Investment Decision Pack

A9.10 – Substation Other and Other TO equipment

As a part of the NGET Business Plan Submission

Engineering Justification Paper; Non-Load Related Substation Other and Other TO Equipment - C2.22 HV Asset Repair & Maintenance, C2.24 Legal and Safety and C2.2a Capex			
Name of Scheme	Substation Other and Other TO Equipment - C2.22 HV Asset Repair & Maintenance and C2.24 Legal and Safety and C2.2a Capex		
Primary Investment Driver	Asset Health (Non-Lead Assets)		
Reference	A9.10 Substation Other and Other TO Equipment		
Output Asset Types	• Civils • 'Non-Civils' substation and circuits equipment including emergency, unplanned replacement • Portable Specialist Tools • Productive Work Environment		
Cost	£209.2m		
Delivery Year(s)	2021-2026		
Reporting Table	C2.22, C2.24 and C2.2a		
Outputs included in T1 Business Plan	No		
Spend Apportionment	**T1**	**T2**	**T3**
	£0m	£209.2m	£0m

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1. Executive Summary

This paper outlines a capex spend totalling £209.2m for management of our substation, cable and overhead line assets. The activities included here relate to the planned and unplanned rectification of defects, faults and failures that fall outside of the scope of normal maintenance or major refurbishment and replacement activities, as well as refurbishment to prevent further deterioration. We also plan to develop our asset management systems further during the T2 period which will enable improved tracking and targeting of the work done on discrete secondary assets on the transmission network.

The investments in this paper maintain reliability through minor capex to enable the primary plant to perform its function. These activities remain distinct from and are complementary to those covered by the specific asset justification papers, which are primarily concerned with major replacement and refurbishment activity to manage end-of-life risk.

The scope of this spend encompasses the civil infrastructure that underpins our high voltage and auxiliary assets. It also includes the auxiliary assets themselves such as the air systems, marshalling kiosks, support insulators and cooling systems that enable the function of our primary transmission plant. The scope further extends to our primary plant too, with budgets for component replacements (e.g. bushings and tap changers), repairs (e.g. leaks) and complete replacement of assets in an emergency. Additionally, this paper covers costs for the enablement of our field force, through the provision of specialist portable tools (PFSA) and through investment in a productive work environment (PWE) for our field force.

The primary driver for these interventions is the reporting of asset condition and/or poor performance through our 'Plant Status' process. The input is generated from routine inspections ranging from weekly tests of air system equipment to maintenance inspections of switchgear and transformers spanning intervals of multiple years. In-service faults also trigger interventions, where a permanent solution is required to a temporary repair or if a repair has not been possible.

From stakeholder feedback we have started from a position of maintaining the level of investment seen annually in the last 5 years of T1 into T2. We have then adjusted the spend between activity areas to incorporate our current understanding of Plant Status issues and those we predict will arise during T2. Table 1 below sets out the T2 spend in these 4 activity areas compared to T1. Overall spend in T2 is approximately the same (0.12% lower than T1) but there is an increase in work allocated to civil assets. This reflects the ageing infrastructure of our substations and the number and nature of issues reported by our field force.

Spend £m	Total T1	T1 Last 5 Years (2017-2021)	Total T2	Difference	% Change
Plant Status (Civils)	£115.44	£66.99	[redacted]	[redacted]	[redacted]
Plant Status (Excl. Civils)	£152.01	£109.99	[redacted]	[redacted]	[redacted]
PFSA	£15.40	£8.01	[redacted]	[redacted]	[redacted]
PWE	£25.36	£24.42	[redacted]	[redacted]	[redacted]
Substation Other & Other TO Equipment Total	**£308.20**	**£209.42**	**£209.16**	**-£0.25**	**-0.12%**

Table 1 – Comparison between T1 expenditure (5yr) and T2 expenditure

Note that spend related to LVAC distribution boards, diesel generators and batteries is covered in a separate justification paper "Substation Auxiliary Systems".

2. Introduction

As described in other justification papers the National Grid electricity transmission system is made up of substations, overhead lines and cable assets that deliver the basic functionality of a transmission network. Items such as transformers, switchgear, cables, protection equipment and LV supplies all form part of a typical substation. The safe and reliable functioning of transmission assets relies upon the provision of a range of non-electrical infrastructure and services which are replicated across the transmission system and which, for the purposes of this investment paper, are sub-divided into the following 4 categories:

2.1 Civils

This category refers to the built-environment within which our assets reside and within which our people work. It includes buildings (both asset housings and working spaces), roadways & access provisions, support structures for assets and environmental management activities such as oil containment. For T2 we have also included a specific provision for civil asset condition assessment that will facilitate improved understanding & management of our civil assets, principally substation support structures such as plinths and A-Frames/ Gantries.

2.2 Non-civils

This category refers to non-civil activities undertaken within the general environment of a substation, cable or overhead line to ensure safe & reliable asset performance and to maintain a safe working environment that poses no safety risks to people, other assets or the environment.

Non-civils for substations

For substations, this includes asbestos management, non-refurbishment SF6 leak repairs, air/oil system renewal, renewal of switchgear auxiliary equipment (cabinets and enclosures), renewal of transformer auxiliary equipment (fans, pumps, coolers, radiators etc) and transformer oil reclamation. It also includes activities driven by our responses to asset issues through our Operational Engineering & Safety Bulletin (OESB) process.

