Investment Decision Pack

A9.07 – Underground Cables

December 2019

As a part of the NGET Business Plan Submission

nationalgrid

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Engineering Justification Paper; Non-Load Related Underground Cables			
Asset Family	Underground Cables		
Primary Investment Driver	Monetised Risk and Asset Performance		
Reference	A9.07		
Output Asset Types	Transmission (Lead) Underground Cables (PITS-WIBA-TEMP - 275kV XLPE Cable) For London Power Tunnels Two please refer to A9.19 For Dinorwig-Pentir Cable please refer to A9.8 Substation (Non- Lead) Underground Cables (3.3kV-132kV Cable)		
Total Cost T2 schemes proposal	£78.5m		
Delivery Year(s)	2021-2026		
Reporting Table	C2.2A		
Outputs included in RIIO T1 Business Plan	Yes		
Spend Apportionment (T2 schemes proposal)	**T1**	**T2**	**T3**
	£2.221m	£75.456m	£0.849m
Completion of T1 schemes		£8.010m	
Development schemes for T3		£5.797m	
Total	£2.221m	£89.256m	£0.849m

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1. EXECUTIVE SUMMARY

This report justifies the T2 asset replacement plan for Underground Cables at a total cost of £78.5m. The cables have been separated into the following:

- Transmission underground cable (Lead) total value of £39.94m – these typically operate at 275kV & 400kV and connect our electricity infrastructure to high voltage substations and demand centres
- Substation underground cable (Non-Lead) total value of £37.08m – these typically operate at lower voltages (≤132kV) and provide links within substations
- Sheath Voltage Limiters (SVL) Portfolio (Non-Lead) total value of £1.477m – SVLs are a critical part of a cable system, helping to manage sheath voltages to acceptable levels.

This report excludes London Power Tunnels 2 (refer to A9.19 for further information) and Dinorwig-Pentir (A9.8 for further information).

Cables are a key component of our electricity transmission system. With many of the cables installed over 40 years ago, over time cables can degrade leading to a reduction in performance and availability. If no intervention action is taken on the aging cables, they are at greater risk of failure leading to systems outages, unavailability (including Energy Not Supplied events), safety incidents and increased maintenance costs.

To date in RIIO-T1, we are embedding innovative solutions to bring about consumer benefits and efficiencies in how we prioritise projects in need of intervention. Thus, we have reduced the volumes forecasted for RIIO-T2 through T1 delivery and but more specifically due to project deferrals from T1 to T3 as we have identified a number of projects that are no longer anticipated to require the initially planned intervention in RIIO-T1.

Our approach to estimating RIIO-T2 intervention volumes ensures that the key stakeholder requirements of maintaining current levels of network risk at the least cost are met, thereby driving longer term benefits for consumers. Our T2 plan is based on the output of both Monetised Risk Methodology (for Transmission cables), plus Asset Health Index, Criticality and Replacement Priority (for Substation cables), and is aimed at targeting the most critical and at-risk assets. Overall, a monetised risk approach shows that an asset replacement plan during T2 leads to a decrease in the residual risk position compared to that at the end of T1 for Transmission cables. This results from the small number of interventions and their comparatively large impact on network risk when considering against other asset classes. For substation cables, the Asset Replacement Priorities highlight that the resin-filled and MIND cables represent much of the cables that have been targeted for replacement in RIIO-T2.

Due to the small volume of large assets making up the Underground Cables portfolio, unit cost performance comparison is challenging due to the bespoke nature of the projects. The individual costs vary significantly depending upon the project characteristics, for example; tunnelling needs, location, consenting expectations impacting upon the final costs. As such the use of a tunnel in LPT2 highlights a higher unit cost per volume at £6.9m compared to the Pitsmoor-Wincobank-Templeborough circuit outlined in this paper (£[redacted]m/cctkm). For Substation cable interventions, while the volume has increased by [redacted] km against that forecast during RIIO-T1, the unit cost per circuit km [redacted] compared to our T1 forecast.

We are confident that our intervention plan represents value for money for consumers and customers. Our costs for RIIO-T2 projects have been built up based on our current understanding of the interventions we expect to make during the period, which draws on the knowledge and experience of our team and project experiences of investments such as London Power Tunnels 1.

2. INTRODUCTION

Underground cabling is one of two options for connecting electricity infrastructure including power stations, High Voltage (HV) substations, and demand centres. The other option being Overhead Lines (OHL).

Although underground cabling is on average more expensive than OHL per kilometre, they have the advantage of reduced visual impact for areas where OHLs are not appropriate or cannot get access (e.g. urban areas, river crossings and subsea applications). This makes underground cabling a good solution for conservation areas, green spaces, and densely populated areas such as central London, where space is at a premium.

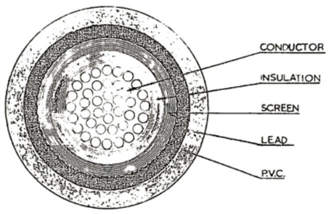
Underground cables are divided into two categories; Transmission underground (or Lead) Cables and Substation underground (or Non-Lead) Cables. National Grid owns and operates around 1200km of High Voltage Alternating Current (HVAC) cables at voltages from 3.3kV to 400kV. We have [redacted] km of transmission cables on the network with an average age of 30.4 years.

Substation cables typically operate at voltages of 132kV or lower and provide links within substations where busbars or OHLs are not suitable. These cable systems are typically shorter than 1km in length.

High Voltage Cable Types

High Voltage cables consist of three major components: conductor, insulation and protective jacket. Cables are mainly distinguished by their insulation type with the 3 main technology types are the subject of this report (Table 1):

Table 1: Overview of cable technology type

Type	Description	Diagram
Mass Impregnated Non-Draining (MIND)	• Paper insulation wrapped around a central conductor, impregnated with viscous resin-based compounds • Largely obsolete technology • Utilised by NGET up to 66kV • Installed 1952-1992	
Fluid Filled Cable (FFC)	• Paper insulation saturated with low viscosity oil fed from pressurised tanks via an oil duct • Mature technology in used at all voltages • Support reducing worldwide as market moves towards XLPE • Installed 1952-2006	
Cross-Linked Polyethylene (XLPE)	• Extruded polyethylene (plastic) insulation surrounding a conductor (aluminium or copper) • Mature technology and used at all NGET transmission voltages • Installed 1990-present	

Many of National Grid's existing underground cable routes were installed over 50 years ago, when the main cable technology was both MIND and fluid filled cables. Over time this outer sheath can degrade, leading to a risk of oil-filled cables leaking oil into cable ducts and the surrounding soil.

Modern cables are typically XLPE technology except for where specific technical or installation requirements require a different technology (e.g. HVDC connections or fault repairs).

Sheath Voltage Limiters (SVL) are a critical part of a cable system, helping to manage sheath voltages to acceptable levels. They act to protect the cable in a similar operation to serge arresters. Four circuits have been identified where the current SVL design/arrangement are not sufficient to meet the requirements of the cable. This is largely due to changes in network topology and how the network is used by the ESO, these are addressed as part of this investment, see Section 6 for further details

3. RIIO-T1 VOLUME AND PERFORMANCE

3.1 T1 Performance

Table 2 summarises the cables replacements carried out in RIIO-T1 by displaying the total volumes delivered (forecasted till the end of RIIO-T1) and the total cost of each category which compares them to the T1 Allowance[1]. The RIIO T1 allowance for Cables includes both Lead and Non-Lead cables.

Table 2: Summary of volumes and costs of Cables assets in RIIO-T1

		T1 Allowance	T1 Actuals	T1 Forecast	T1 (all years)	Annual average
Lead Cables & Tunnels	Cable Total cost (£m)	773.9	187.1	132.7	319.8	40.0
	Tunnel Total Cost (£m)	459.4	241.4	104.9	346.3	43.0
	Total volume (km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Non-Lead Cables	Total cost (£m)	44.9	9.6	0	9.6	1.2
	Total volume(km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

**note rounding on all numbers*

3.1.1 T1 Performance – Transmission cables

We are on track to meet Network Output Measures (NOMs) as set at T1. At the time of our RIIO-T2 submission, the forecast volume of Transmission underground cables in T1 is [redacted] km (against an allowance was [redacted] km). We have delivered transmission underground cable schemes on average over the RIIO-T1 period [redacted] per km (£[redacted]m per km) than our T1 allowance (£[redacted] per km). This has been in part due to external market forces, and in part due to delivery efficiencies in schemes, such as; efficient delivery of complex construction programmes in schemes like London Power Tunnels 1, design efficiencies in Manchester cable replacements, and installation efficiencies on the Beddington-Rowdown circuit. This is expanded upon later in this section.

