bays

The high volumes of bay assets to be delivered in RIIO-T2 are directly related to the installation/asset age profile explained in Section 4.1 above.

Age is the intervention driver- since many bays were installed in the 1960s and 1970s, there is a large percentage of the population beyond 50 years old requiring an intervention- Appendix C gives a breakdown of the assets which are beyond expected life or will become so in RIIO-T2.

A total of [redacted] interventions have been identified based on the age profile (see Figure 8 below). This equates to [redacted] of the total bay assets population. The volume of assets is high, since for every circuit breaker bay there are on average 2 disconnectors and 3 earth switches. This age-based intervention driver is backed up by evidence from RIIO-T1 around the condition of assets sent to refurbishment centres.

The volume of assets reaching their expected life post-RIIO-T2 falls as the does the original installation peak of identical design equipment. However, we are identifying a need to complete a mid-life recondition of IEC129 equipment where there are a number of technical limitations and safety bulletins issued. The impact of a mid-life reconditioning after 25 years is evident in Figure 9 below. With this, intervention volumes are still expected to reduce by the end of RIIO-T3.

[redacted]

Figure 8: Bay assets reaching end of life

[redacted]

Figure 9: Bay assets reaching end of life

The surge arrester population is defined as single phase units (1899), while the disconnector and earth switches are a 3-phase set. Most of the interventions are three phase and for transformers, so this would typically account for 6 units (HV and LV terminals).

The table below provides a breakdown of bay assets requiring intervention during RIIO-T2. Note that the number of bays is lower as typically there will be 2 disconnectors and 3 earth switches in a bay.

Table 10: Non-lead asset interventions in T2

Asset Type (% of population on network)	Voltage Levels	No. of T2 Interventions
Disconnectors (24%)	400kV	[redacted]
	275kV	[redacted]
	132kV	[redacted]
	<132kV	[redacted]
	Total	[redacted]
Earth Switches (22%)	400kV	[redacted]
	275kV	[redacted]
	132kV	[redacted]
	<132kV	[redacted]
	Total	[redacted]
Surge Arresters – single phase units (45%)	400kV	[redacted]
	275kV	[redacted]
	132kV	[redacted]
	<132kV	[redacted]
	Total	[redacted] **([redacted] bay equivalent)**
Total (Combined Bay Assets)		[redacted] **([redacted] bay equivalent)**

Figure 10 below shows the intervention profile over the RIIO-T2 period for bay assets:

[redacted]

Figure 10: RIIO-T2 intervention profile, bay assets

5. OPTIONEERING

This section describes the optioneering we have undertaken to identify the optimum intervention mix to deliver the intervention volumes identified in Section 4. We do this separately for circuit breakers and bays. Of the [redacted] circuit breaker interventions identified in Section 4, our optioneering covers the [redacted] in situ replacements and refurbishment only.

We have used a two-stage approach to identify the most cost-effective package of options for this paper:

1. Firstly, we have identified **potential intervention strategies,** and tested the options on this long list for feasibility/applicability. They include a 'Do Minimum' option. We have not considered non-network or whole systems options here since these cannot substitute for the type of investment we are considering in this paper.
2. For the set of feasible options, we have undertaken **quantitative CBA** to identify the most cost-effective option, supplemented by wider qualitative considerations. We have done separate CBAs for each family/asset sub-type and aggregated the results to identify a preferred overall intervention strategy for each of circuit breakers and bays.

We have used the Net Present Value (NPV) calculation approach in the Ofgem template to identify the most cost-effective option.

For lead assets such as circuit breakers, as well as the direct costs of investment the NPV also accounts for:

- Changes in Monetised Risk as a result of interventions (benefits vs Do Nothing baseline, shown separately in tables below)
- Benefits from reduced SF_6 leakage where applicable (versus Do Nothing baseline, incorporated within NPV)
- Safety impacts: preventative measures captured within investment costs, benefits versus Do Nothing baseline captured in NPV.

For non-lead assets such as bays, the NPV is based on direct investment costs.

The chapter is structured as follows:

- Section 5.1 sets out the full range of intervention options, and which have been taken forward for CBA analysis for each family/asset sub-type
- Section 5.2 summarises the results of our CBA analysis across all family/asset sub-types, and identifies the preferred option for circuit breakers and bays (full CBA results for each family/asset sub-type are presented in Appendix D
- Section 5.3 compares post-optioneering intervention volumes with RIIO-T1.

5.1 Options Considered

5.1.1 Circuit breakers

The long list of options we identified for the delivery of the circuit breaker interventions is set out in Table 11 below, and explains our rationale for accepting/rejecting them for full CBA:

Table 11: Summary of intervention options

Option	Detail	Taken forward for full CBA?
1. Do Minimum	This option involves routine inspection and maintenance but takes no action to refurbish or replace assets to address EoL failure modes as they deteriorate and ultimately fail in service. Adoption of this option will increase the transmission network risk and is highly likely to lead to energy-not-supplied scenarios and we have rejected it for the following reasons: o This strategy would prevent us from meeting our obligation set under the Electricity Safety Act to minimise as far as practicable the	**Not taken forward for consideration** We have included Do Minimum in the CBA to illustrate what a maintenance only option would involve in cost terms.

Option	Detail	Taken forward for full CBA?
	hazards and risks to the safety of any person arising from the supply network. o In order to manage a rise in in-service failures, the strategic spares holding would need to be increased significantly and team(s) of staff put on standby to manage emergency, unplanned replacements. In addition, delivery would not be efficient, as the replacement work could not be planned with sufficient lead times to develop the most economical and efficient delivery strategy and scope. o Unplanned outages, especially extended outages expected with a replace on fail strategy, would also have an inevitable impact on planned work including customer connections which may be delayed until the system was secured.	
2. Refurbishment	This option involves proactively refurbishing circuit breakers to achieve or extending the technical asset life (AL=achieve, EL=extend) through activities supported by the refurbishment centre or the Original Equipment Manufacturer (OEM).	**Taken forward**
3. Full replacement	This option involves proactively replacing circuit breakers identified as per section 4. It is chosen where refurbishment is not cost effective due to small asset populations, lack of asset knowledge or necessary components, and/or asset complexity	**Taken forward**
4. Repair/Capital SF_6 Mitigation	This option applies to SF_6 breakers which are leaking the insulating gas. During RIIO-T1 attempts to utilise leak sealing products have been determined to be ineffective. NGET, with the support of the OEMs, have developed cost effective solutions which will stop further leakage for the remainder of the asset life for RIIO-T2. This intervention is listed as a "Capital Repair" as the scope of works exceeds that which is a maintenance activity. The intervention will exchange or complete work on components which fall within the capitalisation criteria.	**Taken forward**

As explained above, we have conducted optioneering for each circuit breaker family sub-type. For some sub-types, the full suite of options may not be available: for example, replacement is the only option in some cases because the OEM no longer supports the equipment in need of intervention. Table 12 lists the options considered for each circuit breaker family type.

Table 12: Intervention options for circuit-breakers by design type/family

Insulation Medium	Family Type	Option 1	Option 2	Option 3	Option 4
ABCB	DBG20P	Do minimum	Replace	Refurbishment EL	NA
ABCB	Frame R	Do minimum	Replace	Refurbishment EL	NA
ABCB	GA10/6	Do minimum	Replace	Refurbishment EL	NA
ABCB	OB10	Do minimum	Replace	NA	NA
ABCB	OBN	Do minimum	Disposal	NA	NA
ABCB	OBR60	Do minimum	Replace	NA	NA
ABCB	OBYR	Do minimum	Replace	NA	NA
ABCB	OHBR	Do minimum	Replace	Refurbishment EL	NA
ABCB	OIBR	Do minimum	Replace	Refurbishment EL	NA
Oil	L45T Metal Clad	Do minimum	Replace	Refurbishment EL	NA
Oil	Low Voltage Metal Clad	Do minimum	Replace	NA	NA
Oil	OFA11/12	Do minimum	Replace	NA	NA
Oil	OW410/407	Do minimum	Replace	NA	NA

Insulation Medium	Family Type	Option 1	Option 2	Option 3	Option 4
SF_6	AIS Alstom GCB	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS DT1	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS FE	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS FE DT	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS FG1	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS HSPM	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS HPL	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS LTB	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	AIS SPL	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	BRUSH DB 145	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	GIS ELK	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	GIS FB2T Hyd	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
SF_6	GIS FE	Do minimum	Replace	Refurbishment AL	NA
SF_6	GIS GMT11	Do minimum	Replace	Refurbishment AL	NA
SF_6	GIS MFH Hyd	Do minimum	Replace	Refurbishment AL	NA
SF_6	GIS SPD	Do minimum	Replace	Refurbishment AL	SF_6 Leak Repair
VCB	VCB	Do minimum	Replace	NA	NA

***Key**: AIS = Air Insulated Switchgear; GIS = Gas Insulated Switchgear; ABCB = Air Blast Circuit Breaker; Refurbishment AL – Refurbishment to Achieve Asset Life; Refurbishment EL – Refurbishment to Exceed Asset Life*

Should failure modes which are not currently known present themselves during RIIO-T2, the interventions for affected asset families shall be assessed in the same manner to those within this justification report.