Non-civils for cables and overhead lines

For cables and overhead lines, this includes cable joint bay repair and renewal, cable oil leak reduction, repair of overhead line fittings and equipment (e.g. tower step-bolts), integrity management of overhead line signage and access prevention, and delivery of relevant OESB activities.

2.3 Portable and Free Standing Assets (PFSA)

This category refers to the provision and management of equipment for maintaining, surveying and monitoring a wide range of assets safely. This includes equipment dedicated to protection & telecommunications, cables, circuit-breakers, batteries, tunnel monitoring, SF6 management and substation safety equipment.

2.4 Productive Work Environment (PWE)

This category covers renewal of the working accommodation for our people at our substation sites where these fall short of required standards in order to maximise productivity. This includes improvement to welfare facilities, furniture, walls, floors, changes required to allow compliance with display screen equipment requirements and provision of female and disabled toilets on every site.

We also implement designs that create a collaborative culture on sites by assisting in changing behaviours and making it easier for staff to work together. Alongside this we are always looking to make best use of the operational estate through efficiencies such as multiple occupancy and purpose use of buildings.

3. Background and T1 Overview

Our intervention strategies in the various areas described above continue to be linked to the capabilities of our asset systems and the needs of the asset category.

We undertake periodic inspections (see section 3.2) to identify developing and immediate issues which are recorded and planned for intervention via our defect reporting and 'Plant Status' (section 3.1) processes. This approach is appropriate for interventions upon asset families where deterioration is generally slow and readily detected by inspections, and where interventions can be planned without undue constraints or delays. Repairs to civil assets such as building roofs and roadways, fall into this category.

However, we have identified that the management of civil infrastructure will be improved by creating a higher resolution inventory of assets in our core data system. This applies primarily to structures that support high voltage assets in substations e.g. circuit breaker plinths, overhead gantries and A-frames. We have planned to increase the size of this data set, starting in T1 and delivering in T2, to enable condition reporting on discrete assets within a substation bay. Benefits include greater visibility of cost allocation and use of the data in our Geographic Information System (GIS). For example, depicting asset health data geospatially enables simpler communication of investment drivers, layering of other data sets to create more insight (e.g. corrosion maps, health data of other assets) and more effective collaboration between people to reach the right investment decisions.

The investment in this paper also provides for a faster, sometimes immediate response to issues when poor condition is identified, and the immediate consequences of deterioration are more severe. Examples include transformer oil regeneration following a dissolved gas analysis inspection or air compressor replacement following an in-service failure.

Our decision-making process considers the life of the system that an asset is a part of. The repair, replacement or refurbishment decision for an ancillary piece of equipment is taken with knowledge of the remaining life and cost of ownership of the primary plant it supports. Any activity on substation air systems for example must consider the number of remaining air blast or pneumatic mechanism circuit breakers in service and their remaining life. There are a number of works in our plan such as Thorpe Marsh substation where 're-sizing' of the air system is required following the replacement of most of the air blast circuit breakers.

Portable and Free Standing Assets are managed by a process, analogous to the Plant Status process, where we maintain a trained and competent work force who identify the need for new portable assets and monitor the condition of existing assets. The workforce have the capability to identify deterioration and report the change in asset condition and utility, and then manage the replacement or repair of the assets as required to deliver our outputs.

To deliver a Productive Work Environment we have implemented a governance process to decide the priority of sites for refurbishment, and to sanction efficient funding of the works. The Property Transformation (Workplace Services) team, work with field force senior managers to prioritise sites and with local team leaders and staff representatives to identify the workforce needs and requirements. They review the sites and categorisations through a desktop scoping exercise to estimate refurbishment costs. The shortlist of justified sites with estimated costs is approved by NGET's investment committee.

3.1 Plant Status

The 'Plant Status' process enables the reporting of assets that are in poor condition and/or exhibit performance that presents an increased safety, system, environment or financial risk.

Plant status is designed to identify assets early enough to reduce short notice outages arising from deteriorated and unreliable equipment. A report can be made at any time, being triggered either by a planned inspection or on an ad-hoc basis.

Our operational teams have access to a ‘Plant Status User Guide’ enabling them to navigate the process, it explains what the process is designed to achieve and the importance of their role within it. A copy of this user guide is available as an attachment to this paper.

3.2 Asset inspection

The following table identifies the inspection frequencies in our maintenance policy for the asset activity areas in this paper. The questions answered by these interventions generate reports of condition and defects. We also maintain a trained and competent workforce who understand our assets and recognise developing failure modes and their consequences.

