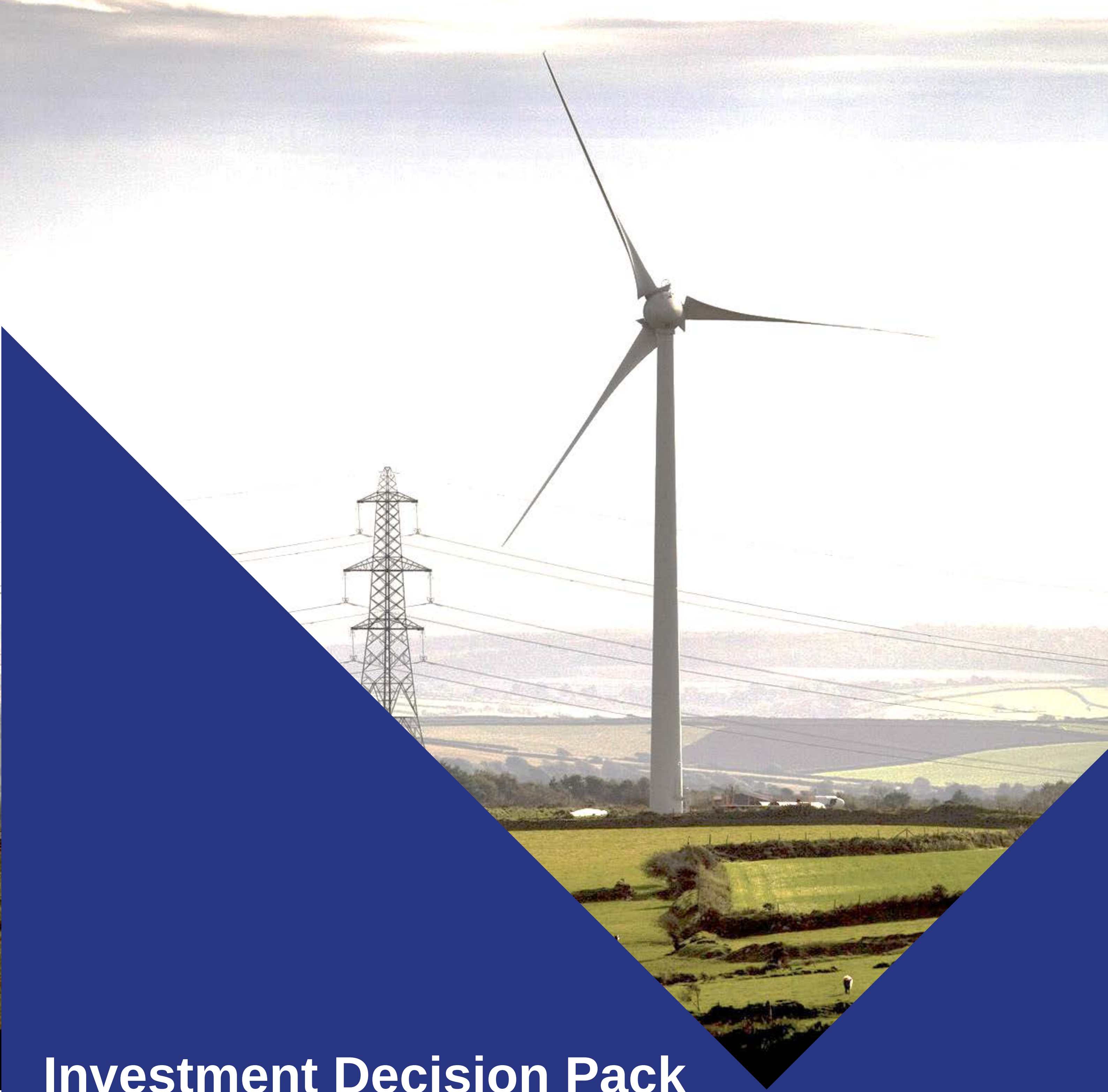

Investment Decision Pack
NGET-A9.15 Protection Control
December 2019

As a part of the NGET Business Plan Submission

nationalgrid

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Engineering Justification Paper; Non-Load Related *Substation Protection, Control, Metering & Monitoring*			
Asset Family	Substation Protection, Control, Metering & Monitoring		
Primary Investment Driver	Network Reliability		
Reference	NGET_A9.15 Protection & Control		
Output Asset Types	**Equipment Type**	**Volume**	**Cost (£m)**
	Feeder Protection	[redacted]	47.7
	Substation Control Systems (SCS)	[redacted]	120.6
	Mesh Corner Busbar Protection	[redacted]	4.9
	Circuit Breaker Fail (CBF): MC & DBB Protection	[redacted]	10.3
	SGT Protection	[redacted]	36.6
	Double Busbar Protection	[redacted]	37.9
	QB Control	[redacted]	21.6
	Mesh Corner DAR	[redacted]	32.1
	Operational Tripping Scheme (OTS)	[redacted]	27.6
	Reactive Equipment MSC	[redacted]	45.1
	Reactive Equipment SVC	[redacted]	40.2
	Auto Switching (Auto Close and Hot Standby Units)	[redacted]	0.4
	Automatic Reactive Switching (ARS)	[redacted]	0.9
	Automatic Voltage Control (AVC)	[redacted]	0.2
	Cable SCADA System	[redacted]	20.0
	Gas Density Monitoring (GDM)	[redacted]	0.5
	Fault Recorder	[redacted]	3.3
	Dynamic System Monitoring	[redacted]	28.3
	Settlement Metering	[redacted]	12.1
	Back-up Protection	[redacted]	6.6
Totals		[redacted]	£497m
Delivery Year(s)	2021 to 2026		
Reporting Table	C2.2A		
Outputs included in RIIO T1 Business Plan	Yes		

	T1	**T2**	**T3**
Spend Apportionment	£14.451m	£481.796m	£0.688m
Completion of RIIO-T1 schemes		£1.019m	
Development of schemes to deliver output beyond T2		£6.217m	
Total		£489.032m	

Contents

1. Executive Summary

This paper provides justification for a total spend of £496.935m to deliver interventions on [redacted] substation Protection, Control, Metering and Monitoring ('P&C') equipment in the RIIO-T2 period.

The electricity transmission system has a wide-ranging portfolio of P&C assets in terms of technology and application. There are a total of circa 18,500 P&C equipment on the transmission network which performs a P&C function. This equipment directly impacts consumers: failure can result in unplanned tripping, causing energy not supplied and loss of available equipment critical for electricity control centres to manage flows on the network. Failure can result in metering errors, affecting how consumers are billed. Failure can also cause safety risks to the public and operational staff if assets are not automatically de-energised by P&C equipment following faults. This availability of P&C equipment is therefore crucial to deliver what our stakeholders have told us; maintain the reliability of the network.

The broad range of technologies employed in P&C equipment have a varied lifetime and reliability factors. Electro-mechanical relays can achieve a 60-year lifetime, while more modern static transistorised electronic relays can achieve up to 25 years, with replacement driven by obsolescence, equipment deterioration and performance rather than age.

In RIIO-T1, through innovative collaboration with our suppliers, approaches such as the Selective Protection Asset Replacement (SPAR) have facilitated interventions which replace only the obsolete components and retain the remaining reliable infrastructure. This negates the need for full replacement of our P&C system assets thereby reducing the cost and system access time required to deliver these works. SPAR will be extended to additional P&C categories and is embedded into the RIIO-T2 plan.

In order to meet stakeholder expectations to maintain network reliability, we must increase the volume of interventions in RIIO-T2. A combination of installation dates and anticipated asset lives has created a convergence of asset replacement drivers, with a subsequent step up of intervention volumes in RIIO-T2 and beyond. This is principally due to equipment obsolescence driven by technology developments, and the anticipated decline in asset health condition.

RIIO-T2 volumes are predominantly for the older generation of assets based on electro-mechanical protection relays and static transistorised electronic relays installed in the 1960's and 1990's respectively. They are also driven by the requirement to replace digital substation control systems installed 20 years ago (following the introduction of IEC 61850 standards allowing for equipment communication and interoperability). The assets identified for intervention in RIIO-T2 are wholly independent and separate from those that have had interventions carried out in RIIO-T1.

We have identified interventions using our Asset Health Index (AHI) and asset criticality scoring, which defines our Asset Replacement Priorities (ARP).

We have conducted extensive optioneering to identify the optimum intervention mix to deliver RIIO-T2 interventions in the most cost-effective way. In determining the proposed intervention strategy four options were considered:

i. Do Nothing / Minimum – scheduled maintenance activities on the equipment identified, utilise the Secondary System Support Contract (SSSC) arrangement and spares where available up until the instance of equipment failure.
ii. SPAR Approach Only
iii. Full Replacement Only
iv. Mixture of Full & Targeted Replacement

For [redacted] assets we have developed Cost Benefit Analysis (CBAs) at a sub category level to determine which option to progress. Not all of the options were applicable to every P&C subcategory. The complexity associated with some equipment types does not allow a SPAR intervention to be undertaken, meaning that a full replacement is the only option for [redacted] of P&C equipment. The CBAs tell us that across all [redacted] assets, a mixture of Full and Targeted Replacement delivers the most value to consumers, maintaining current levels of network reliability at least cost. In addition to the [redacted] assets for intervention in RIIO-T2, we will adopt a do minimum fix-on-fail approach on [redacted] P&C assets rather than replace.