5.1.2 Bays

In developing our RIIO-T2 plan we have considered the following options for bays:

Table 13: Summary of intervention options

Option	Detail	Taken forward for full CBA?
1. Do Minimum	This option involves routine inspection and maintenance but takes no action to refurbish or replace assets as they deteriorate and ultimately fail in service. In this option the functionality of the assets is progressively lost and service to consumers progressively declines and reaches an unacceptable state. Adoption of this option will increase the transmission network risk and is highly likely to lead to energy-not-supplied scenarios and we have rejected it for the following reasons: o This strategy would prevent us from meeting our obligation set under the Electricity Safety Act to minimise as far as practicable the hazards and risks to the safety of any person arising from the supply network. o In order to manage a rise in in-service failures, the strategic spares holding would need to be increased significantly and team(s) of staff put on standby to manage emergency, unplanned replacements. In addition, delivery would not be efficient, as the replacement work could not be planned with sufficient lead times to develop the most economical and efficient delivery strategy and scope. o Unplanned outages, especially extended outages expected with a replace on fail strategy, would also have an inevitable impact on	**Not taken forward** We have included Do Minimum in the CBA to illustrate what a maintenance only option would involve in cost terms.

Option	Detail	Taken forward for full CBA?
	planned work including customer connections which may be delayed until the system was secured.	
2. Refurbishment	This option involves proactively refurbishing disconnectors and earth switches to extend the technical asset life through activities supported by the refurbishment centre or the OEM.	**Taken forward**
3. Full replacement	This option involves proactively replacing disconnectors and earth switches identified as per our RIIO T2 Strategy described below in this section where replacement is the only option available for 132kV and below bay assets.	**Taken forward**

As with circuit breakers, not all the intervention options described above can be considered across all bay asset types due to technical, design and cost considerations. The available options are set out below by asset type.

There are two potential intervention strategies considered for Disconnectors and Earth Switches installed at 275kV and 400kV;

1. Replacement – Like for like replacement of asset with modern equivalent.
2. Refurbishment – To exceed the technical asset life through activities supported by the refurbishment centre. The refurbishment for the 275kV and 400kV disconnectors and earth switches is possible since they are identical design equipment but were produced by different manufacturers, which allows for the creation of a programme where refurbished assets are sent to site prior to disassembly of the intended asset. This results in shorter outage durations as the intervention is not dependent upon the components being disassembled, refurbished at a central location and then sent back to site.

For bay assets at and below 132kV, replacement is the only option. There are multiple variations in the design and construction of the bay equipment depending upon geographic location. As a result, the ability to cost effectively refurbish the 132kV and below equipment is limited owing to the large number of different designs in equipment present in the population.

For surge arresters replacement is the sole option. Surge arresters are hermetically sealed units with no mechanical moving parts: therefore a refurbishment is not possible or economical considering the low unit costs for new surge arresters.

Table 14 summarises which intervention options have been analysed for non-lead bay assets:

Table 14: Intervention options for non-lead assets

Equipment Type	Voltage Level	Option 1	Replace	Refurbish
Earth Switch & Disconnector	400 & 275kV	Do nothing	Replace	Refurbish EL
Surge Arresters	400 & 275kV	Do nothing	Replace	N/A
Earth Switch & Disconnector	132kV & Below	Do nothing	Replace	N/A
Surge Arresters	132kV & Below	Do nothing	Replace	N/A

5.2 Detailed Analysis & CBA

5.2.1 CBA results - Circuit Breakers

Aggregated key metrics (RIIO-T2 investment cost and lifetime NPV) for each of our circuit breaker intervention options are set out in Table 15 below, together with wider technical and stakeholder considerations. These support our strategy across the circuit breaker portfolio of a mixed replacement/repair/refurbish approach which offers significant cost efficiencies compared to full replacement.

The full CBA results are set out in Appendix D for each asset sub-type.

Table 15: Detailed analysis of outcome

Option	RIIO-T2 investment cost (£m)	NPV (£m)	Wider considerations	Taken forward for full CBA?
1. Full replacement only	**£74m**	**£235m**	This option involves proactively replacing [redacted] circuit breakers identified for intervention in RIIO-T2. This option will allow National Grid to mitigate the risk of failure of circuit breakers However this is not the most economically feasible option due to high cost of replacement. It also has a longer outage requirement for complete replacement potentially causing higher system operation costs. Based on this we have **rejected** this option from further consideration due to the high costs. *Investment cost and NPV does not include **GIS MFH Hyd** (CB25) where no replacement option is possible.*	**REJECTED**
2. Refurbishment	**N/A**	**N/A**	This option involves refurbishment of [redacted] circuit breakers identified for intervention in RIIO-T2. Advantages of this option include reduced system access / outage requirements, reduced resource requirements and overall lower cost of intervention. However, not all asset sub-types within Circuit Breaker portfolio can be refurbished due to the range of technical reasons (spare parts availability, technological limitation etc.). Based on this we have **rejected** this option from further consideration. *A total investment cost and NPV is not presented as lower volumes mean it is not directly comparable with Options 1 and 3.*	**REJECTED**
3. Mix of refurbishment, replacement and repair	**£33m**	**£270m**	This option involves proactively replacing or refurbishing deteriorated circuit breakers in an optimised manner. In general cost of refurbishment (when feasible) is lower than full replacement, so with that in mind first option when considering intervention for each asset sub type is refurbishment. Where refurbishment is not cost effective due to small asset populations, lack of asset knowledge or necessary components, and/or asset complexity than the full replacement is considered. This option represents extension of our innovative practice which we developed in RIIO1. At the same time, it allows us to maintain extremely high reliability levels that our stakeholder require. The advantages of this option are: • reduced system access / outage requirements, • reduced resource requirements and • overall lower cost of intervention.	**RECOMMEND**

Table 16 shows the intervention mix across asset types post-optioneering:

Table 16: Circuit breaker intervention mix

Voltage	Asset Category	Scope	T2 Volume (ON) BPDT
Less than 132 kV	**Circuit Breaker**	Refurbish AL	[redacted]
		Replacement	[redacted]
		SF6 Repair	[redacted]
		Refurbish EL	[redacted]
132kV	**Circuit Breaker**	Refurbish AL	[redacted]
		Replacement	[redacted]
		SF6 Repair	[redacted]
275kV	**Circuit Breaker**	SF6 Repair	[redacted]
		Refurbish AL	[redacted]
		Replacement	[redacted]
400kV	**Circuit Breaker**	Refurbish AL	[redacted]
		Replacement	[redacted]
		SF6 Repair	[redacted]
Volumes justified in this Report			[redacted]

5.2.2 Bays

Table 17 below shows the aggregate results from our CBA analysis across different asset types. Full results in each asset sub-type are set out in Appendix D. Results for 132kV earth switches and disconnectors and for surge arresters are set out separately as replacement is the sole option:

Table 17: CBA results, bays

Option	T2 investment (undisc, £m)	Total investment (undisc, £m)	NPV (£m, disc)
	275kV and 400kV		
Do Minimum	3.486	36.953	-15.268
Replace only	486.91	488.578	-421.42
Refurb only	156.45	644.42	-285.073
	132kV and surge arresters		
Do Minimum	1.352	14.331	-5.921
Replace	71.264	71.796	-62.898
TOTAL (PREFERRED OPTION)	**227.71**	**716.216**	**-348.628**

Table 18 below sets out wider considerations around choice of option for 275kV and 400kV bay assets. Together with the CBA, these support our strategy of refurbishment.

Table 18: Bays choice of option (excluding Surge Arresters and sub-132kV Earth Switches and Disconnectors)

Option	Wider considerations	Taken forward for full CBA?
1.Full replacement	This option involves proactively replacing [redacted] circuit bay assets which we identified for intervention in RIIO-T2. This option will allow National Grid to mitigate the risk of failure of circuit breakers. However, this is not the most economically feasible option due to high cost of replacement. It also has a disadvantage of longer outage requirement for complete replacement potentially causing higher system operation costs. Based on this we have rejected this option from further consideration due to the high costs.	REJECTED
2.Refurbishment	This option involves refurbishment of more than [redacted] bay assets (excluding 132kV and below and surge arresters where replacement is the only option) identified for intervention in RIIO-T2. Advantages of this option include reduced system access / outage requirements, reduced resource requirements and overall lower cost of intervention. This option ensures that the risks and issues associated with disconnectors and earth switches are addressed in the most economic manner. Based on this we have recommended this option.	RECOMMEND

5.3 How volumes compare to RIIO-T1

Table 19 sets out intervention volumes for RIIO-T1 and RIIO-T2 across circuit breakers and bays.