Asset	Current Inspection & Maintenance Policy Intervals (Weeks, Months, Years) Routine Inspections, Basic, Intermediate & Major Maintenances, Oil Sampling, Thermography and Radio Frequency Interference
Civil Assets	
Asbestos	Asbestos Containing Material Inspection – Basic (6M), Major (1Y)
Cable Tunnel Refurbishment	Tunnel Fire Systems – Routine Inspection (3M) Basic (1Y) Cable Cooling Systems – Routine Inspection (2M) Basic (1Y), Major (3Y) Power Cables – Routine Inspection (2M) Basic (1Y), Major (3Y) Thermal Monitoring – Routine Inspection (6M) Basic (2Y)
Crossings	No inspection policy, reported ad-hoc
Electrical Domestic	Building Maintenance – Major (15Y)
Environmental	Environmental Routine Inspection – Oil and SF6 Stock (3M) All Others (1M)
Roof, Building, Asset Structures and Roads	Building Maintenance – Major (15Y)
Security	415V Installations – Intermediate (6Y), Major (12Y)
Non-Civil Substation Assets	
Air Systems	General Routine Inspections (1W & 3M) Non Return Valves Routine Inspection (2Y) Air System (High Pressure and Low Pressure) – Basic (4Y), Major (12Y) Air Dryer – Basic (1Y), Major (2Y) Air Compressor – Basic (1Y), Intermediate (2Y), Major (4Y) Statutory Inspections (2Y)
Cables	Cable Cooling Systems – Routine Inspection (2M) Basic (1Y), Major (3Y) Power Cables – Routine Inspection (2M) Basic (1Y), Major (3Y) Thermal Monitoring – Routine Inspection (6M) Basic (2Y)
OHLs	Foot Patrol ground based inspection (1Y) Infra-Red Inspection from Helicopter (High Resistance Joints) (1Y) High Definition Camera Assessment (Fittings and Conductor) (8-12Y) Steelwork Zonal Condition Assessment (6-8Y)
Oil Changes & Reclamation	Oil Sampling – Transformer (1Y), Quad Booster & Reactor (3Y)
Protection & Control (P&C)	Operational Test (2Y) Delayed Auto Reclose (DAR) Test (6Y) Busbar Protection – Basic (12Y) Other Protection – Basic (6Y)
Substation Earthing & Pinning	Site Earthing Systems – Basic (3Y), Major (12Y) *continued overleaf*
Switchgear, Bushings & Instrument Transformers	Air Insulated Circuit Breaker (Various Types) – Basic (3-6Y, can be ops based), Major (9-18Y, can be ops based), Statutory Inspection (3-6Y) Air Insulated Disconnector – Basic (6-9Y) Air Insulated Earth Switch – Major (12Y) Gas Insulated Switchgear and Busbars – Basic (6-18Y) Instrument Transformers and Bushings – Thermography and Radio Frequency Interference (3M), Basic (6-12Y), Oil Sampling (12Y) Surge Arrestors – Thermography and Radio Frequency Interference (3M)
Transformers, Reactors and Quad Boosters	Transformer, Reactor & Quad Booster Basic (3Y), Major (12) Tap Changer – Intermediate (3-6Y), Major (9Y)

	Bushings – Thermography and Radio Frequency Interference (3M)
Portable Free standing Assets	Routine Inspection – Breathing Apparatus (1M) Portable Earth Equipment (1Y) Gas Welding (1M) Portable Electrical (1Y) Grinding wheels (3M) Ladders & Stepladder (1Y) Mobile Access Equipment (Pre-Use)
Productive Work Environment	Buidling Maintenance – Major (15Y) This category relies on engagement with our field force by our Workplace Services Team.

Table 2 – Inspection Intervals for each of the asset categories in this investment paper (Civil and 'Non Civil' equipment, PFSA and PWE

3.3 T1 performance

T1 performance is summarised in Table 3 overleaf. The total T1 spend in this area has exceeded that stated in the 2012 T1 submission for the above activity areas. In this time, the volume of activity has increased. The primary drivers of this increase are:

- Reallocation of maintenance opex to the activity areas outlined in this paper.
    - Where asset interventions planned under substation 'site care' have found to require minor capex refurbishment and replacement, instead of opex repairs.
- Relaunch of the Plant Status process in 2014 to drive increased quality of reporting of issues through core systems
    - Since the 2014 relaunch of our Plant Status process in the last 5 complete years since (2014-2018), the average number of plant status issues reported has exceeded [redacted] per year (see Figure 1 below). Just under half of these entries are Civil related.
    - This compares to just under a 100 a year reported in the previous 5 years (2009-2013) before we improved our process early in T1.

We anticipate that the run rate of plant status submissions from the last 5 years of T1 will be maintained throughout the T2 period. In addition, we expect there to be an increase in submissions for civil assets as we improve the resolution of the asset inventory (see civils data creation in section 4.1) and continue to drive the reporting of condition through our core systems in T2.

Spend £m	2012 T1 Submission	Total T1	T1 Last 5 Years (2017-2021)	Total T2	Difference (T2 to T1 Last 5 Years)	% Change (T2 to T1 Last 5 Years)
Plant Status (Civils)	£102.4	£115.44	£66.99	**£83.56**	£16.57	24.74%
Plant Status (Excl. Civils)	£125.2	£152.01	£109.99	**£106.40**	-£3.59	-3.26%
PFSA	£4.8	£15.40	£8.01	**£4.52**	-£3.49	-43.53%
PWE	-	£25.36	£24.42	**£14.67**	-£9.75	-39.93%
Substation Other & Other TO Equipment Total	**£232.4**	**£308.20**	**£209.42**	**£209.16**	**-£0.25**	**-0.12%**

Table 3 – Comparison between 2012 T1 submission, T1 expenditure (5yr) and T2 expenditure

We have identified the T1 spend associated with the activity areas in this paper, to compare with the T2 spend allocation. There is no direct comparison with the “Substation Other” and “Other TO” categories from T1 because there are elements of spend that are not included in this paper such as LVAC boards, diesel generators and battery equipment.