Our cable asset management and increased understanding of asset condition during the RIIO-T1 period has also enabled deferral of some asset interventions beyond the price control period. Developments include:

- The implementation of Perfluorocarbon Tracer (PFT) tagging and research into tape corrosion has enabled oil leaks to be more easily traced and managed.
- Improved understanding of asset deterioration, enabling assets to be managed rather than replaced.

In RIIO-T1, we will therefore be delivering four major transmission cable replacements; (1) London Power Tunnels 1, (2) Beddington- Rowdown, (3) Bredbury - South Manchester and (4) elements of the Bustleholm – Nechells circuit (Nechells -Witton). Barring the Beddington-Rowdown circuit, the remaining three projects will have some remaining spend that will cross-over to the first year of T2 (further information can be found in Appendix A).

In our RIIO-T1 submission we had planned for a number of other cable replacements to be delivered. However, during this period we have not witnessed the anticipated asset deterioration to warrant the previously planned interventions in T1 to uphold reliability or environmental standards. The deferred cable routes are: (1) Cowley-Minety & Cowley-Walham, (2) Ffestiniog-Trawsfynydd and (3) Sheffield Ring (excluding the Pitsmoor-Wincobank-Templeborough circuit) and have been deferred to RIIO-T3 and beyond (see Appendix C for further details on cable project deferrals). We continue to monitor the health of these circuits, with a view to fix any faults that occur rather than replace the whole route.

[1] The original T1 allowance for Lead and Non-Lead Cable was £1,278m, following an allowance deferral, the revised T1 allowance for this category is £937m. For presentation purposes, the original allowance has been presented.

As summarised earlier in this section, the two main drivers behind our T1 performance are; efficiencies in delivery, and external market factors. Overall, we therefore forecast to deliver our T1 cable plan for lower than our allowance.

Delivery Efficiencies:

- London Power Tunnels 1 – through a proactive risk mitigation strategy and control of multiple interfaces we efficiently delivered the complex construction programme.
- Manchester Cables – design efficiencies identified during the development phase, led to the replacement of existing parallel cables with a single higher rated cable thus reducing the need for additional civil works.
- Beddington-Rowdown – we realised installation efficiencies through sharing the existing Croydon Tunnel and using computational fluid dynamic modelling to minimise ventilation requirements for the project.

Deferrals – External Market Factors:

- Sheffield Ring Cables (excluding PITS-WIBA-TEMPS) – The heavy steel industry in the Sheffield area has closed or been consolidated since the Sheffield ring regional transmission network was initially designed. As the majority of cable circuits in the Sheffield Ring have not deteriorated as fast as we initially anticipated at the beginning of RIIO- T1, this affords the opportunity to consider the appropriate regional network strategy. We are considering whether the existing network configuration remains the most appropriate when considering future electricity demand requirements and continue to work with the Distribution Network Operator (DNO) to consider the most efficient solution for the area. Though the overall route will not be replaced, we have identified that the PITS-WIBA-TEMP circuit required intervention in the T2 period regardless of the final Sheffield ring strategy. Sections of this circuit have been identified as at risk of erosion and subsidence due to their location within a railway embankment. This circuit therefore requires intervention and forms part of our T2 replacement strategy.
- Birmingham Cables (excluding Nechells-Witton) – The original strategy highlighted a load related driver to uprate the Bustleholm-Nechells route from 275kV to 400kV. This load-related driver is no longer required. However, the condition of the Nechells- Witton section of the cable (a subsection of the overall project) means that it requires intervention and will be replaced in RIIO-T1 to mitigate this risk.

3.1.2 T1 Performance – Substation cables

We will deliver [redacted] km of substation cables in the RIIO-T1 period, and as mentioned in Section 3.1.1 above, some of our planned substation cable assets have not deteriorated as fast as anticipated.

4. INVESTMENT NEED

4.1 Investment Drivers

Feedback from our stakeholder engagement highlighted that consumers and customers want us to maintain network risk at current levels at the least cost across RIIO-T2 period; in the absence of appropriate levels of intervention, the level of residual network risk would increase over the period of RIIO-T2. Cables are typically made up of a small number of high-value assets with location-specific installation and environmental concerns, which make predicting the cost of cable projects challenging. Optimal replacement of these assets requires careful consideration of deliverability in addition to the more technical considerations around asset condition and performance.

The RIIO-T2 plan for Transmission and Substation Underground Cables considers the activities required to address reliability and safety concerns associated with cable systems. If no action is taken on the identified cables for intervention, then these systems are at risk of further deterioration, potentially leading to failure and resulting in system outages (and potential Energy Not Supplied events), safety and environmental incidents, and/ or increased maintenance costs. National Grid's strategy for RIIO-T2 is to undertake planned replacements in line with stakeholder feedback on cable assets to maintain levels of network reliability.

Cable replacements for RIIO-T2 to achieve this have been determined using two different methodologies;

- The Monetised Risk methodology for Transmission (Lead) Cable Assets
- Asset Health Index, Criticality and Replacement Priority for Substation (Non-Lead) Cable Assets

4.2 Approach to Establishing Intervention Need

We assess the need for intervention on an asset-by-asset basis. The key considerations feeding into our assessment are set out below for each asset type.

4.2.1 Overview

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 two approaches evident in our business plan.

Failure likelihood may simply be expressed as a probability up to 100% (or 1). This is the case for our Lead assets such as Transmission Cables. A proxy for probability of failure is used in the form of a scoring system - the Asset Health Index (AHI) for other assets termed 'Non-Lead' such as protection & control or substation cables. This scoring system, which places assets into discrete bands of '1' to '4' 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 and forming the basis of the Network Asset Risk Metric (NARM), achieves a greater level of maturity than the Criticality approach that preceded it. It does this in several ways:

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 Criticality approach produces a lower resolution measure and doesn't allow for prioritisation within those bands.
2. By monetising the consequences of asset failure, it is possible to measure whole network risk and enable decision making between different asset classes. The 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. several transformers in Replacement Priority '1' is equal to some volume of cables in the same or different replacement priority bands). This impedes any network-wide measure of risk and prioritisation between asset classes.

The two approaches are summarised in Table 3 below:

Table 3: Summary of NARMs approach for identifying interventions

Principle	**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 (Substation / Non-Lead cables)	Scores assets per their health. AHI1 to AHI4	Each asset is scored per 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 (Transmission / Lead cables)	Each asset has a probability of failure. This probability is arrived at by use of an 'End of Life Modifier'. This is a score that maps an asset to a place on a probability of failure plot, specific to each asset class.	For each asset failure event, there may be safety, system and environmental consequences- these 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. The monetised risk of asset failure can be aggregated to give us a whole network measure of risk and allows us to make prioritisation decisions between different assets.

Figure 1: EOL modifier principle

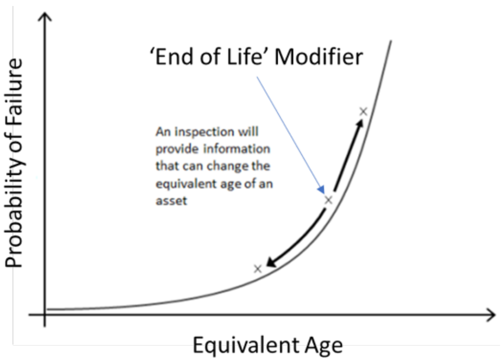


Figure 1 illustrates the principle of the End of Life Modifier. The rise in monetised risk is governed by an asset's probability of failure plot, the magnitude of the risk at any given point in time is a function of the probability of failure (variable) and the probability of an event with a monetised consequence (fixed).

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.

4.2.2 Approach for Transmission Cables

Transmission Underground cables use the monetised risk approach to determining intervention requirements. The key factors considered when determining the need to replace a cable, in addition to asset age, are the risks associated with known failure modes, historical performance, environmental and safety factors and forensic evidence.