Table 19: Comparison of circuit-breaker replacements and refurbishments between T1 & T2

Total volume	RIIO-T1			RIIO-T2	RIIO-T1		RIIO-T2
	T1 Actuals	T1 Forecast	T1 (all years)	T2 forecast	Annual average	Annual av (first 6 years)	Annual average
Circuit breaker replacement	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Circuit breaker refurbishment	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Bays	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: RIIO-T2 forecast volumes for bays also include some non- in situ replacements that are part of the wider switchgear portfolio. The annual average for bays replacements is calculated from 2016/17 onwards, ie 'RIIO-T1 annual average' is calculated over 5 years (2016/17 to 2020/21) and 'Annual average (first six years)' is calculated over 2016/17 to 2018/19. RIIO-T2 circuit breaker refurbishment volumes include SF_6 repair projects.

Over the RIIO-T2 period, circuit breaker replacement volumes are reduced compared to forecast RIIO-T1 annual average. There is also a significant reduction in refurbishment volumes when compared to the RIIO-T1 period. This reflects the diversity of asset families and the asset life stages of the various technologies. In summary:

- Air-blast technology has, in the main, been replaced or refurbished during RIIO-T1 such that the volume of air-blast replacements in RIIO-T2 is limited.
- The majority of SF_6 technology has yet to reach its anticipated asset life and refurbishments undertaken in RIIO-T1 have ensured that significant volumes of replacement are not required in RIIO-T2.
- Bulk oil technology, which is some of the oldest remaining on the network, and which is susceptible to deterioration of the bushings, and now requires major intervention. As described earlier these assets are targeted for replacement and form a significant proportion of the RIIO-T2 replacement volumes in contrast to RIIO-T1.
- In RIIO-T2 there is also a greater focus on <132kV assets.

There is a significant increase in the volume of bay interventions in RIIO-T2. This is driven by assets reaching end of life, together with our prioritisation of circuit breaker interventions in RIIO-T1.

6. ASSESSMENT OF COST EFFICIENCY

The estimating methodology for capital projects is based around a standard and consistent approach. This is controlled by an in-house, central estimating team (e-Hub) within Capital Delivery Project Controls. The detail of this methodology can be found in NGET_A14.09_Internal Benchmarking of Capex unit costs.

In this chapter, we show that the unit costs driving the spend in this paper are efficient. It is structured as follows:

- Section 6.1 sets out unit costs for our RIIO-T2 planned interventions at different voltage levels (400kV, 275kV and 132kV and below) as well as average unit costs from RIIO-T1
- Section 6.2 compares our costs to external benchmarks developed by TNEI Services.

6.1 RIIO-T2 Unit Costs and Explanation of Outliers

In this section we show our project by project estimates for RIIO-T2 unit costs, and how these combine to provide a mean unit cost for comparison with external benchmarks. We also explain unit cost outliers that skew the mean upwards or downwards.

Our RIIO-T2 unit costs embed cost reduction initiatives at RIIO-T1 for both replacement and refurbishment project as follows. For replacement projects, we have: reused existing foundations; enhanced in-house delivery capability; used Tier 3 installation contracts; bulk procured circuit breakers to procure volumetric discounts. For refurbishment projects, we have used a mix of OEMs and our own internal refurbishment centres.

The following graphs are aligned with Ofgem's requirements for reporting capital costs in the Business Plan Data Template, i.e. they exclude development, design and project management costs. **For this reason, they are systematically lower than all the costs per unit discussed previously in this report.**

6.1.1 Circuit Breakers

In order to provide the most meaningful unit costs analysis, we discuss different voltage levels (400kV, 275kV, 132kV and below) in turn below.

400kV projects:

Figure 11 shows unit costs for 400kV RIIO-T2 projects. Unit costs are expressed as annual averages across all interventions in that year. The average unit cost for equivalent RIIO-T1 projects is also shown.

[redacted]

Figure 11: Project unit costs, 400kV circuit breaker refurbishments

Note: this chart just reflects the circuit breaker element of these schemes.

Figure 11 reflects the embedding of RIIO-T1 efficiencies into RIIO-T2 projects. It shows unit costs for full replacement projects are [redacted] with RIIO-T1. Whole site replacement and refurbishments are [redacted] than RIIO-T1. This also reflects the fact that we have a different project mix for RIIO-T2.

Whilst the two 400kV Gas Insulated System (GIS) replacements at [redacted] are not fully whole site replacements, they are more expensive than Air Insulated System (AIS) projects where equipment and installation costs are [redacted] 400kV GIS.

Currently there are three 400kV whole site replacement schemes that are delivered in the RIIO-T2 period, with higher costs due to a greater scope of works, including in some cases cost of land purchase, planning process, complex design interfaces and staged construction for circuit transfers. The variation of unit costs across the whole site replacements are due to variations in the scope of work e.g. number of circuits, location of the substation, DNO interface across each investment.

275kV projects:

Figure 12 shows unit costs for 275kV projects:

[redacted]

Figure 12: Unit costs, 275kV projects

Note: this chart only reflects the circuit breaker element of these schemes.

This reflects the embedding of RIIO-T1 efficiencies into RIIO-T2 projects. It shows unit cost for full replacement and refurbishment projects are lower than RIIO-T1. It also shows that the average unit costs for circuit breaker refurbishment are consistent across the RIIO-T2 period, as are replacements.

The higher unit cost of circuit breaker replacement at [redacted] [redacted] in Figure 12 above) is due to [redacted]. There are also [redacted] whole site replacement schemes:

- **[redacted] (‘[redacted], £[redacted]m unit cost):** The outputs for this will be delivered in RIIO-T1 period and the costs in RIIO-T2 are for the demolition of existing site and closure of the investment. The average unit cost for [redacted] [redacted] (£[redacted]m) due to the fact that the scope of works is whole site replacement with new GIS substation and other new build scope of works.
- **[redacted], £[redacted]m unit cost):** higher costs here are mainly due to the removal of the existing [redacted] substation and conversion into a standard double busbar arrangement fed from new 400kV substation as two circuits are still required at the 275kV voltage level.

132kV and below projects:

Figure 13 below shows unit costs for 132kV and below projects.

[redacted]

Figure 13: Unit costs for 132kV and below projects

Note: this chart just reflects the circuit breaker element of these schemes.

It shows that RIIO-T2 costs are lower than those for RIIO-T1, reflecting embedded RIIO-T1 learning. Refurbishment and replacement costs are consistent across RIIO-T2.

As seen from the above graph the average [redacted] for the 132kv and below circuit breaker refurbishment and associated bay refurbishment are [redacted] during the RIIO-T2 period. Also, the average unit cost for replacement projects and associated bay refurbishments are [redacted] RIIO-T2 period. The [redacted] replacement at [redacted] is mainly due to the design and installation complexities involved in replacing the indoor 132kV Switchgear along with the associated SGT and HV breaker and Bay replacements in agreement with [redacted] interface.

There are several 132kV whole site replacement schemes that are delivered in the RIIO-T2 period- these are shown on the right-hand side of Figure 13 above. The average unit costs of these investments are [redacted]. This is because [redacted], and includes in some cases cost of land purchase, planning process, complex design interfaces and staged construction for circuit transfers [redacted]

6.2 How our Costs Compare to External Benchmarks

In this section we compare our unit costs to external benchmarks developed by TNEI Services where applicable (TNEI benchmarks are comparable to replacement projects only and not to refurbishments).

6.2.1 Circuit breakers

Figure 14 shows unit costs for circuit breaker replacement projects at all voltages versus TNEI benchmarks:

[redacted]

Figure 14: Unit costs versus industry benchmarks, circuit breaker replacement projects

NG unit costs are [redacted] TNEI comparators [redacted] value-based engineering approach, developed and tested in RIIO-T1. Our approach involves reusing existing foundations, using inhouse delivery capability, and bulk purchase of equipment- these contribute to reduced overall programme and system access across the portfolio of breakers. This contrasts with TNEI benchmark costs, which are based on single asset replacement with new foundations using external contractor to deliver the works. TNEI benchmarks includes replacement protection equipment, structures, busbars, connectors, foundation and multicore cables. While this is common amongst benchmark participants it results in additional scope and costs and longer programme.