[redacted]

Figure 1 – Plant Status issues raised by year for selected substation and civil categories

4. Investment drivers

This section sets out our approach for each of the 4 categories of work justified in this paper. Detailed specifics of the drivers for investment at RIIO-2 for each asset sub-type of the 4 categories are included in Appendix 1 for reference.

4.1 Civils

We will continue to act on condition reporting to drive asset investment. We will enhance our capability in this area by capturing and mastering a much larger volume of assets in our core data systems. This will enable higher resolution reporting of condition and cost capture within substation bays. We expect the creation of these discrete assets and more granular condition assessments to drive an increase in investment on substation structures.

	Total T1 Spend	**T1 Last 5 Years (2017-2021)**	**T2**	**Difference**	**Commentary**
Asbestos	£1.31	£1.10	£0.13	-£0.98	Larger spend in later part of T1. Few 'live' plant status drivers. Spend reallocated to fixed electrical wiring upgrades (see below)
Cable Tunnel Refurbishment	£7.94	£7.74	£5.07	-£2.67	Specific programmes of work identified on [redacted]
Crossings	£9.02	£8.99	£4.21	-£4.78	[redacted] issues raised since the beginning of T1. We expect a similar throughput of reports in T2. Spend is bundled with road resurfacing in the *Roof Building, Asset Structures and Roads* category below.
Civil Data Creation	£0.00	£0.00	£4.55	£4.55	Enhances the asset management capability of support structures in substations
Electrical Domestic	£5.60	£0.48	£1.93	£1.45	Campaign of surveys is revealing extensive replacement of building fixed wiring is required.
Environmental	£14.21	£7.62	£4.34	-£3.28	A significant programme of works has been completed in T1 addressing poor condition drainage and oil containment issues on our substation sites - it is anticipated that the work in T2 will be reduced as many of the high-risk sites have been addressed in T1.
Roof, Building, Asset Structures and Roads	£61.73	£30.09	£57.26	£27.17	Due to condition of this asset group, there is more work expected in T2 when compared to T1, and it is also anticipated that the Condition Assessment work across substations will identify significant additional works in this area to be delivered in T2. An example of this is the planned assessment of substation gantry structures, with a likely population of over [redacted] across our substation sites which are showing signs of deterioration in both reinforced concrete and steel variants.
Security	£15.64	£10.97	£6.07	-£4.90	Significant Security works have been delivered on a number of our substation sites ([redacted]) in T1, which reduces the expectation of the works that will need to be delivered in T2 .
Civils Total	**£115.44**	**£66.99**	**£83.56**	**£16.57**	

Table 4 – Civils spend breakdown by subcategory comparing T2 and T1

4.2 Non-Civils

We will continue to act on condition and performance reporting to drive asset investment. In T2 we will develop monetised risk approaches to a greater number of non-lead assets such as air systems, disconnectors and earth switches, protection and control and instrument transformers and bushings.

	Total T1 Spend	T1 Last 5 Years (2017-2021)	T2	Difference	Commentary
Air Systems	£11.42	£7.62	[redacted]	[redacted]	Increased overall spend is expected for T2 due to several condition/asset-health related issues observed with Air Systems over the T1 period - including obsolescence, spares availability and general reliability or air compressors.
OHL & Cable Repairs & Minor Replacement	£82.75	£58.40	[redacted]	[redacted]	A reduced spend is expected given the decommissioning of a number of oil-filled cables. Spend is also re-allocated to the Cable Sealing End [redacted]
Substation Repairs & Minor Replacement	£44.06	£32.62	[redacted]	[redacted]	No step change in the amount of work in T2 is expected, a portion of this spend is reallocated to air compressor replacements above.
OESB	£9.93	£9.93	[redacted]	[redacted]	The size of this investment reflects drivers associated with [redacted] Cable Sealing End Replacements.
Oil Changes & Reclamation	£1.14	£0.42	[redacted]	[redacted]	This activity is driven by oil sampling inspection. This spend reflects approximately [redacted] oil changes or approx. [redacted] oil reclamations, or a combination of both, on a fleet of roughly [redacted] oil filled transformers and reactors.
Substation Earthing and Pinning	£2.70	£1.01	[redacted]	[redacted]	No step change in the work required is expected between T1 and T2
Plant Status (Excl. Civils)	**£152.01**	**£109.99**	**£106.40**	**-£3.59**	

Table 5 – Non-civils spend breakdown by subcategory comparing T2 and T1

4.3 Portable and Freestanding Assets (PFSA)

We will continue to act on condition and performance reporting from our field force staff to renew equipment that is required to inspect and maintain our assets within the limits of health and safety legislation.

	Total T1 Spend	T1 Last 5 Years (2017-2021)	T2	Difference	Commentary
PFSA Total	[redacted]				The reduced requirement in this area is based on the reallocation of spend to condition monitoring equipment, which has its own justification paper and is distinct from this spend.

Table 6 – PFSA spend comparing T2 and T1

4.4 Productive Work Environment (PWE)

The Productive Work Environment campaign will continue to mid T2, to deliver enduring improvements to our workplaces.

	Total T1 Spend	T1 Last 5 Years (2017-2021)	T2	Difference	Commentary
PWE Total	[redacted]				Productive Work Environment is a rolling programme expect to end in the third year of T2. The campaign of upgrades is expected to have achieved enduring improvements to substation work environments by this point. Ongoing, minor building and welfare needs will be catered for by the Civils - Roofs, Buildings, Asset Structures and Roads category.