Costs and volumes for RIIO-T1 and RIIO-T2 are set out in Table 1 below:

Table 1: RIIO-T1 and RIIO-T2 costs and volumes summary

		T1 Allowances	T1 (all years)	T2 forecast	T1 annual average	T2 annual average
Feeder Protection	**Total cost (£m)**	136	101	51	12.6	10.2
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Control Systems	**Total cost (£m)**	271	99	117	12.4	23.4
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Other	**Total cost (£m)**	71	46	322	5.75	64.4
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Within the **Feeder Protection** category, the average annual costs of our interventions will be lower in RIIO-T2. This reflects a much higher proportion of interventions which will be carried out through SPAR during RIIO-T2.

For **Control Systems,** average annual costs will be higher during RIIO-T2. [redacted]

In the **Other P&C** category, the significant increase in average annual costs is driven by the increase in the volume of interventions. This reflects obsolescence, equipment deterioration and performance issues.

The figure below shows the overall cost and volume drivers behind differences between RIIO-T1 and RIIO-T2 average annual costs (£m):

[redacted]

Figure 1: Average annual costs (£m) for RIIO-T1 and RIIO-T2 and drivers of difference

2. Introduction and Background

This chapter provides detail around the P&C equipment covered in this paper. It sets out the role it plays in system operation, and explains how the equipment has been categorised for analysis in this paper.

Substation Protection, Control, Metering and Monitoring ('P&C') equipment is required for the safe, secure, reliable and economic operation of the electricity transmission network. The primary equipment that underpins the transmission network is dependent on the accurate and timely operation of P&C systems.

Correct disconnection of faulty primary equipment from the network is of vital importance to prevent or minimise damage to plant, injury to people and to minimise any impact on operational integrity.[1] The risks associated with P&C mal-operation include disconnection of healthy circuits, slow fault clearances, failure to disconnect faulted circuits, cascade tripping, system stability problems and the possible disconnection of generators from the transmission network. In addition, the GB electricity market is dependent on accurate and timely settlement metering data for trading accounts and greater system awareness of demand.

To report on cost and volume in this paper, we have separated assets into three categories:

- **Feeder Protection** forms its own category. This was one of the main drivers of RIIO-T1 volumes.
- **Control systems** (this is referred to as Substation Control Systems (SCS) in detailed tables) also forms its own category since it was a major driver of RIIO-T1 volumes.
- **Other** includes other asset sub-types which had a small volume in RIIO-T1 relative to RIIO-T2.

The basic functionalities of the equipment that constitutes P&C systems are:

a) **Protection Equipment Category** – *Feeder Protection, Other (Busbar Protection, Super Grid Transformer (SGT) Protection, Mesh Corner (MC) Protection, Delayed Auto Reclose (DAR), Circuit Breaker (CB) Fail and Back-up Protection Systems).*
Protection equipment comprises of several substation or network-based systems or devices and functions which protect the main electricity transmission circuits and equipment under fault or overload conditions. This is done by initiating the disconnection of the faulty circuit or equipment and selectively opening (tripping) the relevant or minimum number of circuit breakers. The transmission network comprises of two-ended and three-ended circuits therefore these protection systems are designed and assembled to be able to protect both these transmission circuit configurations.
Additionally, automatic switching performed by Delayed Auto Reclose (DAR) and other similar systems is critical in restoring healthy circuits and equipment back into service, post-fault. This ensures that the minimum number of circuits are out of service simultaneously when the system is stressed (for example due to high winds or lightning storms) when the transmission network is most vulnerable.

[1] Incorrect operation of protection equipment on the transmission network was highlighted as a cause in both the South London and Birmingham losses of electricity supply in 2003 affecting approximately 700,000 consumers and causing significant disruption to normal activities including transport systems and operation of local infrastructure and services.

Figure 2: P&C relays at a substation

b) **Control Equipment Category** – *Substation Control Systems (SCS), Other (Quad Booster (QB) Control, Operational Intertrip and Cable SCADA).*

SCS consist of a number of substation-based devices and functions which enable the transmission primary equipment to be operated locally at the substation or remotely from the Control Centre. The SCS provides information on the operational state of the primary and secondary transmission assets. SCS form a vital link between National Grid's substations and Distribution Network Operators' substations.

[redacted]

Figure 3: Typical SCS typology/arrangement

Quad Booster Control System simultaneously monitors the Quad Booster[2] to prevent system over-load by interpreting commands from the Control Centre as well as controlling the power sharing across circuits to optimise boundary transfers and boundary imports and exports. It is also used to manually tap the quad booster in the event of a telecommand system failure.

[2] *Quad Boosters* are used to control the flow of power in the transmission network due to the network's interconnected nature so that power flow is optimally shared across circuits.

<u>Operational Intertrip</u> is a device that trips a circuit breaker to disconnect a generator from the Transmission System upon receiving a specific signal. This device is used to operate and manage the transmission network following a credible unplanned fault.

<u>Cable SCADA</u> (supervisory control and data acquisition) is a system made up of software and hardware elements that enables the monitoring, gathering and logging of real time data whilst also enabling the control of devices such as pumps, valves and sensors which are used in cable tunnel systems for various functions.

c) **Other Equipment Category: Reactive Equipment Protection and Control –** Reactive equipment comprises of Mechanically Switched Capacitors (MSCs) and Static VAr Compensators (SVCs). These are required to manage the voltage levels on the Transmission System. Their associated P&C systems enable monitoring and control of the safe and effective operation and performance of the primary equipment.

d) **Other Equipment Category: Metering and Monitoring Equipment –** This category of secondary equipment consists of, Fault Recorders, Gas Density Monitoring (GDM), Dynamic System Monitoring (DSM) and Settlement Metering equipment. This equipment is required to monitor pre-and-post fault events on the transmission system, to constrain generators following an event, and to provide accurate and timely meter readings for the commercial activities that underpin electricity markets.

3. Performance at RIIO-T1

This chapter provides an overview of performance against RIIO-T1 allowances. This is presented across P&C equipment as a whole, and for the three P&C equipment categories. It also highlights RIIO-T1 innovations which have driven efficiency.

Table 2 below summarises the interventions carried out in RIIO-T1 versus allowances.

Table 2: Performance at RIIO-T1 versus allowances

		T1 Allowances	T1 (all years)	T1 annual average
Feeder Protection	Total cost (£m)	136	101	12.6
	Total volume	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]
Control Systems	Total cost (£m)	271	99	12.4
	Total volume	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]
Other	Total cost (£m)	71	46	5.75
	Total volume	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]

In RIIO-T1, interventions on P&C assets were identified based on our Asset Health Indices (AHI). We are forecasting the total spend over the same period to be £246m. This is £232m lower than allowances. More detail on the innovative approaches that have driven efficiencies at RIIO-T1 is provided in Section 3.4.

The following section summarises our volume and cost per unit performance per asset category against our allowance, and highlights how we have innovated to drive efficiency.

3.1 Feeder Protection

Volume performance: Over RIIO-T1 we forecast volume performance in line with our allowance.

Cost per unit performance: At the start of RIIO-T1, feeder protection interventions were based on full replacement (standard bay solution) which comprised complete replacement of the main protection (1st main and 2nd main), protection signalling, synchronisation & voltage selection, circuit breaker fail, back-up protection and delayed auto reclose relays and the associated relay panels and wiring. Through innovation and collaborative working with our suppliers, we have developed interventions such as smart replacement solutions which involve replacing only the obsolete life-expired higher-risk components and retaining the lower-risk reliable infrastructure (such as fixed wiring)- collectively we refer to this as the Selective Protection Asset Replacement (SPAR) approach. This negates the need for immediate full replacement of our assets. An example of savings from the SPAR approach is set out in Section 3.4 below.

By using SPAR rather than full replacement, we have cost efficiently reduced system access time by approximately half. Through RIIO-T1 innovation, we are expecting costs per unit to improve against allowances to £[redacted]m per intervention due to this increased proportion of SPAR interventions.

3.2 Control Systems

Volume performance: Control Systems interventions included both replacement and upgrade / refurbishment of SCS equipment. Over RIIO-T1 we forecast volume performance in line with our allowance.

Cost per unit performance: Over the RIIO-T1 period we are achieving significant cost efficiency (64% reductions in cost per unit versus allowances) in delivering SCS interventions through use of SPAR. Reaching maturity on this targeted approach during RIIO-T1 means volumes change from a forecast refurbishment of [redacted] SCSs and full replacements on the remaining [redacted], to application of SPAR on [redacted] SCSs and fully replace [redacted] over RIIO-T1. SPAR has significantly reduced system access time and specialist engineering resources required, meaning significant efficiencies are realised.

3.3 Other Protection and Control (P&C)

Volume performance: Over RIIO-T1 we forecast volume performance in line with our allowance.

Cost per unit performance: Despite upward pressure on costs in some of the Other P&C categories, across the category as a whole costs per unit are below RIIO-T1 allowances.
We are seeing upward pressure in the cost of Reactive equipment (SVCs) P&C: the OEM has indicated no spares are available to undertake refurbishment, making full replacement the only intervention option.