Figure 15 shows a similar view for circuit breaker refurbishments, showing lower unit costs for RIIO-T2, due to the type of circuit breakers being refurbished and efficiencies embedded from RIIO-T1. There are no equivalent TNEI benchmarks for comparison for refurbishment.

[redacted]

Figure 15: Circuit breaker refurbishment projects RIIO-T1 to RIIO-T2

6.2.2 Bays

Figure 16 shows unit costs for 275kV and 400kV bay refurbishment projects, and 132kV bay replacement projects, showing a reduction* in unit costs from RIIO-T1 to RIIO-T2. There is no equivalent 'bay only' TNEI benchmark for comparison. Note: the number of assets in a bay varies, to aid comparison, costs shown below are for a standard bay scope, consisting of 2 disconnectors and 3 earth switches.

[redacted]

Figure 16: Bay unit costs RIIO-T1 to RIIO-T2 comparison

***Note: 275kV bay refurbishment costs**

The NGET Board has put in place a robust and independently verified assurance process to support the creation of NGET's RIIO-T2 Business Plan. The execution of this assurance process has identified an error that has led to the overstatement of the cost forecasts for asset health works required for one specific asset category, namely 275kV Bay refurbishment, by an amount of £33.8m over the 5-year period covered by the business plan. The root cause of the error has been identified and confirmed by the assurance process as being isolated and specific to this asset category. Due to the timing of the error being identified it has not been possible to correct it in all constituent parts of this business plan prior to the start of the necessary printing process associated with the submission of the final business plan.

[redacted]

The impact of the correction on plan costs is set out in the table below- the £33.8m difference will need to be deducted from the BPDT total:

275kV bay refurbishment	Volume	BPDT unit cost	Corrected unit cost	Total Cost (BPDT)	Total Cost (corrected unit cost)
Earth Switch	[redacted]	£[redacted]	£[redacted]	£41,159,568	£[redacted]
Disconnector	[redacted]	£[redacted]	£[redacted]	£47,262,150	£[redacted]
			Total	£88,421,718	£[redacted]
			Difference		£[redacted]

7. KEY ASSUMPTIONS, RISK AND CONTINGENCY

7.1 Assumptions

7.1.1 SF_6

For the purpose of forecasting within the CBAs, SF_6 leakage calculations are based on the following factors:

1. Average annual Leakage – calculated over 2-5 years to provide the average leakage of the asset. The forecast applied in the calculations is flat and assumes that leakage will not increase over time.
2. Material Cost of Leakage – Based on costs utilised within the Monetised Risk calculation a value of £9.5 per kg of SF_6 is used.
3. Labour cost of leakage – Based on analysis of 1 years' worth of top ups it is assumed that it takes 2 hours to top up 1 kg with a labour cost of £[redacted] per hour.

As this is an initial assessment, complex forecasting including variation in leakage rates has not been included into the calculations. Whilst it is likely that the leakage rate will increase, there is insufficient information to accurately predict this for every asset. Furthermore, whilst there is information relating to more than one year's worth of data available for the calculation of labour costs, the volume of top ups was sufficient to provide an appropriate estimation.

When selecting options, it is acknowledged that the outage duration for a repair of an asset with SF_6 Leakage is significantly lower compared to Replacement as normally this only requires an intervention on one phase rather than the replacement of all three. Therefore, selection of this option allows greater Transmission Network flexibility and resilience. Excluded from the labour costs are any form of system impact cost, which may arise due to low pressure of SF_6 Gas Circuit Breakers and associated alarms.

7.1.2 Low Voltage Metal Clad Oil Circuit Breakers

This justification paper assumes that the busbar and associated infrastructure are in a suitable condition to allow for the safe operation of the replacement asset for the period of its asset life. In the majority of situations, the Busbar and associated housing are air insulated, however where the Busbar is an Oil or Resin Impregnated Paper design additional testing will be required to validate the condition of the insulation medium.

7.1.3 Costs

The costs associated with the decisions within this Justification Paper align with the National Grid Electricity Transmission Cost book. Where an intervention is not listed within the cost book, cost have been estimated through discussion with the relevant delivery organisation based on development costs.

7.2 Risks

7.2.1 System Access

During RIIO-T1, the impact of asset failure, electrical faults or unplanned switch outs of Transmission or Distribution assets resulted in the cancelation of planned outages at short notice. Should this occur during RIIO-T2, there is a risk that this may result in the deferral of outages and reduced deliverability of volumes. Mitigation includes tactical planning and management of volumes to ensure opportunity interventions are bought forward to manage total volumes.

7.2.2 DNO Plans

A number of assets within this justification paper either supply or are located at DNO or customer substations. Interventions on these assets may be restricted through interaction with these networks and are subject to ongoing Stakeholder engagement. This can be mitigated by early engagement with the DNOs to agree the plan and system access or align along with their works.

7.2.3 Original Equipment Manufacturer (OEM)

During RIIO-T1, NGET has seen a decline in support for some asset types by the OEM. Should this continue and the OEM be unwilling to support in terms of spares or drawings then there may be alterations to intervention selection or variances in costs where alternative suppliers will be required.

7.3 Contingency

No Contingency has been applied to any of the CBA calculations.

8. CONCLUSION

This JR justifies £263.88m of spend to deliver [redacted] circuit breakers and [redacted] bay assets during RIIO-T2 in order to maintain a safe and reliable transmission system in line with our stakeholders' expectations.

Section 2 provides detail around the asset types under consideration and explains which fall under the lead and non-lead categories.

Section 3 gives a summary of cost and volume performance at RIIO-T1. This highlights how we have achieved savings versus wider switchgear allowances based on a changing mix of refurbishment and replacement projects, and procurement efficiencies.

Section 4 sets out how we have established required intervention volumes at RIIO-T2 which maintain network risk in line with stakeholder expectations. This plan is based on the output of the monetised risk approach for circuit breakers, aimed at targeting the most critical and at-risk assets that demonstrate a poor asset health. For bay assets, it is based on the output of our asset policies for bay assets, aimed at targeting assets that have known issues, family issues or that have reached their anticipated asset life. This shows a significant increase in bay interventions in RIIO-T2, driven by asset age. Circuit breaker interventions are lower than RIIO-T1, reflecting a lower level of installations reaching the end of their expected life in RIIO-T2.

Section 5 shows how we have identified options which deliver the required volumes of intervention in the most cost-effective manner. For each asset class, it identifies viable options which are then tested through CBA. This shows that:

- A mix of Replacement, Refurbishment and Repair is recommended for Circuit Breakers. This option has an NPV of £259m
- Refurbishment only is recommended for larger bays (275kV and 400kV). For 132kV bays and surge arresters, replacement is the only option. The combined NPV is -£349m

Section 6 demonstrates the cost efficiency of our plan. It sets out how we have developed unit costs for RIIO-T2 projects and compares these to equivalents for RIIO-T1 and external benchmarks. This analysis shows that unit costs for circuit breaker replacement and refurbishment projects are falling compared to RIIO-T1 (driven by fully embedding efficiencies achieved during RIIO-T1 into our RIIO-T2 plans) and are lower than wider industry benchmarks developed by TNEI Services. In this section we also explain a discrepancy with Business Plan Data Table unit cost inputs (see box on p37).

9. APPENDICES

Appendix A: RIIO-T1 investment taking place in RIIO-T2

The following investments listed below due to the complex scope of works are currently being delivered across both T1 and T2 regulatory periods.

[redacted] 275kV to 400kV Rationalisation: -

Replacement of both [redacted] 275kV and 132kV substations in accordance with the Asset Health strategy developed jointly by National Grid and UKPN. National Grid is to remove their existing 275kV exit point and replace them with 400kV assets as well as the replacement of the old 132kV AIS switchboards by UK Power Networks with a new 132kV GIS switchboard. As such this is the largest and probably the most complicated Grid Supply Point scheme that UK Power Networks/National Grid will undertake in their ED1 and RIIO-T1 Period.

National Grid have completed the build and energized the 400kV GIS substation at [redacted] but the transfer of circuits from the 275kV substation cannot be achieved until the 132kV substation is completed by UKPN. UK Power Networks issued a Modification Application in 2018 notifying a 2 year delay in completing the 132kV substation and hence the programme of works to transfer the 275kV circuits has subsequently delayed until the completion and the circuit transfer will take place on completion of the 132kV substation subsequently the 275kV substation will be decommissioned.

The current programme of works primarily linked to the maturity of 132kV Substation design, and critical interfaces regarding construction of National Grid's Infrastructure works and UKPN's circuit diversions to facilitate connection works.