The understanding of cable asset condition is constrained by the limited available condition information due to the inability to easily access these predominantly buried assets. While forensic investigations are conducted on selected circuits following decommissioning or diversion, it is not thought beneficial to take samples from otherwise healthy cables to assess levels of deterioration as this intervention is more likely to introduce failure mechanisms than inform condition knowledge.

Apart from the relatively few known failure modes (tape corrosion and lead sheath deterioration) MIND and fluid filled cables are generally reliable. MIND, fluid filled and XLPE (solid dielectric) cable types will only meet the replacement criteria where refurbishment (such as joint breakdowns and rebuilds, replacement of link boxes etc.) will not address condition and performance issues.

4.2.2.1 Cable Monetised Risk During RIIO-T2

As noted in Section 4.1, stakeholders want us to maintain the current level of risk across our network and the assets detailed in this report directly influence the reliability and security of supply of the network. By delivering on the planned replacements, National Grid will continue to maintain risks at the current levels.

Figure 2 shows the impact on monetised risk positions for Cables if no replacements were carried out during T2.

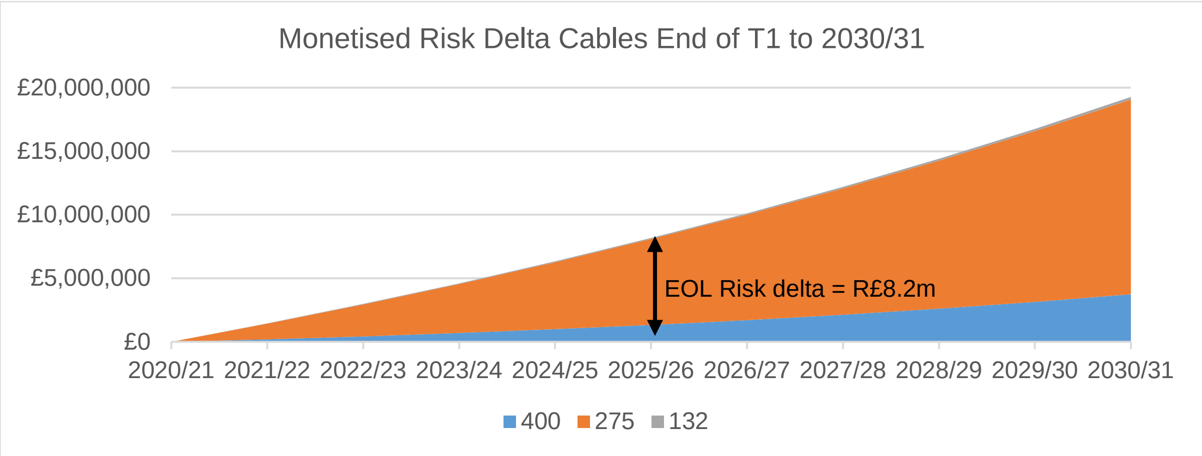


Figure 2: Monetised Risk position for cables with no T2 Interventions

The initial monetised risk output for Lead Cables selected the replacement of all three South London Circuits associated with LPT2 ((1) Wimbledon-New Cross, (2) New Cross-Hurst and (3) Hurst-Littlebrook) as these circuits are classified as having some of the highest risk 'deltas' on the network between the beginning and end of T2. It is not possible to replace all three circuits in T2 due to the length of the construction programme, only two circuits are therefore planned for delivery in T2 ((1) Wimbledon -New Cross 1&2, and (3) Hurst-Littlebrook 1&2 – see Appendix C, whilst the (2) Hurst-New Cross circuit will be delivered in T3). For London Power Tunnels Two RIIO-T2 intervention plan please refer to A9.19.

Though the Dinowig-Pentir circuit was not identified as a circuit for replacement initially, their criticality, deterioration and alignment to substation works required them to be included in the intervention list. For the Dinorwig-Pentir Cable RIIO-T2 intervention plan please refer to A9.8.

Further to the above, the Pitsmoor-Wincobank-Templeborough (PITS-WIBA-TEMP) 275kV cable route (consisting of 3 cables circuits) has been included in the plan for RIIO-T2. This circuit has a failure mode that has not been modelled in the monetised risk approach - subsidence of the ground around the installation. Due to the nature of this failure mode (civils failures are not factored into monetised risk approach), and the fact that failure would likely be without warning, these circuits have been included in our plan. The risks associated with the existing cable route are detailed in Section 5 of this report.

For the reasons explained, the inclusion of the PITS-WIBA-TEMP route will not significantly reduce risk impact as modelled by the monetised risk process. However, Figure 3 below shows that the monetised risk impact of our RIIO-T2 plan will reduce residual network risk below the RIIO-T1 close out position. This is expected, given the significant impact a small number of interventions will have on a relatively small volume of large assets.

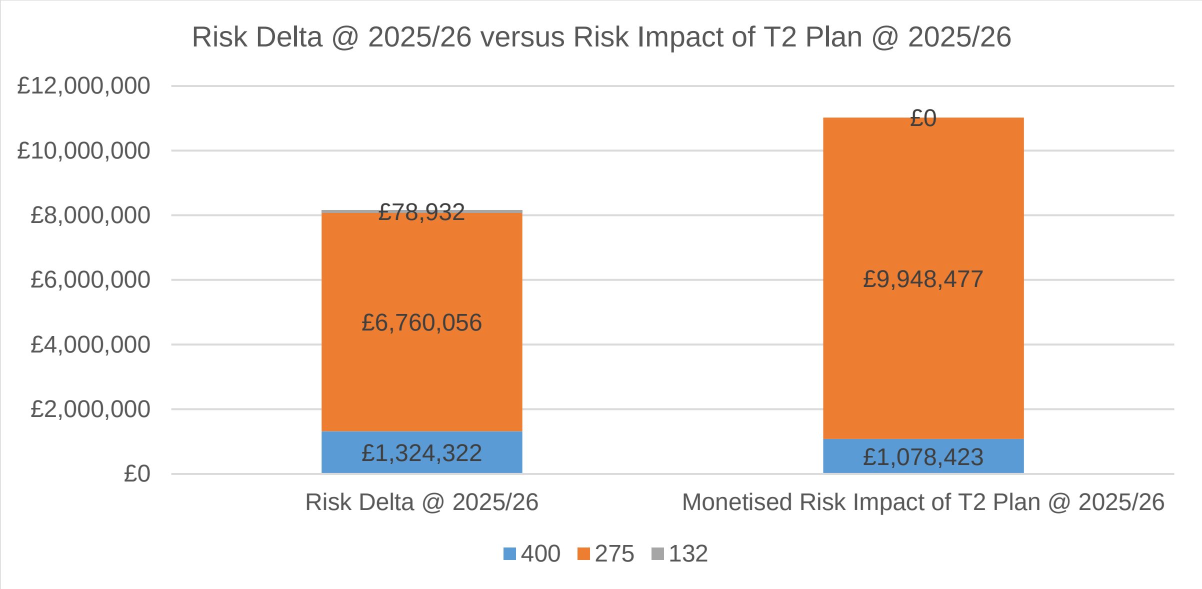


Figure 3: Risk mitigation from RIIO-T2 interventions versus increase in unconstrained network risk

4.2.3 Approaches for Substation Cables

The RIIO-T2 plan for substation cables utilises the Asset Health Index (AHI) to define our replacement priorities. In RIIO-T1 we moved from a ‘replace on age’ to ‘replacement priority’ approach. Each cable was assigned an AHI based on condition assessment and service experience. A Criticality Score, based on the impact of failure or unreliability from a safety, system and environmental perspective was derived for the associated substation assets. The cables were then assigned a Replacement Priority (RP) which is used to prioritise actual interventions (Table 4 below).

Table 4: Substation Cable Replacement Priorities Assignment Matrix

Criticality	Very High	High	Medium	Low
AHI				
1	0-2	0-2	2-5	2-5
2	5-10	5-10	5-10	10+
3	10+	10+	10+	10+
4	10+	10+	10+	10+

Factors considered when determining the need to replace Non-Lead Cables are like Lead Cables (age, risks associated with known failure modes, defects, environmental and safety factors and forensic evidence). However, as there is less detailed information available (than for transmission cables), replacement is mainly determined by age and historical asset performance.