3.4 Continuous improvement through innovation

This section provides more detail on the innovative approaches that have driven efficiencies in RIIO-T1 and form part of our RIIO-T2 approach.

Engineering, asset management and innovation are central to our organisation, forming the foundation of what we do, making sure we provide value for consumers. Some of the innovative interventions and best practices we have developed in RIIO-T1 which we will emulate and continue to improve on in RIIO-T2 are:

i. SPAR application: SPAR has been used on the Hams Hall – Willington East circuit. We utilised our in-house engineering expertise to complete the requisite designs and carry out the Feeder Protection interventions on site. In so doing we reduced system outage durations from 6 weeks to 3 weeks and costs from approximately £[redacted]k to approximately £[redacted]k. SPAR could not be undertaken on some feeder protection circuits due to equipment condition and obsolescence associated with it.
ii. Established the techniques to better assess electronic (analogue and numeric) protection equipment to evaluate the lives of these specific equipment types. This allows us to consider if whole-scale equipment replacement can be avoided. This work was used to inform and expand the SPAR methodology onto new protection sub-categories both in RIIO-T1 and RIIO-T2.
iii. Developed evaluation and desktop design solution of an alternative digital bus bar solution architecture to inform a technical and procurement strategy for bus bar protection. This will enable more efficient replacement of bus bar protection systems. This was undertaken under an innovation project (NIA_NGET0064).

4. Investment need

During RIIO-T2, an increased level of intervention volumes is necessary if we are to meet stakeholders' priority of maintaining current levels of network risk. In this section we describe:

- The main drivers for the increase in volume during RIIO-T2
- How we have identified RIIO-T2 interventions
- How RIIO-T2 volumes compare to RIIO-T1

4.1 Investment drivers

The introduction of numeric and digital technology has significantly shortened the anticipated lives of P&C equipment, which are now driven by obsolescence rather than deteriorating condition and/or performance. Obsolescence is managed through our Secondary System Support Contract (SSSC) arrangements, however this cannot sustain end-of-life assets indefinitely, as support is removed by OEMs.

The planned interventions for RIIO-T2 are predominantly the older generation of assets based on electro-mechanical protection relays and static transistorised electronic relays installed in the 1960s and 1990s respectively, plus the requirement to replace digital substation control systems installed 20 years ago. This requirement is influenced by the introduction of IEC 61850 standards of providing seamless communication and integration of high-speed microprocessor-based Intelligent Equipment Devices (IEDs) from various manufacturers to allow for equipment interoperability.

The increased volume during RIIO-T2 is due to the combination of installation dates and anticipated asset lives that has created a convergence of asset replacement drivers in the RIIO-T2 period and beyond. Failures of these assets can impact on consumers' security of supply, and therefore we need to intervene in a timely, coordinated manner which minimises impact. Our long-term investment cycle for the 'Other P&C' category is shown in Figure 4 below. The profile is similar for the Feeder Protection and Control System categories.

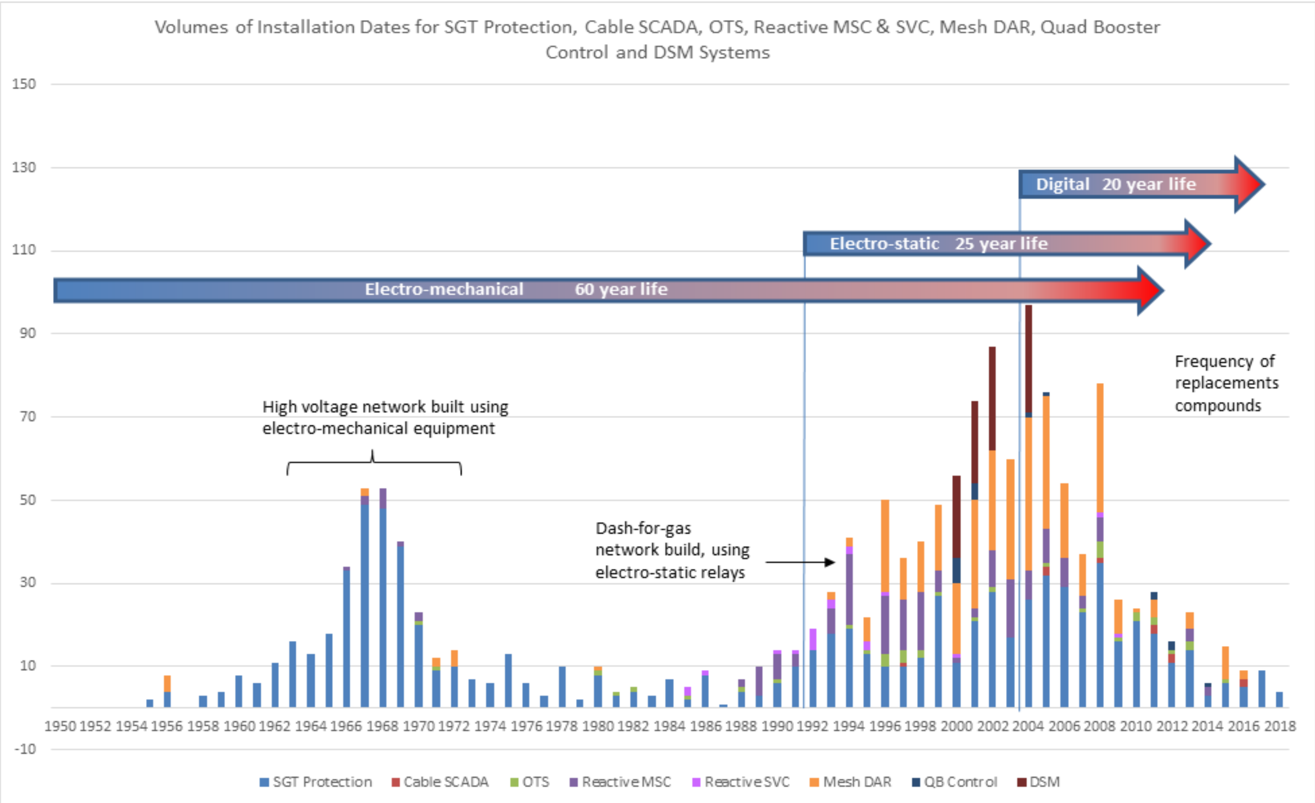

Figure 4: Expected lifetimes versus age of asset, Other P&C equipment

The main performance issues for P&C equipment are:

a. Electromechanical equipment (installed in the 1960s and 1970s, maximum 40 – 60 years anticipated asset life): defects arise from open circuit coils, high resistance contacts that have become burnt, worn out, stuck (due to dirt in parts) or have reduced contact pressure (leading to setting drift).

b. Complex and static transistorised devices (installed in the 1970s and 1980s, 25 years anticipated asset life): failure arises because they are in constant use making the heat they generate accelerate the rate of deterioration.

c. Early generation numerical devices based on microprocessor and programmable logic equipment (installed in the 1990s, typical asset life of 20 years): end of life is governed by technical obsolescence of either the special components used or operational software.

d. Digital numeric & signal processing equipment (installed in the early 2000s, anticipated asset life of 20 years): obsolescence is also the major driver for replacement. A typical example is the numeric protection relays at [redacted] substation which were installed in 2004 and is now due for intervention in RIIO-T2.

An example of obsolescence driven intervention proposed for RIIO-T2 is the busbar protection at our Norwich Main substation. The original equipment manufacturer (OEM) informed us in 2016 that this equipment was already classified as obsolete and their ability to provide spares would end in 2019[3]. To address the risk created by this and ensure reliability of the transmission network, we will need to carry out an intervention in RIIO-T2.

It is important to note that the implementation of SPAR in RIIO-T1 will not create the need for more extensive interventions during RIIO-T2. The equipment identified for intervention in RIIO-T2 are wholly independent and separate from RIIO-T1.

4.2 Approach to defining RIIO-T2 volumes

4.2.1 ARP methodology

P&C assets are classified as non-lead assets and their replacement is based on the Asset Health Indices and Asset Replacement Priorities (ARP) model, not the Monetised Risk approach.

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 safety, reliability 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 two approaches (ARP model and Monetised Risk) evident in our business plans.

Failure likelihood may simply be expressed as a probability up to 100% (or 1). For non-lead assets, a proxy for probability of failure is used in the form of a scoring system - the Asset Health Index (AHI). This scoring system, which places assets into discrete bands of '1' to '4', was used for all Lead assets for RIIO-T1. It is combined in a matrix with an asset criticality score, again banded from 1 to 4 to arrive at 'Replacement Priorities'.

[3] Busbar protection at Norwich Main substation is ABB REB500v5 which the OEM has classified as obsolete since 2013.

Table 3 summarises the AHI approach.

Table 3: AHI core principles

Principle	Likelihood of Asset Failure	Consequence of Asset Failure	Risk is a function of Likelihood of an event and its consequence
Asset Health Index (likelihood) and Criticality (consequence) combined to give an asset replacement priority (risk).	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.