Table 7 – PWE spend comparing T2 and T1

5. Optioneering

5.1 RIIO T2 Strategy

Our strategy is to continue identifying investment drivers through our predominantly time-based asset inspection and maintenances. The defect and plant status reporting process will be used to generate work requirements for prioritisation. Over the course of T2 we will develop comprehensive, periodic health reviews of more non lead assets, including certain civil infrastructure (support structures). This will enable measures of risk to be understood, communicated and aligned with lead asset measures to achieve further risk optimisation of our investment plans.

Investment decision making in T2 will be driven by our standard Investment process, incorporating cost benefit analysis. This is described in more detail below.

5.2 Options for T2

For each area of identified spend a number of options are considered when delivering the work:

1. Do ‘Nothing’ or ‘Minimum’– the risk may be manageable through demarcation of an exclusion zone or coordination with a bigger substation scheme involving more extensive replacement or removal of associated assets
2. Decommission part of or the complete system. A reduced cost of ownership may be achieved by repairing the defect that triggered the Plant Status Report and modifying the system so that it is the right size for the assets it is supporting
3. Repair/Refurb (will usually involve replacement of components within a system such as a new pump and fan monitor for a transformer cooling system)
4. Full Replacement of a system (smaller or larger)
5. Full Replacement of a system (like for like)

5.3 Detailed Analysis & CBA

Costs for interventions in T2 are based on historical performance in T1.

In order to demonstrate the approach taken across the large and varied non-lead asset portfolio we provide three real scenarios from the Civils and Non-Civils categories, and the options approach for Portable and Free Standing Assets and Productive Working Environment improvements in the subsections below.

5.3.1 Options for Civils and Non-Civils CBAs

The following three CBAs are outlined in further detail with full NPV option calculations in accompanying CBA01-CBA03 spreadsheets.

Based on our engagement, stakeholders desire the following outcomes from our non-load activities, and which we apply in each CBA:

- Maintain current levels of reliability
- Comply with all relevant safety legislation
- Maintain asset risk in T2
- Demonstrate long term consumer benefit

Scenario	Description	Options (chosen in bold)
1	Air System – [redacted] Air Compressors are becoming increasingly difficult to maintain. The Air System serves [redacted] circuit-breakers	1. Do minimum until air blast breakers are replaced in T3 **2. Replace compressors** 3. Replace air blast breakers and remove air system earlier

The existing air system, that supports the operation of the [redacted] air blast circuit breakers at [redacted] substation, is at the end of its technical asset life. Not having a working air system would result in not being able to operate the circuit breaker. This CBA assesses the options to address this degradation in supporting air systems through either doing nothing and living with the risk until replacement of the breakers and associated equipment, targeted replacement of compressors to achieve the technical asset life associated with main plant items or acceleration of the replacement of the circuit breaker assets and their associated ancillary equipment.

Option 1 considers living with that risk until the end of the circuit breakers technical life (when the air blast circuit breakers will be replaced with GIS circuit breakers and remove the need for an air system all together). This option allows us to maintain compliance with relevant safety legislation but does not maintain asset risk levels and risks interruption to reliability through the restriction of operability of the circuit breakers supported by the air system. This Option is not favoured as it has increased risk to the network and reduced operation of the circuit breakers potentially leading to reliability issues.

Option 2 considers replacing the [redacted] current compressors with [redacted] new compressors for the remaining 7 years of the air blast breakers life and then making the air system redundant in 2028 when the air blast circuit breakers have been replaced with GIS circuit breakers, which removes the need for an air system all together. This option allows us to maintain compliance with relevant safety legislation, maintains asset risk levels and reduces the risk of interruption to reliability through the restriction of operability of the circuit breakers supported by the air system. This is the preferred option. It generates the most favourable NPV for consumers through the avoided maintenance and operating costs of the air system, ensures the continued utilisation of the current circuit breakers for their full technical asset life, deferring the need for replacement. As well as this, it removes any risk of being able to secure system access to replace [redacted] circuit breakers at the start of T2 which would take over [redacted] outage seasons.

Option 3 considers replacing the [redacted] current air blast circuit breakers with GIS circuit breakers at the start of T2 which removes the need for an air system all together. This option also allows us to maintain compliance with relevant safety legislation, maintains asset risk levels and reduces the risk of interruption to reliability through the restriction of operability of the circuit breakers supported by the air system. Whilst the acceleration of the circuit breaker replacement is beneficial as it removes the requirement for investment for the short need of the air system and does not lead to an increase in Network risk, this option holds risk as it is reliant on being able to secure system access for [redacted] outage season at the start of T2. This option also has a greater cost to consumers than Option 2 above to achieve the same outcome of network reliability in the short term, and is therefore rejected. It also introduces more SF6 to the system, which will be expected to leak by at least [redacted]% of installed volume based on the current international standard.

Scenario	Description	Options (chosen in bold)
2	Civils – Leaking roof of relay room at [redacted]	1. Do minimum – temporary repair to roof 2. Permanent repair to roof **3. Replace roof**

The leak presents a risk to the equipment contained within the substation building through water ingress. Water entering relay boards can trip out circuits and cause energy not supplied incidents.