This has resulted in a spend of approximately £[redacted] in RIIO-T2.

[redacted] 400kV Substation Rebuild: -

[redacted] 400kV GIS Substation was not originally included in our T1 submission for intervention. Following review of the condition of the Circuit Breakers a Refurbishment to achieve asset life was identified to allow the mechanism's and accumulators to achieve the asset life of the rest of the substation. However, following the review of the substation investment drivers during optioneering and detailed development significant levels of subsidence and SF_6 leaks were identified making this substation one of the highest SF_6 leaking assets on the transmission system and whole substation replacement was identified as the optimal alternative. Due to the timescales for land purchase agreement and getting necessary planning permission approvals this investment is currently delivered cross T1 and T2 regulatory period.

National Grid will be completing the new substation build in the T1 regulatory period and the circuit transfers will take place during the first half of the T2 regulatory period.

This has resulted in a spend of approximately £[redacted] in RIIO-T2.

[redacted] 132kV Substation Rebuild: -

This investment was to asset replace the [redacted] 132kV Air Insulated Switchgear (AIS) Substation with a twenty-one bay Gas Insulated Switchgear (GIS) Substation to remove the population of AEI type GA6 circuit breakers from the site. The GA6 type breakers have a known problem which can lead them to destructively fail and have been prioritised for immediate replacement to maintain the reliability of the National Grid Electricity Transmission (NGET) network and to deliver NGET's Network Output Measures (NOMs) obligations within the RIIO-T1 period.

The transfer of all the circuits to the New 132kV GIS is now complete except for the [redacted] circuit and the two temporary interconnector circuits. NGET's Network Output Measures (NOMs) obligations have already been achieved within the RIIO-T1 period by the removal of the old circuit breakers from the AIS substation.

There are system access constraints which are due to the importance of the [redacted] substation in the Transmission system, the complexity of managing multiple Distribution Network Operator (DNO) and Windfarm interfaces when securing system access, alongside significant Electricity Transmission (ET) resource constraints in the area, and system access restrictions implemented by the DNO have delayed the SGT2 circuit transfer and created further delays to the project.

This has resulted in a spend of approximately £[redacted] in RIIO-T2.

[redacted] 132kV Substation Rebuild: -

This investment was to asset replace the [redacted] 132kV Air Insulated Switchgear (AIS) Substation with a Gas Insulated Switchgear (GIS) Substation to remove the existing circuit breakers from the site. This is a multi-User site currently shared between the DNO (Western Power Distribution), Ex-[redacted] Power Station ([redacted]) and NGET.

The following reasons contributed to the longer programme of works at Rugeley.

- Complex nature of the project optioneering and design,
- Circuit transfers from existing substation to the new substation
- Procurement of land for the offline substation build due to housing developments happening after the demolition of the [redacted] Power station.
- Agreement with the DNO for a mutually acceptable design solution to minimise the diversion works and ensure a joint aligned project investment can take place.
- Agreement with the Housing developer ([redacted]) and relevant planning authorities.

Due to the above this investment is currently delivered cross T1 and T2 regulatory period. This has resulted in a spend of approximately £[redacted] in RIIO-T2.

[redacted] 22kV Substation Rebuild: -

This investment was to asset replace the [redacted] 22kV Air Insulated Switchgear (AIS) Substation with its modern equivalent to remove the existing circuit breakers from the site.

This site is currently shared between two DNOs (SSE, UKPN) and also with London Underground and NGET.

Due to Safety requirements it is necessary for some Customer circuits to be completely switched out to conduct condition assessments of the Insulated Busbars, which has led to delays in the development of the scheme. This in combination with the complex interfacing arrangements required to reach agreements on the intervention between 3 customers has prolonged the programme for this investment.

Due to the above reasons this investment is currently delivered cross T1 and T2 regulatory period. This has resulted in a spend of approximately £[redacted] in RIIO-T2.

Appendix B: RIIO-T2 interventions by asset

Justification Report - RIIO-T2 Lead Asset Tables

Circuit Breakers

EoL Score	Description
80-100	Asset is in a state where it is likely to lead to failure in the short term (5 years). Additional monitoring, operational restrictions and ad hoc component replacement is likely
60-79	Asset expected to deteriorate to an AHI 1 within 5 years. May require additional monitoring and/or ad hoc component replacement
35-59	Low level of faults or defect – some known to cause failure
0-34	Good health – no known specific or general life limiting problems.

**This is not related to AHI*

Bulk projects (in situ replacements and refurb, [redacted]* total)

The list of schemes has been redacted.

The above list has [redacted] CB's listed under monetised risk and the justification report is based on [redacted] CB's. The difference due to the following: - [redacted] is currently a Switch disconnector which does not have a monetised risk due to being a non-lead asset and the investment need is to replace the asset with a Circuit Breaker in order to ensure it meets the full switching duty requirements for the reactor. -[redacted] is not included in the monetised risk as this breaker was identified as a spare generator bay disconnected from the sys, hence this breaker was not included in the monetised risk model output. - [redacted] CB is not included in the monetised risk model as a routine maintenance inspection on this asset early this year found that on the mechanisms all six trip coils (two per mechanism) were burned out, the series variable -10ohm resistors were also burned out would have been as a consequence of the failure of the one phase mechanism M90-1) to operate closed. With one phase not closing, the breaker phases not together protection would try and trip the breaker with a standing trip on both coils. Hence, we need to carry out emergency replacement of the mechanism in order to ensure the breaker can be operated safely. Due to this intervention this breaker was not included in the monetised risk output as the intervention reduced the monetised risk for this CB.

Non-bulk projects ([redacted] total)

The list of schemes has been redacted.

Appendix C: RIIO-T2 Non-Lead Asset EoL status

Disconnectors	Beyond expected life	Reaching expected life in T2	Aligned with other bay assets
400kV	[redacted]	[redacted]	[redacted]
275kV	[redacted]	[redacted]	[redacted]
132kV	[redacted]	[redacted]	[redacted]
>132kV	[redacted]	[redacted]	[redacted]

Earth Switches	Beyond expected life	Reaching expected life in T2	Aligned with other bay assets
400kV	[redacted]	[redacted]	[redacted]
275kV	[redacted]	[redacted]	[redacted]
132kV	[redacted]	[redacted]	[redacted]
>132kV	[redacted]	[redacted]	[redacted]

Surge Arresters	Beyond expected life	Reaching expected life in T2	Aligned with other bay assets
400kV	[redacted]	[redacted]	[redacted]
275kV	[redacted]	[redacted]	[redacted]
132kV	[redacted]	[redacted]	[redacted]
>132kV	[redacted]	[redacted]	[redacted]

Appendix D: Full CBA Results

Circuit Breakers

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>ABCB</td><td>[redacted]</td><td>CB01</td><td>
Asset Family History - The DBG20P is a high operation Circuit Breaker used for reactive switching which demonstrated a number of vibration induced failure modes. As this Circuit Breaker is supported by the OEM with both replacement parts and technical expertise a Refurbishment solution to allow the asset to achieve its Anticipated asset life was developed and actioned on the majority of DBG20P’s in RIIO T1. The OEM presented National Grid with the option of spares supply only, however due to the complexity of the onsite refurbishment activities the option of OEM delivery was selected to ensure that a core team of specifically trained experts completed the intervention.
CBA Recommended Option – Refurbishment to Achieve Asset Life
Option Selected – Refurbishment to Achieve Asset Life
Reason for Option Selection – Refurbishment to achieve asset life was identified through the CBA as the most economic option. Refurbishment requires fewer civil works and requires significantly shorter outage periods than full replacement.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0.001</td><td>1.537</td><td>0</td><td>-0.203</td><td>-0.203</td></tr>
<tr><td>Replace</td><td>1.500</td><td>1.500</td><td>0.629</td><td>-1.359</td><td>-0.730</td></tr>
<tr><td>Refurbishment AL</td><td>0.177</td><td>1.677</td><td>0.549</td><td>-0.419</td><td>0.131</td></tr>
</table>
</td></tr>
<tr><td>ABCB</td><td>[redacted]</td><td>CB02</td><td>
Asset Family History: The Frame R Air Blast Circuit Breaker strategy was initially to refurbish in RIIO-T1 with a 25-year life extension through National Grid’s Internal Refurbishment Centre. In 2017/18 following the annual intervention cost review, the Cost Benefit analysis for the intervention was demonstrated to no longer be the best whole life value and the intervention was switched to replacement for the remaining assets within the family.
CBA Recommended Option – – Replacement
Option Selected — Replacement
Reason for Option Selection: As the RIIO T2 Replacement intervention is based on the current [redacted]
Summary of CBA analysis (preferred option shaded green):
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td></td><td>[redacted]</td><td></td><td>
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0.016</td><td>0.330</td><td>0</td><td>-0.128</td><td>-0.128</td></tr>
<tr><td>Replace</td><td>1.474</td><td>1.474</td><td>0.929</td><td>-1.365</td><td>0.436</td></tr>
<tr><td>Refurbishment + Replace</td><td>1.300</td><td>2.773</td><td>0.507</td><td>-1.800</td><td>-1.293</td></tr>
</table>
</td></tr>
<tr><td>ABCB</td><td>[redacted]</td><td>CB03</td><td>
Option Selected – Replacement
Reason for Option Selection:
The GA10 and GA6 Air Blast Circuit Breakers operate at 275kV and 132kV and received a short refurbishment in RIIO-T1. The cost of intervention and life extension provided is such that it is cost beneficial when assessing the whole life cost of the intervention in the RIIO-T1 period. Further refurbishment of this family is not considered feasible at this time due to a reduction in technical knowledge in the refurbishment centres, Operation staff and suppliers of replacement components. On this basis, whilst a CBA has been completed which demonstrates if an intervention of similar cost and life extension were to be planned it would be cost beneficial, it is not National Grid’s choice of intervention for this asset family. [redacted]