The ARP model's component parts are assessed as follows:

- **Asset Health Index:** Equipment demonstrating significant unreliability issues are assigned an AHI of 1 whereas those assets which have become obsolete or where the support from manufacturers has ceased are assigned an AHI of 2a.
- **Criticality:** Using our engineering and asset management expertise and in line with stakeholder expectations, we consider the consequence of asset failure (how the equipment failure or mal operation would impact on network reliability, the environment in which they operate, and safety). This evaluates the criticality associated with the failure and performance of different P&C functions to further prioritise the nature and timing of the intervention necessary. This is scored as Very High/High/Medium/Low.

These combine to give an ARP score (expressed as an intervention timeframe in years) as set out in Table 4 below, e.g. an asset with an AHI of 1 and Very High criticality would be expected to see an intervention within 2 years. Once equipment is replaced, they would last for 20 years so a new ARP of 16+ is assigned to these assets.

Table 4: summary of ARP bands

	Criticality			
Asset Health Index	**Very High**	**High**	**Medium**	**Low**
1	0-2	0-2	2-5	2-5
2a	0-2	2-5	5-10	5-10
2b	5-10	5-10	5-10	10+
3	10+	10+	10+	10+
4	10+	10+	10+	10+

4.2.2 Asset health

Asset health is reviewed on an annual basis. The review considers failure rates, defects and obsolescence factors (availability of spares and engineering knowledge to provide ongoing support and repairs to return equipment to service) to determine the Asset Health Index (AHI). This establishes the likelihood of asset failure. This process is defined in the Policy EPS 12.08.

The individual AHI and associated condition-related issues for candidate asset interventions during RIIO-T2 are reported in the relevant table of Appendix A9.20 - Non-Load related plan build. The table provides a breakdown of the asset specific AHI scores and any relevant criticality factors driving asset replacement priority and intervention volumes.

4.2.3 ARP scores and RIIO-T2 volumes

The asset health review undertaken in late 2018 identified a volume of [redacted] P&C equipment requiring some form of intervention over the next 2-5 years, i.e. during RIIO-T2. This volume excludes equipment requiring an intervention in the next 0-2 years which will be addressed in RIIO-T1. This would require an average of around [redacted] interventions per year over the RIIO-T2 period, compared to an average of [redacted] interventions per year over the first 6 years of RIIO-T1.

Given the high volumes, we have prioritised for RIIO-T2 intervention the main protection units and control functions that are required to correctly identify and disconnect faults on equipment in a timely manner to maintain safety and reliability at acceptable levels. This established a RIIO-T2 replacement priority for [redacted] of the [redacted] candidate intervention units.

The [redacted] remaining units provide back-up protection functions or a secondary action (e.g. automated control and monitoring). These will be managed through a 'replace on fail strategy'. This is on the basis that interventions are successfully undertaken on the main protection units and control functions outlined above. The remainder of the intervention plan addresses the latent risk that the lower criticality equipment presents. Through good asset management practice, we aim to utilise existing assets as long as it is reasonably safe, economic and practicable to do so, to maximise consumer value. For back-up protection and circuit breaker fail with large population sizes, it is prudent to sample the asset population through targeted intervention to continually review the probability of failure, and subsequently manage the rest of the family with a greater degree of confidence. The sample population in RIIO-T2 (approx. [redacted]%) is based on a representative family size to avoid anomalies. This will support continual refinement and optimisation of our intervention strategy through continued learning. This [redacted]% will also cover emergency replacement in the event of a failure.

Our asset management techniques allow us to manage risks around assets identified for Replace on Fail for particular categories of P&C equipment. For example, during the annual cost visit in 2018, we demonstrated to Ofgem how we have used our engineering expertise to innovate and develop Circuit Breaker Fail (CB Fail) protection relays which we successfully trialled on the Blyth – Stella West circuit. By so doing, we are confident that our capabilities provide us with the opportunity to manage the CB Fail and Back-up Protection equipment in RIIO-T2 and beyond. Replace on Fail cannot be adopted for primary P&C equipment as any failure will impact on network reliability.

4.3 Comparison of volumes to RIIO-T1

Table 5 shows how the [redacted] RIIO-T2 interventions are divided between our asset categories, and compares to RIIO-T1. Details of how interventions are split between asset sub-categories is provided in Appendix A.

Table 5: RIIO-T1 and RIIO-T2 intervention volumes

		T1 Allowances	T1 all years	T2 forecast	T1 Annual average	T2 Annual average
Feeder protection	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Control systems	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Other	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 6 shows these volumes broken down by asset sub-category:

Table 6: RIIO-T2 interventions by sob-category

Asset Sub-Type	RIIO-T2
Feeder Protection	[redacted]
Substation Control System	[redacted]
Other P&C	
SGT Protection	[redacted]
Cable SCADA System	[redacted]
Operational Tripping Scheme (OTS)	[redacted]
Reactive Equipment; MSC P&C	[redacted]
Reactive Equipment; SVC P&C	[redacted]
Mesh Corner DAR	[redacted]
QB Control	[redacted]
Dynamic System Monitoring (DSM)	[redacted]
Mesh Corner Busbar Protection	[redacted]
Circuit Breaker Fail (CBF): MC & DBB Protection	[redacted]
Double Busbar Protection	[redacted]
Auto Switching (Auto Close and Hot Standby Units)	[redacted]
Automatic Reactive Switching	[redacted]
Automatic Voltage Control (AVC)	[redacted]
Gas Density Monitoring (GDM)	[redacted]
Fault Recorder	[redacted]
Settlement Metering	[redacted]
Back-up Protection	[redacted]
TOTAL	[redacted]

Feeder Protection volumes reduce slightly versus RIIO-T1 in the per-year volume of interventions. RIIO-T2 volumes are driven by asset performance, deterioration and obsolescence issues outlined in Section 4.1 above. SCS volumes are lower in RIIO-T2 as we addressed a significant part of the population within the RIIO-T1 period.

Over the RIIO-T2 period we are planning to significantly increase the volume of interventions in the Other P&C category when compared with RIIO-T1. The increase in volumes is driven by a combination of two factors:

- **Asset condition** – In section 4.1 we can observe three key waves in installation profiles of our P&C population, hence the sizable increase in population reaching its end of life during the RIIO-T2 period. Examples of asset condition or deterioration-driven RIIO-T2 intervention are the electromechanical busbar protection and transformer protection equipment at our Barking substation which were installed and commissioned in 1960. Some of these assets will have gone beyond their Anticipated Asset Life (AAL) by the commencement of RIIO-T2. Failure of any of these assets would increase network risk.

- **Equipment obsolescence** – Several different sub-asset classes have become obsolete due to lack of OEM support (see Norwich main busbar example in Section 4.1 above).

A combination of the above factors are driving intervention in new sub-asset classes including QB Control, Mesh Corner Busbar Protection, SGT Protection, Auto Switching, MSC P&C, Cable SCADA Systems, Fault Recorders and Dynamic System Monitoring in addition to those sub-asset classes in RIIO-T1. Failure rates and defects also drive RIIO-T2 volumes. Table 6 shows the increased range of asset sub-types that are contained within the 'Other' category at RIIO-T2, and shows the volume of interventions in these additional categories.

All P&C equipment identified in Table 6 is critical to managing network risk. For example, if the protection fails to clear a fault on a transformer, there is a potential safety risk to the public and personnel, and the consequential financial and environmental damage can be extensive. It is therefore important that appropriate interventions are undertaken on all the equipment identified below with the exception of Circuit Breaker Fail (CBF) protection and Back-up protection.

Our strategy for Circuit Breaker Fail (CBF) protection and Back-up protection is to undertake interventions on only [redacted]% of the entire population (units with an ARP 2-5 likely for intervention in RIIO-T2), This will enable NGET to generate spares from the decommissioned equipment to manage any faults with the remainder of the population and importantly enhance our asset and operational knowledge to better target the future intervention requirements for these assets. This [redacted]% will also cover emergency replacement in the event of a failure. This work will not revisit any CBF or Back-up protection associated with Feeder Protection SPAR interventions carried out in RIIO-T1.

This strategy cannot be adopted for the remaining P&C equipment identified in RIIO-T2 as in some instances, the obsolete equipment cannot be reused, or the consequence of failure will have significant impact on network reliability.

Of the [redacted] assets in the 'Other' category with an ARP of 2-5 years, the table below shows [redacted] assets which are 'NEW' asset sub types for RIIO-T2.

Table 7: RIIO-T2 intervention volumes for NEW asset sub-types in Other category

Asset sub-type	RIIO-T1 in Other	RIIO-T2 in Other	Intervention volume in 'NEW' categories
Mesh Corner Busbar Protection		✓	[redacted]
Circuit Breaker Fail (CBF): MC & DBB Protection		✓	[redacted]
SGT Protection		✓	[redacted]
Double Busbar Protection	✓	✓	[redacted]
QB Control		✓	[redacted]
Mesh Corner DAR	✓	✓	[redacted]
Auto Switching (Auto Close and Hot Standby Units)		✓	[redacted]
Operational Tripping Scheme (OTS)	✓	✓	[redacted]
Reactive Equipment; MSC P&C		✓	[redacted]
Reactive Equipment; SVC P&C	✓	✓	[redacted]
Automatic Reactive Switching		✓	[redacted]
Automatic Voltage Control (AVC)		✓	[redacted]
Cable SCADA System		✓	[redacted]
Gas Density Monitoring (GDM)	✓	✓	[redacted]
Fault Recorder		✓	[redacted]
Dynamic System Monitoring (DSM)		✓	[redacted]
Settlement Metering	✓	✓	[redacted]
Back-up Protection		✓	[redacted]
Total			[redacted]

Other P&C equipment with an ARP of 2-5 years is broken down by sub-category in Figure 5 for selected sub-categories. These represent the bulk of the investment ([redacted] as per Table 7) in the Other P&C category in RIIO-T2, although there are a significant number of lower cost interventions which bring the intervention total to [redacted] (as per Table 5 above).