Option 1 considers the do minimum scenario where NGET carries out a single instance of minor/temporary repair works to repair visible leaks. This option allows us to maintain compliance with relevant safety legislation but does not maintain asset risk levels and risks interruption to reliability through the ingress of water affecting operation of plant. This option still presents risk to the assets contained within the substation through water ingress to the relay room via a leaking roof. Temporary repairs require more frequent interventions as only isolated repairs are made and over time new leaks appear.

Option 2 considers NGET carrying out a single instance of a permanent repair to the leaking roof. This option allows us to maintain compliance with relevant safety legislation, maintains asset risk levels and reliability levels through the avoidance of ingress of water affecting the operation of plant. This option still however presents a risk to the assets contained within the substation. The roof repair whilst permanent will still lead to future ingress of water so some further interventions will be required.

Option 3 considers NGET carrying out a single instance of a replacement of the leaking roof. This option also allows us to maintain compliance with relevant safety legislation, maintains asset risk levels and reliability levels through the avoidance of ingress of water affecting the operation of plant. This option minimises the risk to the assets contained within the substation.

Permanent repairs extend the life of the roof but the NPV is in favour of a full roof replacement for maximum life. Option 3 therefore represents best value for consumers as it removes the risk of energy not supplied by replacing the aging roof and requires less interventions once initial investment is made than either of the other options.

Scenario	Description	Options (chosen in bold)
3	Transformer cooler bank leaks at [redacted]	1. Do minimum – live with oil leaks and transformer de-rating until transformer replacement **2. Replace cooler bank** 3. Replace transformer and cooler bank earlier

This CBA is based on the cost of a single instance of an oil leak and considers the cost of repair, accelerated replacement of the transformer or to do nothing and de-rate the transformer until replacement is due.

Option 1 reviews the costs associated with doing nothing and derating the transformer until replacement is due. This option allows us to maintain compliance with relevant safety legislation but does not maintain asset risk levels and risks interruption to reliability through the derating of plant from the nominal ratings as well as increased probability of failure through incomplete cooling cycles. The increased risk of failure of the transformers increases network risk and could lead to an interruption of supply, reducing the network reliability. As such this does not represent the best value for consumers and is not the preferred option.

Option 2 reviews the costs associated with the replacement of the corroding cooler bank with a new cooler bank. This ensures that the transformer meets its expected technical life whilst avoiding the full replacement costs of a transformer. It maintains the level of reliability and network risk through replacement of the corroded components whilst deferring the cost to consumers of a full replacement of the transformer assets.

Option 3 reviews the costs associated with the acceleration of the replacement of the transformer and associated assets to the start of the regulatory price control period. Whilst this option meets the stakeholder criteria of a reliable network, it does not do so at the lowest cost to consumers. This option is preferable to the do nothing Option 1 but it has a greater overall discounted cost than Option 2 replacement of corroded cooler banks.

Therefore Option 2 is the preferred option, and it represents best value to consumers when discounted in the NPV assessment.

5.3.2 Option approach for Portable and Freestanding Assets (PFSA)

The proposed solution is to purchase the PFSA equipment necessary for Operations personnel to complete testing and routines safely and to maintain high reliability on our substations. Additional equipment outside of this scope will be considered on a case by case basis with an assessment of business case for purchase.

5.3.3 Option approach for Productive Work Environment

The Property Transformation team, work with Zonal Managers to appoint a project manager for each zone and implement pre agreed design criteria. Plans are drawn up and costed for each of the sites through site visit inspections, taking into account all workforce requirements and prioritising health and safety issues (at which point further health and safety issues may be discovered and will be added to the scope of works e.g. fire escapes that are assessed to be unusable or unsafe). The finalised plans are then retested with the Zonal Managers and their teams for effectiveness, efficiency, and to prioritise delivery, and upon agreement the project manager follows through with full project delivery of the work environment improvements.

6. Key Assumptions, Risk and Contingency

Volumes

- We anticipate that the run rate of plant status submissions will be maintained throughout the T2 period and in fact increase for civil assets as we improve the resolution of the asset inventory (see civils data creation in section 4.1) and continue to drive the reporting of condition through our core systems.

Costs

- 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.
- The following allocation of the costs in this paper applies to the three Business Plan Data Tables (BPDTs) shown overleaf in Table 8.

Deliverability

- These interventions will be delivered using internal (SAP and Commissioning Engineer) and external sourcing. Specialist engineering services will be required in areas such as civils.
- Volumes are deliverable – most work can be delivered without a system outage. However, where poor condition substation support structures are identified, a site wide strategy will be required to consider the timing of whole substation and/ or bay replacement versus in-situ remedial work.

	Table 2.22 Asset Repair & Maintenance /£m	Table C2.24 Legal and Safety /£m	Table C2.2a Capex /£m	Grand Total /£m
Plant Status (Civils)	[redacted]	[redacted]	[redacted]	[redacted]
Asbestos	[redacted]	[redacted]	[redacted]	[redacted]
Cable Tunnel Refurbishment	[redacted]	[redacted]	[redacted]	[redacted]
Crossings	[redacted]	[redacted]	[redacted]	[redacted]
Data Creation	[redacted]	[redacted]	[redacted]	[redacted]
Electrical Domestic	[redacted]	[redacted]	[redacted]	[redacted]
Environmental	[redacted]	[redacted]	[redacted]	[redacted]
Roof, Building, Asset Structures and Roads	[redacted]	[redacted]	[redacted]	[redacted]
Security	[redacted]	[redacted]	[redacted]	[redacted]
Plant Status (Excl. Civils)	[redacted]	[redacted]	[redacted]	[redacted]
Air Systems	[redacted]	[redacted]	[redacted]	[redacted]
OHL & Cable Repairs & Minor Replacement	[redacted]	[redacted]	[redacted]	[redacted]
Substation Repairs and Minor Replacement	[redacted]	[redacted]	[redacted]	[redacted]
OESB	[redacted]	[redacted]	[redacted]	[redacted]
Oil Changes & Reclamation	[redacted]	[redacted]	[redacted]	[redacted]
Substation Earthing and Pinning	[redacted]	[redacted]	[redacted]	[redacted]
PFSA	[redacted]	[redacted]	[redacted]	[redacted]
PWE	[redacted]	[redacted]	[redacted]	[redacted]
Substation Other & Other TO Equipment Total	[redacted]	[redacted]	[redacted]	[redacted]