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0.459</td><td>15.074</td><td>0</td><td>-8.718</td><td>-8.718</td></tr>
<tr><td>Replace</td><td>13.311</td><td>13.311</td><td>15.766</td><td>-11.580</td><td>-4.186</td></tr>
<tr><td>Refurbishment + Replace</td><td>2.476</td><td>15.787</td><td>12.346</td><td>-11.468</td><td>0.878</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>ABCB</td><td>[redacted]</td><td>CB04</td><td>
Option Selected – Replacement
Reason for Option Selection:
The assets grouped within this asset family is obsolete with no support from OEMs, Suppliers or National Grid Electricity Transmission refurbishment centres for an intervention to extend life.
Replacement is the only option which will allow National Grid to manage a safe and reliable transmission network
[redacted]
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>2.819</td><td>3.679</td><td>2.942</td><td>-3.270</td><td>0.328</td></tr>
</table>
</td></tr>
<tr><td>ABCB</td><td>[redacted]</td><td>CB05</td><td>
Option Selected – Replacement
Reason for Option Selection:
The Main Refurbishment Programme for this family ended in 2015 with the process space in the Refurbishment Centre utilised for the GA6/10 refurbishment programme. Similar to the GA6 and 10, there is a lack of Technical expertise available to support the refurbishment of this asset.
[redacted]
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>0.442</td><td>0.442</td><td>0.248</td><td>-0.414</td><td>-0.165</td></tr>
<tr><td>Refurbish</td><td>0.570</td><td>1.012</td><td>0.262</td><td>-0.818</td><td>-0.556</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>ABCB</td><td>[redacted]</td><td>CB06</td><td>
Option Selected – Replacement
Reason for Option Selection:
The Main Refurbishment Programme for this family completed in early RIIO – T1 when the majority of the family received either a Full 25-year life extension or a Skinny 10-year life extension. Due to the cost of Replacement reducing and a lack or replacement Vitriolic Air seals which are no longer manufactured, refurbishment is no longer a viable option for this asset family.

[redacted]

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>2.456</td><td>2.456</td><td>1.404</td><td>-2.298</td><td>-0.894</td></tr>
<tr><td>Refurbish and Replace</td><td>3.006</td><td>3.252</td><td>0.567</td><td>-2.895</td><td>2.328</td></tr>
</table>
</td></tr>
<tr><td>Oil</td><td>[redacted]</td><td>CB07</td><td>
Option Selected – Refurbishment
Reason for Option Selection:
After identifying the asset family for intervention in RIIO T2, National Grid engaged with the OEM who confirmed that it is able to support a refurbishment of the mechanism and contacts to extend the asset life by 25 years.
Most of these assets are associated [redacted] Lengthy outages are difficult to obtain on these assets so the refurbishment option [redacted] to ensure supply is adequately maintained at a lower cost compared to replacement.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>0.687</td><td>0.687</td><td>0</td><td>-0.643</td><td>-0.643</td></tr>
<tr><td>Refurbish and Replace</td><td>0.324</td><td>1.011</td><td>0</td><td>-0.592</td><td>-0.592</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>Oil</td><td>[redacted]</td><td>CB08</td><td>
Option Selected – Replacement
Reason for Option Selection:
The [redacted] Switchgear classified within this family was designed and built between the late 1950's and early 60's and as such is obsolete with minimal Original Equipment Manufacture Support. [redacted] switchgear was the equivalent of modern GIS utilising oil circuit breakers and busbars insulate with resin impregnated paper to produce a compact design. This leads to restrictions in the potential alternatives as normally it will require the replacement of all the switchgear associated with the substation.
National Grid has investigated an alternative to offline rebuild for the replacement of these assets [redacted]. There is a risk that the Resin Impregnated Paper may not have the same asset life as the replacement Circuit Breakers, however National Grid has and will continue to monitor the effectiveness of this medium.

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>0.382</td><td>0.382</td><td>42.798</td><td>-0.643</td><td>42.155</td></tr>
</table>
</td></tr>
<tr><td>Oil</td><td>[redacted]</td><td>CB09</td><td>
Option Selected – Replacement
Reason for Option Selection:
The assets within this family grouping are Dead Tank Oil Circuit Breakers for which there is limited support from the Manufacturer for Internal components or the porcelain bushings which provide electric insulation between the Busbars and Main tank. The bushings are a life limiting factor and cannot be life extended. Replacement of six bushings is a disproportionate cost, as per our experience with JW420, 275kV circuit-breakers, and would be comparable to the replacement cost of a New Dead tank SF_6 Circuit breaker. This replacement option is an Industry Standard solution, has been completed [redacted] and provides a reliable solution which fits within the existing footprint.

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>3.949</td><td>4.234</td><td>61.540</td><td>-3.811</td><td>57.729</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB010</td><td>
Option Selected – Refurbishment AL / SF_6 Repair
Intervention cost per asset: £[redacted]m
Reason for Option Selection:
This Family grouping encompasses two Equipment Groups which were designed and manufactured [redacted]. These assets have similarities in their design and failure modes allowing for this grouping.
Analysis of the EoL Components indicates that the driver for intervention against these assets is to stop the SF_6 Leakage which will reset this aspect of the EoL Equation. Analysis through CBA demonstrates that SF_6 Repair is the efficient investment choice for this asset grouping rather than replacement. Furthermore, a SF_6 repair has a significantly shorter duration of Network outage which would mean a lower impact on accessibility of the network. The costs for this intervention are based on development works completed by the OEM and National Grid During RIIO T1 on similar assets.
There is a risk that, should there be changes to the Transmission System Requirements by the System Operator, the static capacitors, which [redacted] assets support, are no longer required. In this instance this may result in the optimal intervention changing to removal.

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0.008</td><td>1.079</td><td>0</td><td>-0.303</td><td>-0.303</td></tr>
<tr><td>Replace</td><td>1.032</td><td>1.032</td><td>1.426</td><td>-0.522</td><td>0.904</td></tr>
<tr><td>Refurbishment/ SF6 repair</td><td>0.300</td><td>1.392</td><td>1.472</td><td>-0.244</td><td>1.228</td></tr>
</table>
</td></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB011</td><td>
Option Selected – SF_6 Repair
Reason for Option Selection:
This asset family encompasses [redacted] asset for the RIIO-T2 intervention Plan. Whilst also manufactured by [redacted] [redacted] is of the Dead Tank Variety and therefore of a significantly different design.
Analysis of the EoL Components indicates that the driver for intervention against these assets is to stop the SF_6 Leakage which will reset this aspect of the EoL Equation. Analysis through CBA demonstrates that SF_6 Repair is the efficient investment choice for this asset grouping rather than replacement. Furthermore, a SF_6 repair has a significantly shorter duration of Network outage which would mean a lower impact on accessibility of the network. [redacted]