Most cables planned for replacement in RIIO-T2 have reached or are approaching (average age of 53 years), the end of their anticipated asset life. Cable circuits have been prioritised for replacement in RIIO-T2 based on the factors driving AHI, such as known family condition, asset performance and age. Many of the substation cable families have known failure modes or have long been out of manufacture, and the insulation technologies that they employ (Mass impregnated Non-Draining (MIND), Solid, Hessian) are now obsolete.

The Replacement Priorities for the Substation cables, disaggregated by cable type, are shown in the chart below (Figure 4). The resin-filled MIND cables represent the majority of the cables that are in the poorest condition and it is primarily these that have been targeted for replacement in RIIO-T2 (see Appendix C for a specific list of assets for replacement in RIIO-T2).

[redacted]

Figure 4: Substation Cable Replacement Priorities

In some types of cable, including hessian wrapped and some resin filled MIND insulated cables, we are beginning to identify cable issues related to quality at the time of manufacture. These manifest in the loss of integrity of the outer protective layers, and in some cases failures of the lead outer sheaths (see Figure 5 of compromised hessian cable). A further principal deterioration mechanism that we are witnessing within our asset portfolio is tape corrosion.

Figure 5: shows a compromised Hessian outer sheath [redacted]

Our RIIO-T2 strategy is to focus on Substation cables with; known poor health, where repair is costly, and where failure occurrences have an unacceptable impact on our customers and on network reliability.

In the Optioneering section below, we show how we have arrived at an optimised selection of replacements across our Cables that mitigate the risks.

5. OPTIONEERING

To determine the optimal mix of interventions to make the Transmission and Substation Cable asset, a Cost Benefit Analysis (CBA) was undertaken. We have analysed CBA output for each of the options together with a wider technical and stakeholder justification for the work proposed to be undertaken. Detail of the analysis and our outcome is presented below.

5.1 Approach to Estimating Cost and Benefits

5.1.1 Summary of Overall Approach

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

1. Firstly, we have **identified potential intervention strategies** for Transmission and Substation Cables separately. This identified several intervention strategies which were then tested for feasibility/applicability. They include a 'Do Minimum' option for both Cables assets. 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. Once the set of feasible options for Cables has been established, we combine these into **packages of options**. Quantitative **Cost Benefit Analysis (CBA)** is carried out on these options packages to identify the most cost effective.
3. For the most cost-effective option, deliverability and cost efficiencies are considered to ensure that the optimal solution has been planned.

We have included Investment Costs and Monetised Network Risk into our quantitative CBA, using the NPV calculation approach in the Ofgem template to arrive at an NPV estimate for each of the options packages. For substation cables, we have not quantified wider societal benefits for each options package. Whilst these factors are important to our business, their minor impact on the overall costs of the investment package means that we address societal impacts qualitatively in the analysis below.

Each asset type will have a different approach and options for intervention, so we have conducted optioneering assessment for each of the asset sub types separately.

5.2 Potential Intervention Strategies

5.2.1 Transmission (Lead) Cables

Three Transmission Cable circuits were considered for replacement within RIIO-T2.

1. London Power Tunnels 2 (Circuit 1: Wimbledon-New Cross 1&2 and Circuit 2: Littlebrook-Hurst 1&2),
2. Pitsmoor-Wincobank-Templeborough; and
3. Dinorwig- Pentir.

The replacement strategy and options for London Power Tunnels and Dinorwig-Pentir Cable routes are covered in Justification report A9.19 (London Power Tunnels 2) and A9.8 (Dinorwig-Pentir cables) respectively.

The Pitsmoor–Wincobank-Templeborough circuit is addressed in this paper. The background and list of options (Table 5) are considered for this cable circuit are outlined below.

Pitsmoor-Wincobank-Templeborough

The cable route (Figure 6) Pitsmoor (PITS) - Templeborough (TEMP), Pitsmoor - Wincobank (WIBA) and Wincobank - Templeborough was commissioned in 1968 and is over 51 years old. These assets for part of the Sheffield 275kV Ring.

1. Pitsmoor (PITS) – Templeborough (TEMP) 275kV circuit
2. Pitsmoor (PITS) – Wincobank (WIBA) 275kV circuit
3. Wincobank (WIBA) – Templeborough (TEMP) 275kV circuit

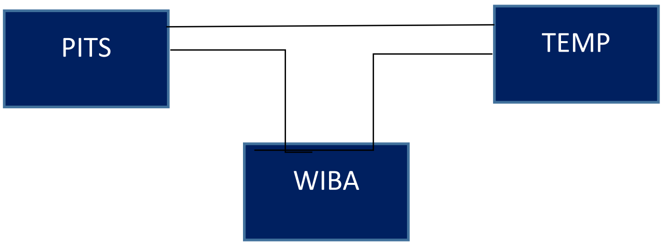


Figure 6: Pitsmoor-Wincobank-Templeborough 275kV cable route

Though the monetised risk methodology indicates these circuits do not require replacement until RIIO-T3, large sections of the circuits are located within a railway embankment which is known to be affected by erosion and is unstable with significant risk of subsidence. Along this embankment, the neighbouring distribution network cable troughs have collapsed (which have already been decommissioned and relocated). Due to the steep slope, reinforcing the embankment would cause a significant engineering challenge, plus the busy neighbouring railway would require closure for a substantial duration while reinforcement work is undertaken. The embankment is not owned by National Grid and the bank is likely to continue to move. The cable troughs are at risk of subsidence making it necessary to replace these circuits in RIIO-T2 - earlier than our monetised risk model suggests. Such civil failures are not factored into the monetised risk model.

[redacted]

The Sheffield Ring circuits were originally planned to be replaced within RIIO-T1, however the introduction of PFT tagging has enabled the replacement of these circuits to be deferred to T3 because oil leaks can be identified and repaired, delaying their need for replacement. For the PITS–WIBA–TEMP section however, cable monitoring of the bank stability was undertaken to ensure economic and efficient spend. Following this assessment and further condition concerns being identified (see below), a detailed optioneering assessment was completed during T1 to establish the most appropriate intervention strategy.

Figure 7: Bulging cable showing damage to cable sheath

Secondary factors closely monitored, were the condition of the cables within the two cable bridges that cross over a canal and a river. Here, damage to the cable lead sheaths is clearly visible (Figure 7). The oversheath is bulging under the mass of oil occupying the void between the lead and the oversheath. Additionally, the bridges are in poor condition and will require replacement. Loss of oil into the water system could cause a significant environmental event also.

Table 5: Summary of Cable intervention options for Pitsmoor - Wincobank - Templeborough

<table>
<tr><th>Option</th><th>Detail</th></tr>
<tr><td>BASELINE: Do Minimum</td><td>Under this option there are no planned intervention during RIIO-T2, and we will continue to complete standard maintenance as per National Grid policy requirements.

This is not a viable option because there are several severe implications to not mitigating the risks, including:
a) the failure of cable system due subsidence (possibly leading to loss of supply and oil leaks);
b) polluting the river and canal; and
c) safety of the public, due to subsidence of the embankment onto the railway.

Additionally, continuing to maintain this route means high operating costs (around £100k per annum which is based on the 10-year average of maintenance/defect repair costs for maintaining these circuits) and emergency repairs until the cable fails or is replaced. While it is possible the bank will hold until the next regulatory period, this is not certain, and the consequences of significant movement may affect both circuits (PITS–WIBA, PITS–TEMP).

If the extreme happened, it is estimated the present routes would need to be abandoned at short notice and new routes agreed. In addition, the costs of repairs to restore supplies to customers will be much higher than a planned replacement.</td></tr>
<tr><td>1. Rationalised Replacement, A single new circuit route between Pitsmoor – Wincobank – Templeborough

(PREFERRED)</td><td>All three existing circuits are Fluid Filled Cables (FFC).

This solution proposes to rationalise the network by decommissioning and removing the PITS–TEMP circuit, and replacing the existing fluid filled cable on the PITS–WIBA and WIBA–TEMP circuits with XLPE cables along a new route.

Once the new XLPE PITS–WIBA and WIBA–TEMP circuits are commissioned, the redundant fluid filled cables can be removed.

This solution also reduces the cable replacement from a total of [redacted] cct-km to [redacted] cct-km (by rationalising 3 circuits to 2), benefiting from both reduced expenditure and duration on the construction programme. The XLPE cable replacement would be a new ducted route which eliminates the risk of damage from subsidence of the railway embankment, the cable bridges and potential environmental issues (via oil leak).