[redacted]

Figure 5: Other P&C RIIO-T2 interventions ('NEW' asset sub types only)

Whereas we are planning RIIO-T2 interventions on 37% of equipment with an ARP of 2-5 years across the P&C portfolio as a whole, for the sub-categories in Figure 5 we will intervene on over [redacted]%. This is because these assets' failure poses a greater risk to the network. For example, we do not have duplicate OTSs in the event of failure, such that one system failure means network constraints will need to be managed by the ESO manually. This means we cannot shift investments on this equipment into RIIO-T3. By contrast, for auxiliary P&C equipment e.g. back up and CB fail, we can employ a replace on fail strategy: this is considered the best approach for this equipment type because we will be able to rely on the main protection, which by design has a quicker clearance time than auxiliary systems meaning it will operate first[4].

Figure 6 shows the high number of assets with an ARP of 2-5 years across P&C categories as a whole. Since a significant volume of these assets will be managed through a replace on fail strategy, they will require intervention in periods beyond RIIO-T2. It is clear that RIIO-T2 marks the start of a period of sustained high intervention volumes, and means that interventions identified for RIIO-T2 cannot be shifted into the RIIO-T3 if volumes ae to remain deliverable (and if network risk is to be managed).

[redacted]

Figure 6: ARP scores, all asset category volumes

[4] Following an event on the transmission system, the protection system, designed in adherence to Chapter 2 of the Security and Quality of Supply Standards (SQSS), operates in such a way that the 1st Main protection is expected to operate to clear the fault. If the 1st Main protection fails to operate, the 2nd Main protection is next in line. If both the Main protections fail to operate, it is expected that the Back-up protection will operate to clear the fault. The CBF protection on every circuit breaker on the transmission network functions by tripping the circuit breaker if the breaker fails to operate as expected.

5. Optioneering

To determine the optimum mix of interventions on P&C assets, a Cost Benefit Analysis (CBA) was undertaken. The options considered were informed by:

- Lessons learnt from RIIO-T1 including use of SPAR
- Interactivity of future equipment with current equipment – whether any newly installed equipment enables equipment, or parts thereof, that have not been replaced to continue functioning unhindered
- Internal stakeholder feedback through our Asset Life Cycle Working Groups
- Network Reliability stakeholder forum and webinars
- Collaborative innovation with our suppliers
- Testing the market for new suppliers, manufacturers and installers
- System access / outage and resource constraints
- Value for the end consumer
- Enduring Transmission System reliability and risk position.

This section sets out:

- Our approach to developing options and assessing costs and benefits
- The results from our analysis and choice of option.

5.1 Approach to calculating costs and benefits

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 equipment sub-category and aggregated the results to identify a preferred overall intervention strategy.

We have used the Net Present Value (NPV) calculation approach in the Ofgem template to identify the most cost effective option. The driver of NPV is the investment cost under each option. We have not quantified monetised risk under each option because monetised risk is at this moment only applicable to lead assets. We have not quantified wider societal benefits because these are likely to be marginal for investments of this kind. We are committing to work with Ofgem to incorporate P&C equipment into the NARM methodology during RIIO-T2 to provide a more robust quantification of the risks and system consequences associated with P&C equipment.

5.2 Options considered

The long list of P&C options is set out in Table 8 below:

Table 8: summary of P&C intervention options

Option	Detail	Taken forward for full CBA?
1. Do Minimum	This option involves undertaking scheduled maintenance activities on the equipment identified up to the instance of failure. A major disadvantage of this option is that failure of P&C equipment could lead to catastrophic failure of primary equipment which in turn could lead to not only loss of energy supply but also injuries and fatalities to operational staff and the wider public.	**Taken forward** This option would increase the overall transmission network risk position rather than reduce or maintain it at a stable level and therefore is not a credible / viable option. We have quantified this option in the CBA to show the investment costs of a pure maintenance approach.
2. SPAR approach only	For this option, only the obsolete or unreliable critical 'decision making' components within P&C systems are replaced whilst retaining the remaining infrastructure and components. Advantages of this option include reduced system access / outage requirements, reduced resource requirements and overall lower cost of intervention. Due to technical limitations[5], not all P&C equipment can use SPAR, meaning some will need full replacement. Another disadvantage of this option is that obsolete equipment would still be left on the transmission network thereby increasing the overall network risk position and adversely affecting reliability.	**Not taken forward across portfolio** This is not a feasible option across the portfolio as a whole as SPAR is not possible for all asset sub-types. Where a SPAR-only approach is possible for individual asset sub-types, this is costed.
3. Full replacement only	For this option, all P&C equipment would be replaced in full on a 'new-for-old' basis.	**Taken forward**
4. Mixture of full and targeted replacement	For this option, SPAR is used where possible whilst full replacement will only be carried out where necessary. Due to equipment obsolescence, some of the P&C equipment do not allow the hardware / software to be supported any longer or incorporated into modern systems thereby leaving full replacement as the only option.	**Taken forward**

5.3 Cost Benefit Analysis

P&C equipment has a number of different sub-categories with different operational properties and characteristics. In order to conduct meaningful analysis, we have produced separate CBAs for each sub-category. The full CBA results for each sub-category are provided in Appendix B. This section provides summary CBA results and the rationale for our choice of option.

As explained in Table 8 above, SPAR will not be possible for all assets. Within each sub-category we have identified equipment where SPAR is not feasible. For these, we have carried out CBA for Do Minimum and Full Replacement. For other assets where SPAR is possible, we have carried out CBA for Do Minimum, Full Replacement and Targeted Replacement.

The CBA results are summarised in Table 9. These show that:

- Do Minimum has the lowest investment cost, but is discounted because it leads to increased levels of network risk, contrary to stakeholder priorities
- There are some assets and asset types where a SPAR approach is not possible, leaving Full Replacement as the only option

[5] for example, inability to interface new relays with existing relay panels and wiring, and due to poor condition and obsolescence of auxiliary relays and ancillary P&C equipment

- Overall, Mixed SPAR and Full Replacement is preferred to Full Replacement only, as it meets stakeholder priorities around maintaining reliability levels and maintaining asset risk in RIIO-T2 in the most cost effective fashion.

Table 9: Aggregate CBA results and option choice across all P&C sub-categories

Option	Rationale	CBA results			Decision
		RIIO-T2 investment (undisc, £m)	Total investment (undisc, £m)	NPV (£m, disc)	
Do Minimum	See Table 8 above for rationale for ruling out the Do Minimum option	11	112	-44	**REJECT**
Full replacement	The cost to carry this out would be high and not represent an economic benefit to the end consumer. Due to the greater scope of work, this option will command a higher unit cost than our current targeted replacement approach and will present a deliverability challenge as full replacements would require longer system outages and resource requirements. Taking into the account that during RIIO-T1 period we have proven effectiveness of SPAR we have **rejected** this option from further consideration due to the high costs and due to the deliverability risks.	644	1966	-910	**REJECT**
Mixed SPAR and full replacement	The total cost for this option has been calculated using SPAR whenever possible while full replacement will only be carried out where necessary. Due to equipment obsolescence, some of the existing P&C equipment do not allow the hardware / software to be supported any longer or incorporated into modern systems thereby leaving full replacement as the only option. This option represents extension of our current innovative practice which allows us to maintain reliability levels that our stakeholders require. The advantages of this option are: o reduced system access / outage requirements o reduced resource requirements and o overall lower cost of intervention. For these reasons, this option is recommended.	482	1488	-689	**RECOMMEND**

In building our plan, we extended the SPAR approach to new asset sub-types, which were not covered in the RIIO-T1 period. This was based on the assumption that through innovative collaboration with our Suppliers, SPAR can be applied either in full or partially to the asset sub-types indicated in Table 10. This gives an overview of where SPAR is currently applicable, and where we plan to implement it for RIIO-T2.