Table 8 – Summary of T2 costs and their allocation by Business Plan Table

7. Conclusion

The activities within this paper deliver two of the primary RIIO-T2 outputs, namely Safety and Reliability that our stakeholders have told us are important to them. The activities ensure compliance with health & safety and environmental legislation by intervening on assets before they fail and providing a contingency when failures do occur. We have outlined the variety of work that is covered by this paper and how it is complementary to and supports our proposed plans in the lead asset justification papers.

This report has provided background information and asset descriptions on the sub-categories of Substation Other and Other TO Equipment non-lead assets that deliver this output. A summary of costs for RIIO-T1 was provided and compared with the proposed T2 plan. We have outlined our tailored approach to assessing the intervention options for each of the 4 categories of work; Civils, Non-civils, Portable and Free Standing Assets and a Productive Working Environment, exploring CBA examples where appropriate.

We have balanced stakeholder feedback which values maintaining network reliability, and therefore stable asset failure rates, with ensuring the plan delivers the best value to end-consumers. We have done this by starting from a position of maintaining the level of investment seen annually in the last 5 years of T1 into T2 and adjusted the spend in and between the categories and sub-categories to account for our current understanding of Plant Status issues and those we predict will arise during T2. This leads to a proposed expenditure in T2 is £209.16m capex across all categories, a 0.12% decrease from the last 5 years of T1.

We also plan to develop our asset management systems during the T2 period which will enable improved tracking of the work done on discrete secondary assets on the transmission network. Overall the T2 strategy minimises the safety, reliability or environment consequences that may arise from asset defects, faults and failures across the Transmission portfolio during RIIO-T2 and beyond.

Outputs included in the T1 Business Plan

None

6. APPENDIX 1 Investment Drivers by Sub-Category

A.1.1 Civils

A significant amount of our infrastructure on substation sites, having been installed in the 1960s and 1970s, is deteriorating to a state where it requires intervention to reduce the level of risk associated with the infrastructure asset(s), and this is reflected in the condition reported by our Operations teams.

When interventions are planned on our High Voltage (HV) assets, this is the ideal time to intervene on our civil assets. However, it is not always the case that these asset interventions will align and often we need to make sure the condition of our civil assets do not have an adverse effect on the condition and/or performance of our HV assets. This category is diverse and includes the following areas of activity:

Crossings (vehicle and pedestrian) - Following several safety incidents involving the collapse of concrete trench covers resulting in lost time injuries to staff, the redesign and replacement of substation trench covers adjacent to critical plant items is being undertaken. The legacy concrete trench covers have corroded impacting their integrity and making them fragile and subject to collapsing.

Replacement of the covers is required to ensure the safe movement of personnel and vehicles around substation sites and remove the manual handling issues associated with vehicle crossing equipment – which was deployed to reduce the impact on legacy concrete trench covers by spanning across ground surfaces with safe bearing capacities thus limiting the load on deteriorating trench covers.

Figure A1: Vehicle trench crossing

Roofs - The majority of NGET plant buildings have flat roofs which suffer from water ponding and leaking. Leaking plant roofs degrade over time from the water ingress which results in a weakening of the structural integrity. This poses a risk to health and safety as they have the potential to collapse on site personnel. In addition to this they hold a risk to reliability by causing a network failure from damage to high voltage secondary equipment within such as protection relays. Refurbishment when the deterioration is less severe controls costs by preventing progression to more significant deterioration that is disproportionately more expensive to repair and may occur more rapidly.

Buildings – Where condition and performance dictates, structures, doors, windows and welfare facilities will require work to comply with current legislation, including the Health and Safety at Work Act 1974 and the Workplace (Health Safety and Welfare) Regulations 1992. Deterioration of buildings requires intervention to address heightened health and safety and security risks.