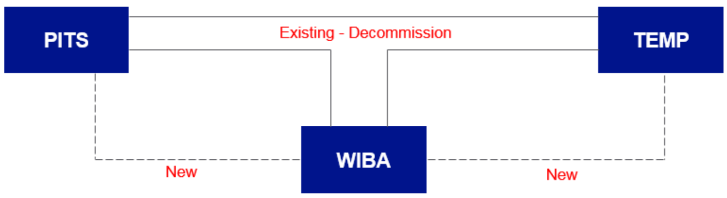
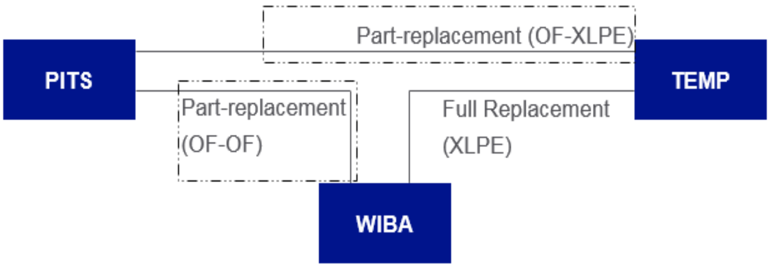


Figure 8: PITS-WIBA and WIBA-TEMP Cable Replacement (New Route)</td></tr>
<tr><td>2. Full Replacement</td><td>The full replacement of (1) PITS–TEMP, (2) PITS–WIBA and (3) WIBA–TEMP with XLPE cable.

This option is a [redacted] cct-km full replacement of the existing cable route. It removes all the risks associated with the current route .i.e. environmental, civils risks etc.; however, the length of the route and the location introduces new risks. The area is heavily congested, the route is highly complex (urban route with crossings required over a railway and motorway)</td></tr>
</table>

	with multiple stakeholder involvement. This may lead to long delays and issues with constructability.
3. *Target Replacement (Oil Filled/XLPE)*	Option 3 is the replacement of high-risk areas which have a mixture of oil filled cables and XLPE (refer to Fig. 9), with targeted replacement at the railway embankment and cable bridge locations. There are a limited number of oil-filled cable manufactures, each with lead times of c.2 years, which would likely delay the construction and increase the risk of failure. Technical feasibility related to jointing oil filled to XLPE cable remains an issue and my not be feasible due to space constrains. Replacing with new oil filled cables means the environmental risk of oil leakage into the waterways remains. The remaining cable sections not replaced will require replacement in approximately 5 – 10 years' time too  *Figure 9: Targeted replacement, Oil filled and XLPE*
4. *Target Replacement (XLPE)*	This option is similar to Option 3. However, only replacing oil filled cable with XLPE in high priority areas. The technical feasibility of connecting new XLPE cable to the existing oil filled cables are also unknown. The cost of hybrid joint bays and space is substantial compared to full replacement. Furthermore, additional space would be required for oil tanks and ancillary equipment.

5.2.2 Substation Cables

The list of options to be considered for Substation Cable intervention is summarised in Table 6 below:

Table 6: Summary of Substation Cable intervention options

Options	**Detail**
BASELINE: Do Minimum: replace on failure	Under this option, the planned replacement of substation cables would stop and allow them to fail in service. Under the "Do Minimum" option, all substation cable replacements would be carried out as emergency replacements. Whilst the maximum lifetime of these assets is uncertain, fix-on-fail is not a valid strategy. Fix-on-fail would increase transmission network risk (where our stakeholders have stated they want us to maintain it at least cost), as there would be limited control over when replacements would occur (outages could not be planned). Many of these cables serve customers, such as Network Rail, Steelworks, and DNOs, and so circuit reliability is important. Allowing for failure in-service would restrict customers from operating and could have a wider economic impact on society. It could also introduce significant system risk with increasing volumes of demand being supplied from depleted networks. This strategy could also lead to Energy Not Supplied

	events. It is therefore incompatible with National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS). Whilst it is true that most of a cable system is underground and therefore doesn't pose significant safety risk, it is possible that unplanned failures could impact the safety of operational staff should the faults affect the integrity of cable sealing ends (CSE) in substations. Collateral damage to adjoining substation components is also possible. Under a 'Do Minimum' option, to support an anticipated rise in, in-service failures, the strategic spares holding would need to be increased to manage emergency and unplanned replacements. As noted, many of the cable technologies installed are long out of manufacture, resulting in a full cable replacement in such circumstances. In addition, delivery would not be efficient, as the replacement work could not be planned with enough lead time to develop the most economical and efficient delivery strategy and scope. This would be resource intensive and not cost effective.
1. Replace on poor condition	Under this option, the plan is to replace [redacted]km of Substation Cable circuits in RIIO-T2. This replacement plan is based on the Asset Health Index and Replacement Priority of substation cables. Cable circuits prioritised for replacement in RIIO-T2 are based on the factors driving AHI, such as known family condition asset performance and age. This allows for efficient planned replacement, enabling the annual outage programme to be optimised both with the System Operator and customers. This option also allows lead times for the procurement of cable to be factored into the delivery programme. Partial replacement has not been considered as an option for substation cables because of the short cable lengths involved (typically a few hundred metres), therefore, making it more economical to replace the whole cable. In addition, many of the existing cable technologies are no longer manufactured and jointing old and new cable technologies is complex and often not feasible due to space constraints. Furthermore, there is limited availability of spares for some of the existing cable technologies which have long been out of manufacture. Single phase replacement of cables has not been considered because disturbing the cables to replace a single phase is likely to disturb and damage adjacent cable phases.

5.3 Detailed Analysis and CBA

To determine the optimum interventions for the above Cable options in RIIO-T2 a detailed CBA was completed for the Lead (Transmission) and Non-Lead (Substation) Cable portfolios.

5.3.1 Transmission Cables: PITS-WIBA-TEMP

All 4 options were considered for the CBA. The selected option following the CBA was 'Option 1: Rationalised Replacement'. Excluding the 'Do Minimum' Option, which is not considered a viable option to progress, all other options would result in the replacement of circuits within their respective options by 2023, therefore the driving factor is capital cost. The 'Rationalised Replacement' option reduces the circuit kilometres of cable to be replaced, and in turn reduces the kilometres of cables to be maintained (from three circuits to two). Table 7 below provides a summary of all the options considered to manage the Pitsmoor-Wincobank-Templeborough route.

For Lead assets, such as Transmission cables, as well as the direct costs of investment, the NPV also accounts for:

- Changes in Monetised Risk because of interventions (benefits vs Do Minimum baseline, shown separately in tables below)
- Societal benefits from reduced oil leakage where applicable (versus Do Minimum baseline, incorporated within NPV)
- Avoided costs that would have been incurred by the transmission operator such as constraint charges driven by the System Operator
- Safety impacts: preventative measures captured within investment costs, benefits versus Do Minimum baseline captured in NPV