Table 10: RIIO-T2 SPAR ambition

Asset Sub-Type	SPAR Approach Currently Applicable	RIIO-T2 SPAR Application	RIIO-T2 SPAR Volume
Feeder Protection	Partial	Partial	[redacted]
Mesh Corner Busbar Protection	Yes	Yes	[redacted]
Circuit Breaker Fail (CBF): MC & DBB Protection	No	No	[redacted]
SGT Protection	No	Yes	[redacted]
Double Busbar Protection	No	No	[redacted]
QB Control	No	No	[redacted]
Mesh Corner DAR	Yes	Yes	[redacted]
Auto Switching (Auto Close and Hot Standby Units)	No	No	[redacted]
Operational Tripping Scheme (OTS)	No	No	[redacted]
Reactive Equipment; MSC P&C	No	Partial	[redacted]
Reactive Equipment; SVC P&C	No	No	[redacted]
Automatic Reactive Switching	No	No	[redacted]
Automatic Voltage Control (AVC)	No	No	[redacted]
Cable SCADA System	No	No	[redacted]
Gas Density Monitoring (GDM)	No	No	[redacted]
Fault Recorder	No	No	[redacted]
Dynamic System Monitoring (DSM)	No	No	[redacted]
Settlement Metering	No	No	[redacted]
Back-up Protection	No	No	[redacted]
Substation Control System (SCS)	Partial	Partial	[redacted]

6. Assessment of cost efficiency

This section provides an explanation of how our costs have changed in relation to RIIO-T1. It is structured as follows:

- Section 6.1 provides a 'top down' view of costs per unit
- Section 6.2 shows how we have built our bottom up unit cost estimates which drive the RIIO-T2 costs in this paper. In order to demonstrate that our costs are efficient, we compare unit costs to industry benchmarks developed by TNEI Services. This section is split by sub-category. Comparison with TNEI benchmarks is only possible for Feeder Protection and Control Systems.

6.1 Comparison with RIIO-T1- cost per unit

The table below compares cost per unit (i.e. cost per intervention) performance across RIIO-T1 and RIIO-T2:

Table 11: RIIO-T1 versus RIIO-T2 cost comparison[6]

		T1 Allowances	T1 (all years)	T2 forecast	T1 annual average	T2 annual average
Feeder Protection	Total cost (£m)	136	101	51	12.6	10.2
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Control Systems	Total cost (£m)	271	99	117	12.4	23.4
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Other	Total cost (£m)	71	46	322	5.75	64.4
	Total volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

The drivers of RIIO-T2 costs per unit are provided below for each category.

6.1.1 Feeder Protection

Overall, we are forecasting [redacted]% reduction in cost per unit between RIIO-T1 and RIIO-T2. This is driven by building on the success of SPAR which significantly reduces outage durations and resource requirements, thereby significantly reducing intervention costs when compared to the full replacement standard bay solution. An example of the efficiencies provided by SPAR is set out for the Hams Hall – Willington East circuit in Section 3.4 above.

Additional efficiencies driving lower RIIO-T2 costs are provided by bundling of works where possible.

6.1.2 Substation Control Systems

Overall, we are forecasting a [redacted] between RIIO-T1 and RIIO-T2. This is driven by the significant change in intervention mix required for SCS in RIIO-T2 when compared to RIIO-T1. In RIIO-T1 there are [redacted] SCS upgrades and [redacted] full system replacements whilst in RIIO-T2 there are [redacted] upgrades and [redacted] full replacements.

[redacted]. Some of the existing equipment does not allow the hardware / software to be supported any longer or incorporated into modern systems thereby leaving full replacement as the only option. OEMs have informed us that they no longer carry any replacement spare parts nor offer fixes / repairs for some of the existing assets.

[6] The RIIO-T2 costs per unit presented in this table are top down calculations which divide total spend by total number of interventions. They include 'Edge' schemes where RIIO-T2 spend is for outputs delivered in RIIO-T1 RIIO-T3. They are not therefore directly comparable with the bottom up unit costs developed in this section

They are also driven by the requirement to replace digital substation control systems installed 20 years ago (following the introduction of IEC 61850 standards allowing for equipment communication and interoperability).

6.1.3 Other P&C

The overall cost per unit to replace Other P&C equipment will increase from £[redacted] m for RIIO-T1 to £[redacted] m in RIIO-T2. In Section 4.3 above we set out how many new asset sub-types are now included for consideration in this category. This change in asset mix means that costs per unit from RIIO-T1 and RIIO-T2 cannot be directly compared.

6.2 How we have calculated RIIO-T2 unit costs

6.2.1 Overview of methodology

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.

Below we provide more detailed information around what is driving our unit cost estimates across the different categories.

6.2.2 RIIO-T2 unit costs- feeder protection and SCS

We have developed estimates for the unit costs for RIIO-T2 interventions based on the particular characteristics of the projects. Figure 7 below shows expected RIIO-T2 unit costs for Feeder Protection projects, split by SPAR and Full Replacement, plus the mean unit cost. These are presented as ‘intervention bundles’ showing average annual unit cost. Figure 8 shows this information for SCS.

[redacted]

Figure 7: Average annual RIIO-T2 unit costs, Feeder Protection

[redacted]

Figure 8: Annual average RIIO-T2 unit costs, SCS

Figure 9 below summarises our RIIO-T2 unit costs against RIIO-T1 averages and external benchmarks developed by TNEI Services. [redacted] OEMs have informed us that they no longer carry any replacement spare parts nor offer fixes / repairs for some of the existing assets (see Section 6.1.2). [redacted] will form part of our £44m future efficiency commitment.

[redacted]

Figure 9: Unit costs versus TNEI benchmarks. Note: costs shown reflects SPAR & Replace, TNEI benchmark is replace.

6.2.3 Other P&C costs at RIIO-T2

Our costs for projects in the Other P&C category are based on information we have gathered from RIIO-T1 projects. For some sub-categories, no interventions were undertaken in RIIO-T1. Here we explain the basis for unit cost estimates for these sub-categories.

Feeder protection replacements comprise of full replacements (standard bay solutions) and SPAR (selective protection asset replacement). Full replacements involve complete replacement of the main protection (1st main and 2nd main), protection signalling, synchronisation & voltage selection, circuit breaker fail protection, back-up protection and delayed auto reclose relays and the associated relay panels and wiring.

In completing full feeder protection replacements in RIIO-T1, we have been able to ascertain our internal costs and those of our suppliers for circuit breaker fail protection, back-up protection and delayed auto reclose. This has enabled us to estimate costs for these now stand-alone asset sub-types in RIIO-T2.

In RIIO-T1 we completed ARS and AVC interventions bundled with SCS upgrades. We therefore have actual RIIO-T1 costs to use in estimating our RIIO-T2 costs.

For the asset sub-types which had no interventions in RIIO-T1, we have worked with our suppliers and contractors to estimate costs. We have also used market intelligence, including examples of similar interventions carried out for other TOs and DNOs.

Table 12 below shows how most unit costs in the Other category are based on RIIO-T1 costs.

Table 12: assets included in Other P&C category, RIIO-T1 and RIIO-T2

Asset sub-type	RIIO-T1 in Other	RIIO-T2 in Other
Mesh Corner Busbar Protection		□
Circuit Breaker Fail (CBF): MC & DBB Protection	✓	✓
SGT Protection		✓
Double Busbar Protection	✓	✓
QB Control		✓
Mesh Corner DAR	✓	✓
Auto Switching (Auto Close and Hot Standby Units)		✓
Operational Tripping Scheme (OTS)	✓	✓
Reactive Equipment; MSC P&C		✓
Reactive Equipment; SVC P&C	✓	✓
Automatic Reactive Switching (ARS)	✓	✓
Automatic Voltage Control (AVC)	✓	✓
Cable SCADA System		✓
Gas Density Monitoring (GDM)	✓	✓
Fault Recorder		✓
Dynamic System Monitoring (DSM)		✓
Settlement Metering	✓	✓
Back-up Protection	✓	✓

✓ represent asset sub-types that were delivered as part of Feeder Protection and SCS portfolios.

Figure 10 shows RIIO-T2 unit costs for interventions in the other category. Given the volume of interventions, these have been bundled into annual packages.

[redacted]

Figure 10: RIIO-T2 unit costs by year, Other P&C category

For some categories, there is significant variation in unit costs between years. The outliers are explained in Table 13:

Table 13: Cost outlier drivers, Other P&C category

Other sub-type	Year	Explanation
Busbar Protection	RIIO-T1	[redacted] Numeric Busbar Protection Replacement is a RIIO-T1 intervention and the costs recorded are related to close-out hence they appear on the lower end of the spectrum.
	2023	Scope of works involves replacement of busbar protection systems at [redacted] and [redacted] substations. These involve works on a total of [redacted] bays which represents the highest number of bays per year in this portfolio. Comparatively, Busbar Protection Replacement [redacted] involves work on a total of [redacted] bays.
DAR	2024	[redacted], with a volume of [redacted] at [redacted] sites namely [redacted], [redacted] and [redacted] For example, in 2023 we plan to deliver a volume of [redacted] across [redacted] sites.
Reactive Protection	2021, 2023	We intend to [redacted] in these years hence the unit cost is tracking higher than the other RIIO-T2 years

7. Key Assumptions, Risks and Contingency

a. System Access

Asset failure and / or faults in the Transmission and Distribution Networks may adversely affect the availability of outages by causing delays or cancellations.

b. Original Equipment Manufacturer (OEM) Support

As more components of Protection, Control, Metering and Monitoring systems became obsolete in RIIO-T1, OEMs have been unable to support planned interventions through provision of spares and drawings in some instances. There is a risk that this is a continuing trend that then necessitates a change to some of the planned interventions in RIIO-T2 leading to cost variances where alternative interventions or Suppliers are sought.

c. SPAR Methodology

It is assumed that the SPAR methodology can be applied either in full or partially to the asset sub-types indicated in Table 10. There is a risk that SPAR may not be fully applicable to some of the P&C systems resulting in cost variances.

d. Deliverability

In recognition of the significant volume increase between RIIO-T1 and RIIO-T2, we are introducing new ways of working internally to make more of our key (commissioning & site) resource available as well as working with our suppliers to introduce new delivery frameworks. A substantial proportion of the work proposed for RIIO-T2 is on sub-asset types that we have good experience of and have made significant improvements in RIIO-T1. Further to this, work bundling assessments have been carried out and will continue to be carried out to ensure that we bundle work where possible e.g. complete a transformer replacement alongside a transformer protection intervention, or make use of overhead line outages to complete work on the circuit's feeder protection.