Summary of CBA analysis (preferred option shaded green):
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td></td><td>[redacted]</td><td></td><td>
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0.035</td><td>0.399</td><td>0</td><td>-0.160</td><td>-0.160</td></tr>
<tr><td>Replace</td><td>0.147</td><td>0.147</td><td>0.525</td><td>2.789</td><td>3.314</td></tr>
<tr><td>Refurbishment/ SF_6 repair</td><td>0.060</td><td>0.207</td><td>0.547</td><td>2.839</td><td>3.386</td></tr>
</table>
</td></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB012</td><td>
Option Selected – SF_6 Repair
Reason for Option Selection
This family encompasses [redacted] [redacted] Dead Tank 400kV SF_6 Circuit Breakers which were reconditioned in RIIO T1. The scope of this reconditioning was to replace or refurbish life limiting components, namely the Hydraulic Accumulators and Mechanisms. Prior to intervention these assets had not demonstrated SF_6 Leakage.
Analysis of the EoL Components indicates that the driver for intervention against these assets is to stop the SF_6 Leakage which will reset this aspect of the EoL Equation. Analysis through CBA demonstrates that SF_6 Repair is the efficient investment choice for this asset grouping rather than replacement. Furthermore, an SF_6 repair has a significantly shorter duration network outage which would mean a lower impact on accessibility of the network. [redacted]
There is a risk that should the leakage rate increase these assets may receive an intervention to remedy this within RIIO-T1.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0.024</td><td>1.997</td><td>0</td><td>-3.092</td><td>-3.092</td></tr>
<tr><td>Replace</td><td>0.974</td><td>1.948</td><td>0.748</td><td>-1.764</td><td>1.015</td></tr>
<tr><td>SF6 repair</td><td>0.030</td><td>2.008</td><td>0.809</td><td>-1.736</td><td>0.925</td></tr>
</table>
</td></tr>
</table>

CB design (Insulation Medium)	Family Type	CBA Ref	Option Selection
SF_6	[redacted]	CB13	**Option Selected** – Refurbishment AL / SF_6 Repair **Reason for Option Selection**: The [redacted] Family of Circuit breakers includes the [redacted]. This family has three main components scheduled for intervention in RIIO T1; the Hydraulic Accumulator, Mechanism and the Mark 1 version of the electronic control system. Management of SF_6 leakage for these assets during RIIO-T1 was an ad-hoc activity as the life limiting factor was not considered when the Health index process was defined due to the lack of regulation or legislation to require it. Development of SF_6 repairs with the OEM have occurred during RIIO-T1 providing the costs utilised within the CBA. There is a risk that should the leakage rate increase these assets may receive an intervention to remedy this within RIIO-T1. Summary of CBA analysis (preferred option shaded green):

Option	T2 investment (undisc, £m)	Total investment (undisc, £m)	Change in monetised risk (disc, £m)	NPV (£m, disc)	NPV inc monetised risk (£m, disc)
Do Nothing	0.374	8.715	0	-4.079	-4.079
Replace	7.515	7.515	2.725	-0.306	2.419
SF_6 repair	0.560	7.633	2.767	3.997	6.764

CB design (Insulation Medium)	Family Type	CBA Ref	Option Selection
SF_6	[redacted]	CB14	**Option Selected** – Refurbishment AL / SF_6 Repair **Reason for Option Selection**: The [redacted] is a SF_6 Circuit breaker designed for operation at 132kV and below. The design of this asset is different to the [redacted] family as the interrupter is arranged vertically and is colloquially known as a candle stick design. Major refurbishment or replacement of these assets is not expected until after the RIIO-T3 period, with Refurbishment dependant on support from the OEM due to the complexity of the mechanism and accumulator design. SF_6 repair to remedy the leakage associated with these assets is a cost-effective intervention to effectively manage the monetised risk of this asset. There is a risk that should the leakage rate increase these assets may receive an intervention to remedy this within RIIO T1. Summary of CBA analysis (preferred option shaded green):

Option	T2 investment (undisc, £m)	Total investment (undisc, £m)	Change in monetised risk (disc, £m)	NPV (£m, disc)	NPV inc monetised risk (£m, disc)
Do Nothing	0.019	0.745	0	-0.430	-0.430
Replace	0.688	0.688	1.065	0.379	1.444
SF6 repair	0.240	0.928	1.207	0.363	1.571

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td rowspan="2">[redacted]</td><td>CB15</td><td>
Option Selected – Replacement
Reason for Option Selection:
Due to the size of the population no SF_6 repair intervention has been developed. Until it is investigated to confirm if the asset is suitable for repair, the only intervention for this asset is replacement.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Replace at end of life</td><td>0.001</td><td>0.324</td><td>0</td><td>-0.126</td><td>-0.126</td></tr>
<tr><td>SF_6 repair and replace at end of life</td><td>0.065</td><td>0.385</td><td>0.421</td><td>-0.091</td><td>0.330</td></tr>
<tr><td>Replace</td><td>0.320</td><td>0.320</td><td>0</td><td>-0.189</td><td>-0.189</td></tr>
</table>
</td></tr>
<tr><td>SF_6</td><td>CB16</td><td>
Option Selected – SF_6 Repair
Reason for Option Selection:
The [redacted] Circuit breakers operating at 400kV and 275kV were installed in the early 1990's and are of a design which currently do not have any midlife limiting failure modes identified. The CBA confirms that the repair of the SF_6 leakage is more beneficial than replacement or leaving the asset to leak.
[redacted]
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0.013</td><td>0.995</td><td>0</td><td>-0.392</td><td>-0.392</td></tr>
<tr><td>Replace</td><td>0.933</td><td>0.933</td><td>0.475</td><td>0.308</td><td>0.783</td></tr>
<tr><td>SF 6 and repair at end of life</td><td>0.040</td><td>0.973</td><td>0.486</td><td>0.729</td><td>1.216</td></tr>
</table>
</td></tr>
</table>

nationalgrid

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB17</td><td>
Option Selected – SF_6 Repair
Reason for Option Selection:
The [redacted] is similar in design [redacted] in that it is arranged vertically and is of a design which currently does not have any midlife limiting failure modes identified. The CBA Demonstrates that the Do-Nothing option and the SF_6 repair have the same total expenditure, however the Repair options is more cost efficient over the lifetime of the decision.
There are two risks associated with these assets
1) Should the leakage rate increase these assets may receive an intervention to remedy this within RIIO-T1
2) [redacted] assets within this CBA are utilised to control Capacitive switching. There is a risk that should there be changes to the Transmission System Requirements by the System Operator, the Static capacitors will no longer be required. In this instance this may result in the optimal intervention changing to removal.

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0.006</td><td>2.614</td><td>0</td><td>-0.818</td><td>-0.818</td></tr>
<tr><td>Replace</td><td>2.751</td><td>2.751</td><td>4.432</td><td>-1.765</td><td>2.667</td></tr>
<tr><td>SF6 repair</td><td>0.240</td><td>2.819</td><td>4.643</td><td>-0.378</td><td>4.265</td></tr>
</table>
</td></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB18
CB19</td><td>
Option Selected – Refurbishment AL / SF_6 Repair
Reason for Option Selection:
The [redacted] family is supported [redacted]. During RIIO-T1 the OEM has supported National Grid with a midlife refurbishment against the pneumatic mechanism and where necessary the interrupters in cases of high mechanical or interruptive duty. Similar to the [redacted] Family, management of SF_6 leakage for these assets during RIIO-T1 was an ad-hoc activity as the life limiting factor was not considered when the Health index process was defined due to the lack of regulation or legislation to require it.
[redacted]
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0.021</td><td>2.852</td><td>0</td><td>-1.335</td><td>-1.335</td></tr>
<tr><td>Replace</td><td>5.516</td><td>6.400</td><td>8.825</td><td>-3.816</td><td>5.008</td></tr>
<tr><td>Refurbish AL/ SF_6 repair</td><td>1.312</td><td>6.217</td><td>9.336</td><td>-1.683</td><td>7.653</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB20</td><td>
Option Selected – Replacement
Reason for Option Selection:
The [redacted] 132kV SF_6 breaker is of candlestick design with a very limited population of assets on the network. As there has been minimal interaction with this asset family in RIIO-T1 no SF_6 repair intervention has been developed. Until it is investigated to confirm if the asset is suitable for repair, the only intervention for this asset is replacement.
There is a risk that should the leakage rate increase these assets may receive an intervention to remedy this within RIIO-T1.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Nothing</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>0.320</td><td>0.320</td><td>0.193</td><td>-0.300</td><td>-0.107</td></tr>
</table>
</td></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB21</td><td>
CBA required – Y
Option Selected – Repair
Reason for Option Selection:
The [redacted] Family of assets are Designed and Manufactured by [redacted] as a Gas Insulated Switchgear (GIS) asset. GIS is an integrated solution incorporating the Circuit breaker and other bay assets into a combined metal clad unit which in turn makes individual asset or bay replacement difficult if not impossible. The level of difficulty will be dependent on the design of the “Bay” of GIS” particularly the Gas Zone Isolation points. On this basis, the CBA supports a repair of this asset.