Table 7: CBA Summary for Pitsmoor-Wincobank-Templeborough

	Baseline	**Option 1 (Preferred)**	**Option 2**	**Option 3**	**Option 4**
Option	Do Minimum	Rationalised Replacement	Full Replacement	Target Replacement (Oil Filled/XLPE)	Target Replacement (XLPE within oil)
Cost (£m)	£40.72m	£39.94m	64.7m	£47.02m	£61.0m
T2 Circuit Length (cct km)	0	[redacted]	[redacted]	[redacted]	[redacted]
Total NPV	(37.48)	(35.09)	(55.09)	(39.79)	(51.93)
Investment in T2 (£m un-disc)	0.392	37.74	37.86	27.25	35.64
Total Investment cost	40.72	39.94	64.70	47.02	61.00
Monetised risk (disc £m)	0	13. 29	13.29	0	0
Total NPV (disc. £m)	-37. 48	-35.09	-55.09	-39.79	-51.93
NPV inc. monetised risk (£m)	**-37.48**	**-21.800**	**-41.800**	**-39.79**	**-51.93**
NPV ranking	**N/A**	**1**	**3**	**2**	**4**
Key options assumptions	No intervention in T2, only cable maintenance. Rationalised cable replacement in 2031, (please see assumptions detailed in Option1 for rationale cable replacement)	Approx. [redacted] XLPE cable is to be installed between PITS-WIBA and WIBA-TEMP through an urban area. It is assumed the cables are installed in ducts and CSE's are to be replaced at all three sites. The existing [redacted] cable route is to be decommissioned. This includes removing two cable bridges.	Approx. [redacted] XLPE cable is to be installed replacement between PITS-WIBA, PITS-TEMP, and TEMP-WIBA, through an urban area. It is assumed the cables are installed in ducts and CSE's are to be replaced at all three sites. The existing [redacted] cable route is to be decommissioned. This includes removing two cable bridges.	[redacted] of XLPE cable is installed between TEMP-WIBA. Approx. [redacted] of oil filled cable is to be installed between PITS-WIBA within ducts. Approx. x[redacted] of XLPE is to be installed between PITS-TEMP within ducts. This new section of XLPE will required 1 transition joint, to join to the remaining section of existing oil cable left insitu. Approx. [redacted] km of oil filled cable will be decommissioned.	[redacted] km of XLPE cable is installed between TEMP-WIBA. Approx. [redacted] of XLPE cable is to be installed between PITS-WIBA within ducts. This new section of XLPE will required 1 transition joint, to join to the existing oil cable. Approx. x[redacted] of XLPE is to be installed between PITS-TEMP within ducts. This new section of XLPE will required 1 transition joint, to join to the existing oil cable. Approx. [redacted] of oil filled cable will be decommissioned.
Key Risks		**<u>CHOSEN OPTION</u>**	Construction risks due to long,	Oil filled cable lead times long	XLPE/Oil transition joints may not be

	Subsidence of embankment leading to cable failure and loss of supply Significant oil leaks into local waterway due to cable failures	Construction risks due to complex urban route. Removes both embankment stability and environmental risks.	complex urban route and number of crossings Removes both embankment stability and environmental risk.	Introduces more oil filled assets onto the network This option will not fully address the asset condition of the full-route	viable on the canal towpath This option will not fully address the asset condition of the full-route

Considering all the options, a rationalised circuit replacement plan is the preferred option as the most cost-effective solution which removes significant construction challenges. To assess the feasibility of this option we have worked closely with Northern Power Grid (the local Distribution Network Owner) to understand their requirements and forecasted future demand growth. We will continue to engage with Northern Power Grid as we develop this option further, in the context of any wider Sheffield Ring development, to ensure it meets with their requirements, as this option is sensitive to growth in customer demand.

5.3.2 Substation Cables

The preferred option selected for Non-Lead Cables is 'Replacement on Poor Condition', the alternative option 'Replacement on Failure' is not considered a viable option because it would result in putting customer demand at risk and lead to higher replacement costs under emergency conditions. In addition, 'Replacement on Failure' would not meet the Stakeholder feedback we have received, regarding the maintenance of the same level of network risk during RIIO-T2. Table 8 provides a summary of Non-Lead Cable interventions for RIIO-T2.

For Non-Lead assets (Substation cables), the NPV is based on direct investment costs and assumes one demand loss event associated with a cable failure while an adjacent Super Grid Transformer (SGT) on the same site is out of service due to major maintenance for replacement.

Table 8: CBA Summary for Substation Cables

	Baseline	**Option 1**
Option	Do Minimum (Replace on Fail)	Replace on Poor Condition
T2 investment cost (£m, undisc)	54.13	36.25
Cost (£m)	57.55	37.08
NPV (£m, disc)	-58.07	-31.16
Circuit Length (km)	[redacted] km	[redacted] km
Total NPV	**£58.07m**	**£31.16m**
NPV ranking	2	1
Key option assumptions	• [redacted] km (30%) of substation cables planned for replacement in RIIO-T2 fail in-service due to condition • Replacement costs are 20% higher costs under an emergency scenario. • An additional [redacted] km of cable is held as strategic stock to enable quick replacement of failed cables. • One cable failure leads to a demand loss event due to a cable failure occurring while an adjacent SGT/cable on the same site is out of service due to major maintenance or replacement.	• This option assumes like for like replacement of substation cables identified as at risk of significant unreliability based on age and condition
Key risks	• Failure of cable in-service leading to a loss of supply event • Environmental event as a result of a cable fault leading to the realise of oil into the ground	• Securing site access and system access at customer sites to enable cable replacements • Identification of suitable cable routes in already congested substations

6. ASSESSMENT OF COST EFFICIENCY

The costs and volumes in our RIIO-T2 plan (as well as those in RIIO-T1) are set out in Table 9 below:

Table 9: Comparison lead and non-lead cable interventions for the RIIO T1 and RIIO-T2 periods

						RIIO-T2	RIIO-T1		RIIO-T2
		T1 Allowance	T1 Actuals	T1 Forecast	T1 (all years)	T2 forecast	Annual average	Annual av (first 6 years)	Annual average
Lead Cables & Tunnels	Cable Total cost (£m)	773.9	187.1	132.7	319.8	[redacted]	40.0	31.2	[redacted]
	Tunnel Total cost (£m)	459.4	241.4	104.9	346.3	[redacted]	43.3	40.2	[redacted]
	Total volume (km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Non-Lead Cables	Total cost (£m)	44.9	9.6	0.0	9.6	[redacted]	1.2	1.6	7.3
	Total volume(km)	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	Cost per unit volume	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: Table includes forecast for LPT2 and Dinowig-Pentir and have been rounded for presentation purposes. For specific numbers, see papers A9.08 and A9.18.

Overall the planned volume of Transmission Cable interventions in RIIO-T2 is [redacted] km lower than in RIIO-T1. The unit costs for T2 projects are higher than T1 unit costs, however, unit cost comparison across cable installations is challenging due to the bespoke nature of these projects (see Section 6.2 for further information). In RIIO-T2 the cost per unit volume [redacted] to £[redacted]m per km against the forecast £[redacted]m per km in RIIO-T1 – [redacted] (see Table 9). Specifically, for the PITS-WIBA-TEMP transmission cable circuit discussed in this paper, the forecast cost in the RIIO-T2 period is £[redacted]m /km – this is outlined further in Section 6.2 below.

For Substation cable interventions in RIIO-T2, there is a greater emphasis for replacement which sees [redacted] while the forecast unit cost has reduced by a third from T1 forecast (Table 9). This is further explained in the sections below.

**Table 10: Cost breakdown by asset type, from total cost forecasts in per Table 9*

Projects	Amount £ m
Pitsmoor – Wincobank - Templeborough	[redacted]
Substation cables	[redacted]
Sheath Voltage Limiters (SVL)	1.48
T1 projects with T2 cost (Appendix A)	8.00
T3 projects with T2 cost (Appendix B)	5.80
Total forecast for A9.07	**89.26**

Table 10 provides the breakdown of the Total Cable forecast from Table 9. Of the £361.1m, £89.26m is associated with; the PITS-WIBA-TEMP transmission cable circuit investment, substation cable investments, cable sheath voltage limiter investments and other T2 costs associated with T1 and T3 cable circuit delivery (see Appendix A and B for more information). In addition, Table 10 outlines the Transmission Cables (Δ) that contribute to the total cost outlined in Table 9.

There are [redacted] circuits currently identified where SVLs are failing at rates far more than that expected. SVLs are a sacrificial component that protect the cable from sheath over voltages. Extensive investigative has been carried out into the root causes of these high failure rates and mitigation identified. Of the [redacted] circuits, only [redacted] will remain in service after T2 and as such the investment here is to address these issues on these 4 circuits. The mitigation is likely to be a replacement of all SVLs in the circuit with a higher rated design and/or installation of wound Voltage Transformers at the circuits ends.

6.1 RIIO-T2 Volumes

For **Transmission Cables** the key driver for a reduction in volumes during RIIO-T2 are due to a large cable volume being replaced in RIIO-T1, largely associated with LPT1. In addition, volumes in T2 are lower due to the deferral to T3 of some cables during T1 that have not demonstrated the deterioration that was initially anticipated during the period (as mentioned in Section 3.1, and further information is provided in Appendix B on each deferral).