Contingency

No contingency has been applied to any of the Cost Benefit Analysis calculations.

8. Conclusion

This paper justifies £497m of investment to deliver [redacted] P&C interventions over the RIIO-T2 period.

Section 2 provides background around P&C asset types, and explains how they are grouped for the analysis in this paper. It describes how the reliability and safe operation of the primary equipment that underpins the transmission network is dependent on the accurate and timely operation of P&C systems.

Section 3 gives information about our performance in RIIO-T1 to date. It explains how we have driven efficiencies in terms of cost and volume, in particular through our innovative SPAR approach and improved asset information which allows us to make more targeted interventions.

Section 4 establishes the investment need for RIIO-T2, explaining why increased volumes of interventions are necessary to maintain network reliability, due to a combination of factors relating to equipment age and obsolescence. It sets out how we have identified interventions for RIIO-T2 based on our assessment of asset health, and prioritised key assets based on their criticality. We also summarise the drivers of changes to intervention volumes for the different categories of asset.

Section 5 sets out our approach to optioneering and explains how we have identified our preferred approach for RIIO-T2 interventions. It sets out NPV results and wider considerations for each asset sub-type as well as in aggregate, to show that an approach of SPAR interventions (where feasible) and full replacement delivers best value for consumers.

Section 6 sets out why our investment costs are efficient. It shows the process we have gone through to arrive at unit cost estimates and shows how we have embedded innovation from RIIO-T1 to ensure that targeted, low-cost delivery continues in RIIO-T2. Comparison with TNEI benchmarks is made for Feeder Protection and SCS, [redacted]

Section 7 highlights the risks to deliverability of the investment in this paper, and how we will mitigate these. It also describes sources of uncertainty to the cost of this investment package relating to applicability of the SPAR methodology.

9. Appendix A

RIIO-T2 Non-Lead Asset Tables

Equipment Type	AHI	RP	Volume
Feeder Protection	2	2-5	[redacted]
Substation Control Systems (SCS)	2	2-5	[redacted]
Mesh Corner Busbar Protection	2	2-5	[redacted]
Circuit Breaker Fail (CBF): MC & DBB Protection	2	2-5	[redacted]
SGT Protection	2	2-5	[redacted]
Double Busbar Protection	2	2-5	[redacted]
QB Control	2	2-5	[redacted]
Mesh Corner DAR	2	2-5	[redacted]
Operational Tripping Scheme (OTS)	2	2-5	[redacted]
Reactive Equipment MSC	2	2-5	[redacted]
Reactive Equipment SVC	2	2-5	[redacted]
Auto Switching (Auto Close and Hot Standby Units)	2	2-5	[redacted]
Automatic Reactive Switching (ARS)	2	2-5	[redacted]
Automatic Voltage Control (AVC)	2	2-5	[redacted]
Cable SCADA System	2	2-5	[redacted]
Gas Density Monitoring (GDM)	2	2-5	[redacted]
Fault Recorder	2	2-5	[redacted]
Dynamic System Monitoring	2	2-5	[redacted]
Settlement Metering	2	2-5	[redacted]
Back-up Protection	2	2-5	[redacted]
TOTAL			[redacted]

10. Appendix B: Detailed CBA results

<table>
<tr><th>Asset sub-type</th><th>Commentary/rationale</th><th>CBA reference</th></tr>
<tr><td>Feeder protection</td><td>

CBA supports SPAR approach where possible

SPAR possible on [redacted] of the [redacted] circuits as some circuits have auxiliary relays and ancillary equipment that are in poor condition that also require replacement and will therefore not support the SPAR methodology.

RIIO-T1 Comparison: [redacted] SPAR and [redacted] Full Replacements, this equates to [redacted]% SPAR and [redacted]% Full Replacement.
We are therefore proposing to carry out a larger percentage of interventions on Feeder Protection circuits using the SPAR methodology in RIIO-T2 when compared to RIIO-T1.

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>1.500</td><td>15.300</td><td>-6.041</td><td>-6.041</td></tr>
<tr><td>Full Replacement</td><td>75.945</td><td>227.835</td><td>-105.70</td><td>-105.70</td></tr>
<tr><td>Mixed SPAR and Full Replacement</td><td>47.031</td><td>143.108</td><td>-66.523</td><td>-66.523</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA09_Feeder Protection 01
NGET_A9.15_Protection & control_CBA10_Feeder Protection 02</td></tr>
<tr><td>Mesh Corner busbar protection</td><td>

CBA supports SPAR approach over full replacement option.
SPAR possible on all assets.

Use of TP162 contingency planning and targeted replacements to reduce system outage / depletion requirements. This methodology has worked well in RIIO-T1 (for example at Creyke Beck substation) therefore we will build on it for RIIO-T2.

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>0.750</td><td>7.650</td><td>-3.021</td><td>-3.021</td></tr>
<tr><td>Full Replacement</td><td>15.979</td><td>47.937</td><td>-22.239</td><td>-22.239</td></tr>
<tr><td>SPAR</td><td>4.780</td><td>14.792</td><td>-6.848</td><td>-6.848</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA13_Mesh Corner BBP</td></tr>
<tr><td>SGT Protection</td><td>

CBA supports SPAR approach

SPAR is possible on all assets.

Targeted replacements and alignment where possible with primary equipment interventions, especially circuit breakers and bay equipment. Only the obsolete life-expired higher-risk components will be replaced retaining the lower-risk reliable infrastructure (such as fixed wiring).

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>0.750</td><td>7.650</td><td>-3.021</td><td>-3.021</td></tr>
<tr><td>Full Replacement</td><td>53.760</td><td>161.280</td><td>-74.823</td><td>-74.823</td></tr>
<tr><td>SPAR</td><td>35.967</td><td>109.685</td><td>-51.117</td><td>-51.117</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA24_Transformer Protection</td></tr>
</table>

<table>
<tr><th>Asset sub-type</th><th>Commentary/rationale</th><th>CBA reference</th></tr>
<tr><td>Double Busbar Protection</td><td>
Full Replacement only possible on these assets.
Use of TP162 contingency planning to reduce system outage / depletion requirements. This methodology has worked well in RIIO-T1 (for example at [redacted] substation) therefore we will build on it for RIIO-T2.
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>0.750</td><td>7.650</td><td>-3.021</td><td>-3.021</td></tr>
<tr><td>Full Replacement</td><td>37.319</td><td>113.670</td><td>-53.307</td><td>-53.307</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA06_DBB Protection</td></tr>
<tr><td>QB Control</td><td>
Full Replacement only possible on these assets.
Post-delivery Support Agreements (PDSAs) termed Secondary Systems Support Contracts (SSSCs) with Original Equipment Manufacturers (OEMs) are required due to where the complex nature of systems and / or supplier intellectual property rights mean that NGET does not retain the technical expertise to rectify faults for these assets. Targeted (smart) replacements not available from OEMs therefore full replacement is the only viable option.
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>1.250</td><td>12.750</td><td>-5.034</td><td>-5.034</td></tr>
<tr><td>Full Replacement</td><td>21.469</td><td>64.914</td><td>-29.662</td><td>-29.662</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA18_QB Control|</td></tr>
<tr><td>Circuit Breaker Fail (CBF)</td><td>
Full Replacement only possible on these assets.
Full replacement of the CB Fail relays and alignment where possible with primary equipment interventions, especially circuit breakers and bay equipment. Whilst this is classified as a “full replacement,” it is a targeted intervention only replacing the relay and not the wiring and associated infrastructure. In RIIO-T1 CB Fail protection was replaced as part of the full replacement strategy for feeder protection (standard bay solution highlighted in 4.1).
<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>0.125</td><td>1.275</td><td>-0.503</td><td>-0.503</td></tr>
<tr><td>Full Replacement</td><td>9.773</td><td>30.915</td><td>-14.359</td><td>-14.539</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA05_CB Fail Protection</td></tr>
<tr><td>Mesh Corner DAR</td><td>
CBA supports SPAR approach
SPAR is possible in all assets in this category.
Targeted replacements and alignment are planned where possible with primary equipment interventions. Only the obsolete life-expired higher-risk components will be replaced retaining the lower-risk reliable infrastructure (such as fixed wiring).
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>0.750</td><td>7.650</td><td>-3.021</td><td>-3.021</td></tr>
<tr><td>Full Replacement</td><td>60.413</td><td>181.240</td><td>-82.994</td><td>-82.994</td></tr>
<tr><td>SPAR</td><td>31.814</td><td>96.405</td><td>-44.191</td><td>-44.191</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA14_Mesh Corner DAR</td></tr>
<tr><td>Auto Switching (Auto Close and Hot Standby Units)</td><td>
Full Replacement only possible on these assets.
Replacement of relays for auto-switching functions. Part replacement of relays not possible hence full relay replacement is only feasible option. Existing assets unable to have their hardware / software incorporated into modern systems thereby leaving full replacement as the only option.
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>0.025</td><td>0.255</td><td>-0.101</td><td>-0.101</td></tr>
<tr><td>Full Replacement</td><td>0.436</td><td>1.317</td><td>-0.561</td><td>-0.561</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA02_Auto Switching</td></tr>
</table>

<table>
<tr><th>Asset sub-type</th><th>Commentary/rationale</th><th>CBA reference</th></tr>
<tr><td>Operational Tripping Scheme (OTS)</td><td>

Full Replacement only possible on these assets.