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0.006</td><td>1.604</td><td>0</td><td>-0.388</td><td>-0.388</td></tr>
<tr><td>Replace</td><td>1.566</td><td>1.566</td><td>0.564</td><td>-0.408</td><td>0.156</td></tr>
<tr><td>Repair</td><td>0.130</td><td>1.696</td><td>0.568</td><td>0.502</td><td>-1.088</td></tr>
</table>
</td></tr>
</table>

nationalgrid

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB22</td><td>CBA required – Y
Option Selected – Repair
Reason for Option Selection:
The [redacted] was designed by [redacted] and is currently supported by [redacted]. As the asset is a GIS installation, replacement of single assets is very complex and difficult. Outage duration and associated replacement costs will be very high resulting in repair being the best long-term option.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0.009</td><td>1.077</td><td>0</td><td>-0.392</td><td>-0.392</td></tr>
<tr><td>Replace</td><td>1.032</td><td>1.032</td><td>0.126</td><td>0.494</td><td>0.620</td></tr>
<tr><td>Repair</td><td>0.065</td><td>1.097</td><td>0.205</td><td>0.971</td><td>1.175</td></tr>
</table></td></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB23</td><td>CBA required – Y
Option Selected – Refurbish AL
Reason for Option Selection:
CBA: option Supported
The Refurbishment to Achieve Asset Life of the [redacted] Circuit Breaker is an activity which was undertaken with support from the OEM in RIIO-T1 against other circuit breakers on this substation. Costs from previous interventions have been utilised in the CBA to confirm that this is the appropriate option compared to replacement.

Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>21.200</td><td>21.200</td><td>1.200</td><td>-19.729</td><td>-18.529</td></tr>
<tr><td>Refurbish AL</td><td>3.798</td><td>16.398</td><td>1.682</td><td>-10.861</td><td>-9.180</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB24</td><td>
CBA required – Y
Option Selected – Refurbish AL
Reason for Option Selection:
The [redacted] GIS Circuit breaker acts as a supply point [redacted]. Due to the integrated design of this type of GIS, individual Circuit Breaker or GIS Bay replacement will have considerable difficulties.
The costs for this intervention are based on assets with a similar scope of works which occurred in RIIO-T1.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>0.320</td><td>0.320</td><td>0.098</td><td>-0.300</td><td>-0.201</td></tr>
<tr><td>Refurbish AL</td><td>0.035</td><td>0.355</td><td>0.098</td><td>-0.228</td><td>-0.129</td></tr>
</table>
</td></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB25</td><td>
CBA required – Y
Option Selected – Refurbishment AL
Reason for Option Selection:
The [redacted] [redacted] GIS circuit breakers act as transformer supply points for a DNO GIS substation. Replacement interventions whilst possible would require significant development beyond the scope of this justification paper as a custom design would be required.
[redacted]
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Refurbish AL</td><td>0.140</td><td>0.140</td><td>0.310</td><td>-0.125</td><td>0.185</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CB design (Insulation Medium)</th><th>Family Type</th><th>CBA Ref</th><th>Option Selection</th></tr>
<tr><td>SF_6</td><td>[redacted]</td><td>CB26</td><td>
CBA required – Y
Option Selected – Repair
Reason for Option Selection:
The [redacted] Circuit breaker is a GIS equivalent of the [redacted]. National Grid has refurbished both the [redacted] and [redacted] in RIIO T1 to allow the asset to achieve its anticipated asset life. This asset was installed in the early 1990's and has seen normal levels of mechanical and interruptive duty. Whilst it is possible to apply a Refurbishment to resolve the SF_6 leakage, this would have a negative impact on the asset life of the Mechanism which does not require an intervention until the 2030's. Therefore, the scope for this intervention to achieve the appropriate monetised risk reduction would be SF_6 Repair.
Whilst the CBA supports the Do-Nothing option, there are factors which cannot currently be accounted for such as the location of the asset. As per the assumptions it is not possible to calculate the system impact of this asset however gas low alarms would result in considerable effort to rearrange the substation. For this reason, SF_6 Repair has been selected as the appropriate intervention.
Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0.015</td><td>1.102</td><td>0</td><td>-0.444</td><td>-0.444</td></tr>
<tr><td>Replace</td><td>1.032</td><td>1.032</td><td>0.180</td><td>-0.071</td><td>0.109</td></tr>
<tr><td>Repair</td><td>0.065</td><td>1.097</td><td>0.188</td><td>0.365</td><td>0.553</td></tr>
</table>
</td></tr>
<tr><td>VCB</td><td>[redacted]</td><td>CB27</td><td>
CBA required – Y
Option Selected – Replacement
Reason for Option Selection:
The [redacted] Vacuum Circuit Breaker is the only one of its type within the National Grid Circuit Breaker Inventory. Due to there only being one asset, no Refurbishment option has been developed. Replacement is the only option which will allow National Grid to manage a safe and reliable transmission network. Summary of CBA analysis (preferred option shaded green):
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>Change in monetised risk (disc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Replace</td><td>0.285</td><td>0.285</td><td>0.222</td><td>-0.266</td><td>0.045</td></tr>
</table>
</td></tr>
</table>

CB design (Insulation Medium)	Family Type	CBA Ref	Option Selection
Aggregate CBA for preferred Circuit Breaker options			(see table below)

Option	T2 investment (undisc, £m)	Total investment (undisc, £m)	Change in monetised risk (disc, £m)	NPV (£m, disc)	NPV inc monetised risk (£m, disc)
Mixture of repair and replacement	33.274	72.551	292.757	-30.489	259.309

Bays

Voltage & Asset Type	CBA Ref.	T2 Volume	T2 Spend £m	Option Selection
400kV Earth Switches & Disconnectors	Bay01	[redacted]	67.23	**Option Selected** – Refurbishment to Achieve Asset Life CBA supports Refurbishment to Achieve Asset Life on cost grounds. Furthermore, the in-house refurbishment facilities combined with OEM parts allows us to achieve required asset life in most economic and efficient manner. CBA summary:

Option	T2 investment (undisc, £m)	Total investment (undisc, £m)	NPV (£m, disc)	NPV inc monetised risk (£m, disc)
Do Minimum	-1.806	-19.145	-7.910	-7.910
Replace	-139.870	-139.870	-117.95	-117.95
Refurb	-67.232	-207.634	-98.971	-98.971

<table>
<tr>
<td rowspan="2">275kV Earth Switches & Disconnectors</td>
<td rowspan="2">Bay02</td>
<td rowspan="2">[redacted]</td>
<td rowspan="2">89.21</td>
<td>Option Selected – Refurbishment to Achieve Asset Life</td>
</tr>
<tr>
<td>CBA supports Refurbishment to Achieve Asset Life on Cost. Furthermore, the in-house refurbishment facilities combined with OEM parts allows us to achieve required asset life in most economic and efficient manner

CBA summary:

<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>-1.680</td><td>-17.808</td><td>-7.358</td><td>-7.358</td></tr>
<tr><td>Replace</td><td>-347.040</td><td>-348.708</td><td>-303.47</td><td>-303.472</td></tr>
<tr><td>Refurb</td><td>-89.217</td><td>-436.788</td><td>-186.101</td><td>-186.101</td></tr>
</table>
</td>
</tr>
<tr>
<td rowspan="2">132kV or below Earth Switches & Disconnectors</td>
<td rowspan="2">Bay03</td>
<td rowspan="2">[redacted]</td>
<td rowspan="2">36.25</td>
<td>Option Selected – Replacement only</td>
</tr>
<tr>
<td>Due to large number of variants at 132kV (and below) and relative lower population, replacement is deemed to be the most economic and efficient solution. Developing refurbishment solution for each variant and refurbishing would cost more than directly replacing them.

CBA summary:

<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>-0.825</td><td>-8.740</td><td>-3.611</td><td>-3.611</td></tr>
<tr><td>Replace</td><td>-36.246</td><td>-36.778</td><td>-32.157</td><td>-32.157</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><td rowspan="2">Surge Arrester</td><td rowspan="2">Only one feasible option</td><td rowspan="2">[redacted]</td><td rowspan="2">35.01</td><td>Option Selected – Replacement only</td></tr>
<tr><td>Surge Arresters are hermetically sealed units with no mechanical moving parts. Refurbishment is not possible and economical considering the low unit costs for new surge arresters

CBA summary:
<table>
<tr><th>Option</th><th>T2 investment (undisc, £m)</th><th>Total investment (undisc, £m)</th><th>NPV (£m, disc)</th><th>NPV inc monetised risk (£m, disc)</th></tr>
<tr><td>Do Minimum</td><td>-0.528</td><td>-5.592</td><td>-2.310</td><td>-2.310</td></tr>
<tr><td>Replace</td><td>-35.017</td><td>-35.017</td><td>-30.741</td><td>-30.741</td></tr>
</table>
</td></tr>
</table>