The deferrals are a result of improvements in asset management techniques and the employment of PFT tagging that has enabled us to locate and address oil leaks with greater ease and expedience, allowing repair rather than replacements to take place. This has enabled some cable projects which were originally planned for replacement in RIIO-T1, to now be deferred to T3 and beyond as per their latest condition assessments. These circuits include (1) the Sheffield Ring (excluding PITS-WIBA-TEMP), (2) Iver-North Hyde and (3) Fawley –Lovedean / Fawley-Botley Wood (Appendix B provides information on all T1 deferred projects).

Asset interventions such as the Dinorwig-Pentir circuit have been brought forward for replacement in RIIO-T2 (due to the system criticality and the high cost of circuit outages) by aligning it to work being carried out in T2. Intervention on the Beddington-Rowdown circuit was bought forward to T1 because its condition deteriorated faster than anticipated.

For **Substation Cables** the key driver behind an increase in volume is the age and obsolescence of these assets. The cable insulation technologies are now obsolete making refurbishment and repair un-viable, impacting short and long-term reliability of the network. During T1 there were several substation cable projects that had an unplanned impact on the network:

- During a MIND cable repair, the existing cable in Templeborough SGT1A suffered further damage during the necessary movement to enable the repair. This increased cost and repair time to fix the issue, as the cable had to be cut back further, with more spare cable utilised.
- We no longer have strategic spares stock of ‘MIND’ cable and the cables are now obsolete, with repairs now requiring a transition joint to XLPE. In RIIO-T1 we observed lead sheath crystallisation during the repair of these cables. This resulted in a brittle outer sheath to the cable, meaning any further movement to the cable can cause further damage. This is compounded by the need to repair using the XLPE transition joints, which require space and movement of the existing brittle cable. In these instances, outages were extended from those planned, at critical network supply points, using extra unplanned specialist contractor resource to fix the cable and restore supply.

6.2 RIIO-T2 Unit Cost

6.2.1 Unit cost – Transmission Cables

Due to the nature of the portfolio, being made up of a small volume of large assets, unit cost comparison is difficult and arguably not a good measure of cost performance for cable assets, mainly driven by the bespoke nature of the projects. The individual costs vary significantly depending upon the project characteristics for instance, whether tunnelling is needed, the location of the project, whether significant consenting is expected are amongst some examples of how costs can vary amongst these types of projects and ultimately the final cost.

Table 11: Cost per unit volume by Transmission Cable RIIO-T2 projects

Cable Project Spend only	Total	T2 Volume On (km)	Cost per unit volume (£m)
Dinorwig-Pentir Cables	[redacted]	[redacted]	[redacted]
London Power Tunnels Phase 2 (excluding tunneling)	[redacted]	[redacted]	[redacted]
PITS-WIBA-TEMP	[redacted]	[redacted]	[redacted]

Table 11 above highlights the cost per unit by projects, we can deduce that the costs are mainly driven from LPT2 and associated tunnel costs (not included in Table 11 but highlighted in Table 9). The routes planned in T2 are complex and challenging and are without existing civil infrastructure (increasing the comparative cost of replacement) – this makes comparison of per unit costs between T1 and T2 misleading and need to be considered on a case-by-case basis. In addition, the unit cost for RIIO-T1 is not reflective of the full costs for the volume of cable delivered as a large proportion (circa. £500m) of spend occurred on some of these assets in the previous regulatory period. However, Table 11 demonstrates that, even without this consideration, the per-unit cable costs (excluding tunnels) are lower for all planned T2 Transmission Cable interventions than the average per-unit cost forecast throughout the T1 period (Table 9).

To ensure best value for cable replacements, minimum cost solutions have been explored, for example, through DNO engagement and understanding future demand scenarios. Thus, we have been able to rationalise the PIT-WIBA-TEMP route rather than undertake a like-for-like replacement – this demonstrates savings from a whole system approach. In addition, a whole system approach has been considered for LPT2 with the inclusion of Bengeworth road providing the best solution for both customers and consumers (please refer to A9.19 for further information).

More detailed information on the cost build up and costs benchmarking can be found in LPT2 (A9.19) and Dinorwig-Pentir (A9.8) Justification Reports. Most of our planned investment over the T2 period is associated with London Power Tunnels 2 (in South London); the main tunnelling work is currently out to tender, and we will be letting contracts and starting work in the T1 period.

For PIT-WIBA-TEMP the preferred option has been reviewed to ensure it proposes the most efficient cost to meet the investment driver. Simple cost per unit length analysis for cable projects can distract from the fact that each circuit solution is bespoke and highly dependent on scope, e.g. whether the cable is direct-buried or in a new or existing tunnel, and physical location.

6.2.2 Unit cost – Substation Cables

For Substation Cables the overall costs for RIIO-T2 are lower than T1 allowances. Commercial efficiencies in contracting and investment bundling developed in RIIO-T1 have been embedded in the cost estimates for RIIO-T2 cable replacements. The cost estimate for substation cables is built up using historical costs, based on incurred costs for substation cable replacements in the T1 period. The requested unit costs for the T2 period are lower than the realised unit costs for the T1 period.

6.3 Benchmarking

As mentioned in Section 6.2, like for like comparison is difficult to do for bespoke projects such as these, as a number of factors can determine the final costs. We have, attempted to benchmark this investment following the normalisation of internal and external data to compare the overall cost of the Transmission and Substation cable projects, the sections below set out the analysis.

6.3.1 Benchmarking – PIT-WIBA-TEMP

[redacted]

[redacted]

7. KEY ASSUMPTIONS, RISK AND CONTINGENCY

The key assumptions, risks and uncertainties which will affect RIIO-T2 volumes and costs are set out below:

7.1 Assumptions

Cost Estimation - The cost forecast is made up of a small number of high value projects (majority of which is associated with LPT2). The cost estimation for these investments in some cases has been made prior to surveys being carried out. As these projects go through the development and delivery process the cost forecasts could vary and this could impact the overall RIIO-T2 cost forecast we learn more definitive information about the project becomes available.

Most of our planned investment over the T2 period is associated with London Power Tunnels 2 (in South London); the main tunnelling work is currently out to tender, and we will be letting contracts and starting work in the T1 period. Our current cost estimates have taken account of detailed learning from the London Power Tunnels 1 project (in North London) which was similar in scope and as we further develop the costs, they should become firmer.

Transmission Network Access - Asset failure or faults on the transmission or distribution network may affect the availability of resource or outages. Delays or cancellation of outages may result in under-delivery of cable replacements as they can require comparatively long outages compared to other equipment. In addition, most substation cables planned for replacement are located at Grid Supply Point (GSP) substations and replacement of these assets may be affected by works on the DNO system or other unplanned work at the substation.

Early engagement with the DNOs is anticipated so works can be optimised, and increasingly collaborative ways of working can be explored.

Stakeholders - For each investment, engagement will be required with stakeholders to ensure that the scheme balances their requirements with that of an economic solution. Stakeholders will be different depending on scheme specifics but include local authorities, landowners, and residents close to project. Overall, our stakeholders have told us that they want us to retain a reliable transmission network and our cable replacement plans are a key element of this.

7.1 Risks

7.1.1 PITS -WIBA -TEMP specific risks

- DNOs do not see any restrictions from their perspective for the proposed rationalisation of the PIT-WIBA-TEMP circuits in this paper. If restrictions, such as demand recovery, are seen by the DNO, full replacement of the circuits will be required.
- It is assumed a rationalised network solution for the Pitsmoor-Wincobank-Templeborough circuit is feasible, and forecast expenditure is reflected as such. However, if a rationalised network solution is not possible then forecast expenditure would need to be revised. At which point, any advancements in developing a solution for the wider Sheffield ring should be considered in re-defining the optimum solution for the Pitsmoor-Wincobank-Templeborough circuit in the context of this wider regional (Sheffield Ring) development.
- To replace these cables a new cable route will need to be found through a build-up urban area, detailed surveys are yet to be completed so it is assumed a viable route can be found and the necessary easements obtained.

7.1.2 Substation Cable specific risks

- It is assumed that where an in-situ replacement is not possible a viable alternative route of a similar length can be found across the substation.
- The plan replacements will be coordinated with National Grid, DNO and work at customer sites. It is assumed that suitable access is available during RIIO-T2 to enable the planned cable replacements.

8. CONCLUSION

This report provides justification for our RIIO-T2 Transmission Cables (Lead Asset) replacement plan, based on a monetised risk approach at a total of £78.5m over a 5-year T2 period.