Operational intertrips cover not only a single substation or circuit but several substations on a regional basis with centrally located OTS logic units. Changes to the transmission network, including changes due to generation connections / closure and changes by DNOs necessitate whole system interventions rather than targeted interventions. Also, existing assets unable to have their hardware / software incorporated into modern systems thereby leaving full replacement as the only option.
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>0.350</td><td>3.570</td><td>-1.410</td><td>-1.410</td></tr>
<tr><td>Full Replacement</td><td>27.640</td><td>82.920</td><td>-36.942</td><td>-36.942</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA17_OTS</td></tr>
<tr><td>Reactive Equipment; MSC P&C</td><td>

CBA supports SPAR where possible

SPAR technically applicable on [redacted] of the [redacted] units.
Targeted replacement possible only on Protection elements and not feasible on Control elements.
[redacted] units – CBA supports SPAR over full replacement.
[redacted] units – SPAR not feasible. Only option is full replacement.
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>1.500</td><td>15.300</td><td>-6.041</td><td>-6.041</td></tr>
<tr><td>Full Replacement</td><td>57.684</td><td>178.338</td><td>-82.934</td><td>-82.934</td></tr>
<tr><td>Mixed SPAR and Full Replacement</td><td>43.336</td><td>135.294</td><td>-62.964</td><td>-62.964</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA15_MSC P&C 01

NGET_A9.15_Protection & control_CBA16_MSC P&C 02</td></tr>
<tr><td>Reactive Equipment; SVC P&C</td><td>

Full Replacement Only possible on these assets.

Post- delivery Support Agreements (PDSAs) termed Secondary Systems Support Contracts (SSSCs) with Original Equipment Manufacturers (OEMs) where the complex nature of systems and/or supplier intellectual property rights mean that NGET does not retain the technical expertise to rectify faults for these assets. Targeted (smart) replacements not available from OEMs hence full replacement is the only feasible option.

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>1.250</td><td>12.750</td><td>-5.034</td><td>-5.034</td></tr>
<tr><td>Full Replacement</td><td>40.195</td><td>122.147</td><td>-57.335</td><td>-57.335</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA23_SVC P&C</td></tr>
<tr><td>Automatic Reactive Switching</td><td>

Full Replacement only possible on these assets.

Replacement of relays and alignment with SCS works where possible as done in RIIO-T1. Existing assets unable to have their hardware / software incorporated into modern systems thereby leaving full replacement as the only option. SPAR approach not technically possible.
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>0.025</td><td>0.255</td><td>-0.101</td><td>-0.101</td></tr>
<tr><td>Full Replacement</td><td>0.436</td><td>1.317</td><td>-0.561</td><td>-0.561</td></tr>
</table>

</td><td>NGET_A9.15_Protection & control_CBA02_Auto Switching</td></tr>
</table>

<table>
<tr><th>Asset sub-type</th><th>Commentary/rationale</th><th>CBA reference</th></tr>
<tr><td>Automatic Voltage Control (AVC)</td><td>Full Replacement only possible on these assets.

Replacement of relays and alignment with SCS works where possible as done in RIIO-T1. Existing assets unable to have their hardware / software incorporated into modern systems thereby leaving full replacement as the only option. SPAR approach not feasible.

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>0.010</td><td>0.102</td><td>-0.040</td><td>-0.040</td></tr>
<tr><td>Full Replacement</td><td>0.201</td><td>0.603</td><td>-0.280</td><td>-0.280</td></tr>
</table></td><td>NGET_A9.15_Protection & control_CBA03_AVC</td></tr>
<tr><td>Cable SCADA System</td><td>Full Replacement only possible on these assets

Replacements of the SCADA system on the [redacted], [redacted], [redacted] and [redacted] cable tunnel systems. SPAR approach not possible. The existing cable systems (along with associated alarms, controls and protection) are very specific to the OEM design and any intervention to the cable SCADA system would need to fully integrate with the exiting cable system fully.
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>0.075</td><td>0.765</td><td>-0.302</td><td>-0.302</td></tr>
<tr><td>Full Replacement</td><td>20.000</td><td>60.000</td><td>-27.836</td><td>-27.836</td></tr>
</table></td><td>NGET_A9.15_Protection & control_CBA19_SCADA</td></tr>
<tr><td>Gas Density Monitoring (GDM)</td><td>Full Replacement only possible on these assets

Replacement of SF6 gas density monitoring equipment available from suppliers. SPAR methodology not feasible.

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>0.015</td><td>0.153</td><td>-0.060</td><td>-0.060</td></tr>
<tr><td>Full Replacement</td><td>0.511</td><td>1.647</td><td>-0.775</td><td>-0.775</td></tr>
</table></td><td>NGET_A9.15_Protection & control_CBA11_Gas Density Monitoring</td></tr>
<tr><td>Fault Recorder</td><td>Full Replacement only possible on these assets.

Replacement of fault recording equipment at identified substations. SPAR methodology not feasible as necessary equipment is not available from suppliers.
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>0.010</td><td>0.102</td><td>-0.040</td><td>-0.040</td></tr>
<tr><td>Full Replacement</td><td>2.350</td><td>9.870</td><td>-4.681</td><td>-4.681</td></tr>
</table></td><td>NGET_A9.15_Protection & control_CBA08_Fault Recorders</td></tr>
<tr><td>Dynamic System Monitoring (DSM)</td><td>Full Replacement only possible on these assets.
SPAR methodology not feasible as existing assets unable to have their hardware / software incorporated into modern systems thereby leaving full replacement as the only option
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>0.250</td><td>2.550</td><td>-1.007</td><td>-1.007</td></tr>
<tr><td>Full Replacement</td><td>27.523</td><td>84.848</td><td>-39.112</td><td>-39.112</td></tr>
</table></td><td>NGET_A9.15_Protection & control_CBA07_DSM</td></tr>
<tr><td>Settlement Metering</td><td>Full replacement only possible on these assets

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>0.050</td><td>0.510</td><td>-0.201</td><td>-0.201</td></tr>
<tr><td>Full Replacement</td><td>12.100</td><td>36.300</td><td>-16.841</td><td>-16.841</td></tr>
</table></td><td>NGET_A9.15_Protection & control_CBA22_Settlement Metering</td></tr>
</table>

<table>
<tr><th>Asset sub-type</th><th>Commentary/rationale</th><th>CBA reference</th></tr>
<tr><td>Back-up Protection</td><td>Full Replacement only possible on these assets

Full replacement of the Back-up protection relays and alignment where possible with primary equipment interventions, especially circuit breakers and bay equipment. Whilst this is classified as a “full replacement,” it is a targeted intervention only replacing the relay and not the wiring and associated infrastructure. In RIIO-T1 Back-up protection was replaced as part of the full replacement strategy for feeder protection (standard bay solution highlighted in 4.1).

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>0.005</td><td>0.051</td><td>-0.020</td><td>-0.020</td></tr>
<tr><td>Full Replacement</td><td>3.007</td><td>19.749</td><td>-9.640</td><td>-9.640</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA04_Backup Protection</td></tr>
<tr><td>Substation Control System (SCS)</td><td>CBA supports SPAR where possible

Upgrades possible on [redacted] of [redacted] control systems. Upgrade / refurbishment packages available from only some of the OEMs and SSSC providers thereby leaving full replacement as only feasible option for these.

[redacted] sites – CBA supports SPAR over full replacement.
[redacted] sites – SPAR approach not feasible. Only option is full replacement.
This equates to [redacted]% Refurbishment and [redacted]% Full Replacement.

RIIO-T1 Comparison: [redacted] SPAR and [redacted] Full Replacements, this equates to [redacted]% Refurbishment and [redacted]% Full Replacement.
There is a larger proportion of full replacement interventions in RIIO-T2 when compared to RIIO-T1 because of obsolescence becoming more prevalent. OEMs have informed us that they no longer carry any replacement spare parts nor offer fixes / repairs for some of the existing assets.
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>1.50</td><td>15.30</td><td>-6.04</td><td>-6.04</td></tr>
<tr><td>Full Replacement</td><td>177.642</td><td>537.952</td><td>-249.199</td><td>-249.199</td></tr>
<tr><td>Mixed SPAR and Full Replacement</td><td>115.532</td><td>357.606</td><td>-165.247</td><td>165.247</td></tr>
</table>
</td><td>NGET_A9.15_Protection & control_CBA20_SCS Replacement

NGET_A9.15_Protection & control_CBA21_SCS Upgrade and Refurb</td></tr>
</table>