Section 3 provides the summary of our cost and volumes performance at RIIO-T1. Which shows we will replace broadly the allocated cable lengths and achieve to spend against our T1 allowances. Which have been realised through the implementation of innovative solutions such as PFT tagging, which has allowed the deferral of cable replacement to a later period as they may have not deteriorated at the rate initially expected.

Section 4 sets out the investment need for RIIO-T2, covering investment drivers and our approach to identify where interventions are required based on the NARMs methodology for Lead asset, and Asset Health Index, Criticality and Replacement Priority for Non-Lead assets. The monetised risk methodology, engineering judgement and asset specific knowledge has been used to make asset replacement and investment decisions for cables. This shows that the asset replacement plan leads to a decrease in monetised risk for cables, in comparison to a no intervention approach.

Section 5 sets out the Cost Benefit Analysis which utilises the options identified in Section 4 which identified that for Cables the proposed Option to take forward was Option 1 'Rationalised Replacement' and for Substation Cable was Option 1 'Replace on Poor Condition'. These options have been identified as the most economic and efficient plan to maintain network reliability as per the request via stakeholder feedback.

Section 6 explains that the unit costs for the RIIO-T2 Cable projects vary and therefore the comparison between T1 and T2 unit costs are not a like for like comparison of efficiencies due to the bespoke nature of each project. For Non-Lead substation cable interventions, while the volume has increased by [redacted]km, the unit cost remains comparable to our T1 forecast. This section also includes benchmarking (internal and external) analysis on project basis and highlights our project costs are below similar projects and therefore creating consumer value.

Section 7 identifies the potential risks to the deliverability of the proposed investments and how we propose to mitigate these.

Appendix A - RIIO T1 to RIIO T2 Delivery Crossover

All schemes listed in the Table 13 below are nearing completion, with the remaining spend within the first year of T2 and spend has been included into this report.

Table 12: Planned RIIO T1 Cables Scheme Expenditure

RIIO T1 Scheme	T2 Forecast Spend	Justification
(1) BRED - SMAN Cable Replacement	£[redacted]m	Programmed delivery at the end of RIIO T1 with closure spend in T2
(2) BUST - NECH Cable Replacement	£[redacted]m	Programmed delivery for beginning T2, with closure spend in T2.
(3) London Power Tunnels 1 Cable Decommissioning	£[redacted]m	Programmed delivery at the end of RIIO T1 delivery with closure spend in T2

The complexity of the urban environments has provided design challenges on both the Bredbury - South Manchester and Bustleholm - Nechells circuits. In turn, programmed float has been absorbed, pushing spend into the first year of T2.

London Power Tunnels 1 Cables Decommissioning of old cables is intrinsically linked to the commissioning of London Power Tunnels 1 (LPT1). LPT1 has now been fully commissioned, allowing decommissioning of old cables to be undertaken. Spend in T2 reflects the final stages of the extensive London Power Tunnels capital programme, successfully delivered in T1.

Appendix B - RIIO T1 Deferred Projects to T3

This list has been redacted

Appendix B - RIIO T1 Deferred Projects to T3 and Beyond

RIIO-T1 Projects	Deferrals to RIIO-T3 and beyond (as per RRP 18/19)
(1) Sheffield Ring (excluding PITS-WIN-TEMP) Replacement Priority: 5-10 and 10+ (various cables)	Original T1 strategy was for a like-for-like replacement. Due to changes within the local area, this configuration is no longer appropriate. We are engaging with the DNO to consider best action and therefore has been deferred. Whilst our monetised risk approach does not indicate any replacement in RIIO-T2 in the Sheffield Ring, specific intervention is proposed on the Pitsmore -Wincobank – Templeborough circuits due to subsidence of the railway embankment in which they are situated.
(2) Cowley-Minety and Cowley-Walham circuits Replacement Priority: 10+	We were due to deliver in T1; however, their conditions have not deteriorated to a point where they are anticipated to have significant reliability or environmental issues. Will continue to monitor the health with a view to fix faults rather than replace the whole cable route.
(3) Ffestiniog-Trawsfynydd circuit Replacement Priority: 10+	We were due to deliver in T1; however, their conditions have not deteriorated to a point where they are anticipated to have significant reliability or environmental issues. Will continue to monitor the health with a view to fix faults rather than replace the whole cable route.
A few long lead time cable routes, planned for delivery in RIIO-T2, were forecast to incur development expenditure in RIIO-T1. These routes have not seen their condition deteriorate to a point where we forecast significant reliability or environment issues, which has delayed the planned cable replacement and removed the need for development spend in RIIO-T1. These were related to the following cable projects: (4) Iver-North Hyde (development cost deferral) (5) Fawley-Lovedean and Fawley-Botley Wood (development cost deferral) (6) Grangetown-Lackenby (development cost deferral) (7) Ealing-Laleham-Willesdon (development cost deferral)	

Appendix C - RIIO-T2 Lead Asset Tables (Cables)

EoL Score	Description
98-100	Definite evidence exists of a serious problem with the cable which covers a significant portion of the cable or is distributed along the route. The problem has been identified and it is considered that it will lead to an unacceptable condition in a relatively short period of time (within 10 years, due to the long lead times associated with cable replacement schemes, particularly if there is a requirement for tunnelling). This unacceptable condition is likely to lead to cable failure. No cost-effective repair method is available, refurbishment would not address the problem and replacement is therefore the most economic solution.
55-98	Evidence exists of a problem with the cable, possibly with a specific section that is particularly problematic. The cable system would be expected to deteriorate to Priority 1 within 5 years.
21-55	Cable known to have faults or defects – some of which could cause failure. May be a known issue with the cable family.
0-21	Good condition - no known specific or general life limiting problems with the cable.

[redacted]

Appendix C - RIIO-T2 Non-Lead Asset Tables (Cables)

Non-lead	AHI1	AHI2	AHI3	AHI4
66kV	0	3	0	0
33kV	1	9	0	0
25kV	1	0	0	0
13kV	0	15	0	0

Asset	Voltage (kV)	Length (km)	AHI	RP
Aldwarke SGT4 Cable	33	[redacted]	1	0-2
Poppleton SGT2B cable	25	[redacted]	1	0-2
Aldwarke SGT1A Cable	33	[redacted]	2	5-10
Aldwarke SGT2 Cable	33	[redacted]	2	5-10
Bustleholm Shunt reactor 4 cable 1	13	[redacted]	2	5-10
Bustleholm Shunt Reactor 4 cable 2	13	[redacted]	2	5-10
Elland Shunt Reactor 2 cable	13	[redacted]	2	5-10
Exeter SGT4 cable	13	[redacted]	2	5-10
Exeter Sync. Comp. cable A	13	[redacted]	2	5-10
Exeter Sync. Comp. cable B	13	[redacted]	2	5-10
Fleet Shunt Reactor 3a cable	13	[redacted]	2	5-10
Hackney SGT1 cable	66	[redacted]	2	5-10
Hackney SGT2 cable	66	[redacted]	2	5-10
Iver SGT5A Shunt Reactor cable	13	[redacted]	2	5-10
Iver SGT6B Shunt Reactor cable	13	[redacted]	2	5-10
Kearsley Shunt Reactor 3A cable	13	[redacted]	2	5-10
Kingsnorth Shunt Reactor 1 cable	13	[redacted]	2	5-10
Lackenby SGT3 cable	66	[redacted]	2	5-10
Macclesfield SGT1 cable	33	[redacted]	2	5-10
Macclesfield SGT2 cable	33	[redacted]	2	5-10
Pelham Shunt Reactor 1 cable	13	[redacted]	2	5-10
Sheffield City SGT2 cable	33	[redacted]	2	5-10
St Johns Wood SGT11A cable	13	[redacted]	2	5-10
St Johns Wood SGT2A Neutral cable	33	[redacted]	2	5-10
St Johns Wood SGT3A Neutral cable	33	[redacted]	2	5-10
St Johns Wood SGT4A Neutral cable	33	[redacted]	2	5-10
Stanah SGT1 ET cable	33	[redacted]	2	5-10
West Boldon Shunt Com 1 cable	13	[redacted]	2	5-10
Willesden SGT3B Tertiary cable	13	[redacted]	2	5-10

** Certain non-lead cable length data are not available. Assumed a nominal length of [redacted] m for purposes of determining EoL modifier; highlighted above.*