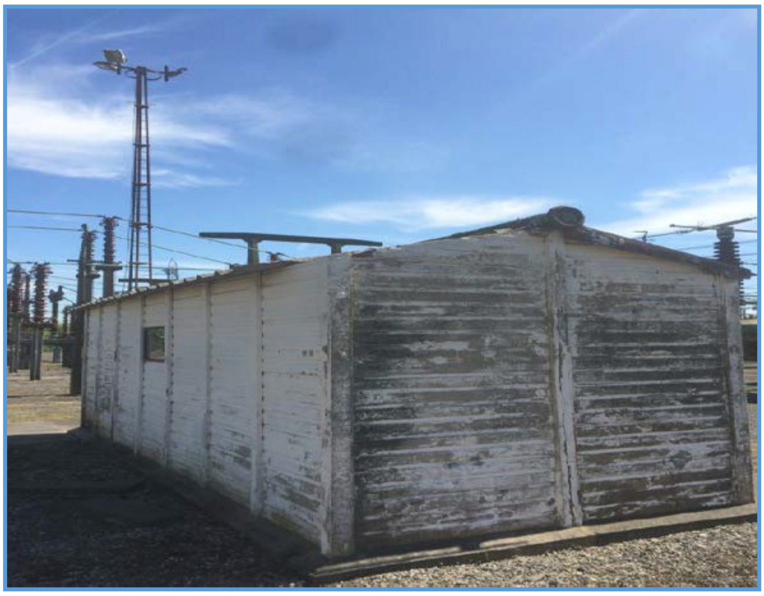

Figure A2: Deteriorating buildings

Environmental – Works on site water drains, and services, oil containment systems (including transformer bunds) to ensure compliance with environmental legislation and to avoid contamination of the surrounding landscape. This legislation includes the Pollution Prevention and Control Act 1999, the Control of Pollution (Oil Storage) (England) Regulations 2001, the Water Resources Act 1991, and the Water Act 2003 - supply, management, quality and pollution of water in the UK including flood defences.

Electrical Domestic Installations – Improvements, refurbishments and/or replacement to low voltage electrical systems, electrical wiring, lighting, air conditioning, heating and smart meters in substation buildings to ensure temperature and humidity are kept within acceptable limits for protection and battery equipment, wiring is compliant with regulations and services are safe and fit for purpose.

Substation Structures – Refurbishment when the deterioration is less severe controls costs by preventing progression to more significant deterioration that is disproportionately more expensive to repair and may occur more rapidly. For example substation structures such as plinths and overhead line gantries that support our lead assets are predominantly made of concrete. Chemical degradation of the concrete and corrosion of the steel reinforcing bar within the concrete impacts the integrity of the structure and poses a risk to the system from failure as well as the health and safety risk of falling debris. Managing the replacement of deteriorating porcelain and glass insulators, prone to cracking and shattering respectively, is a second example.

Figure A3: Corrosion of concrete structure.

Cable Tunnels – This activity area includes minor civil refurbishment works to cable tunnels, such as sump pumps and repairs to the tunnel/shaft structures to prevent excessive flooding/water ingress, to limit the degradation of the tunnel structure and to maintain safe access and egress**.**

Roads/paving/surfaces (Non-Routine Maintenance) – Refurbishment to the structure of roads and pavements to maintain safety and reduce the number of slips trips or falls at operational sites. Refurbishment when the deterioration is less severe controls costs by preventing progression to more significant deterioration that is disproportionately more expensive to repair and may occur more rapidly.

Security – Works to improve substation perimeter fences and access gates, proximity access control (PAC) systems and site security measures to ensure that all occupier duties are fulfilled and prevent/deter unauthorised access to substation sites.

Civil Asset Data Creation – Civil engineering assets (gantries, post insulator and switchgear support structures) are critical for the safety and reliability of the HV network. It is proposed that in T2, a substation-wide programme of asset inventory data capture is to be carried out on all system-critical civil assets. All data captured will be migrated into the core asset management system (Ellipse).

A trial survey scheme is currently being developed, focusing on substation gantries and substation support structures, and is designed to be non-intrusive so there is no impact on system operation. This is intended to be completed by 2020 with any learning or efficiencies to be passed on to a wider roll out for all sites. It is anticipated that once the trial scheme has been completed by 2020, the wider rollout of the surveys will commence in 2021/22 and are planned to complete before the end of T2.

A1.2 Non-Civils - Substation

Asbestos monitoring and removal - 83% of National Grid Electricity Transmission's substations were built prior to the ban on asbestos use in 1999. Monitoring and removal of asbestos is necessary to facilitate safe working and to comply with the current legislation, the Control of Asbestos Act 2012.

OESBs (Substations)

Operational Engineering Safety bulletins (OESB) state the need to undertake activities on the transmission network as a result of an incident or on discovery of a transmission network critical issue though inspection / condition assessment. The T2 spend covers ongoing commitments in substations (not including substation cables and overhead lines).

Switchgear Management

Switchgear management contains expenditure for minor repair and replacement of mechanism boxes, oil systems, greasing, air and control systems. It also addresses HV busbar systems and their support insulators.

Air systems are required to reliably supply compressed air to our population of circuit breakers that rely on compressed air to operate. Loss of an air system could result in either maloperation of the associated circuit breaker, or the circuit breaker being unable to perform its rated function, requiring it to be safely switched out of service until the air system is restored. Air systems include air compressors, receivers, panels, dryers and associated pipe work.

The asset replacement plan for air systems is considered and developed in conjunction with proposals for the refurbishment or replacement of a site's circuit breakers, to ensure optimum time for decommissioning. The asset replacement and refurbishment of an air system can be required numerous times during the life of its associated breaker. There are a number of variables which determine this frequency, including equipment type, running hours, maintenance done, obsolescence and spares availability.

Transformer Management

Transformer expenditure includes replacement of coolers, radiators, fans, pumps and associated control equipment that are used to prevent transformers over-heating in service. We must invest in these assets to ensure they match the asset life of the transformer they are associated with. Environmental conditions have accelerated the degradation of some cooler banks, leading to corrosion, oil leaks and fan failure. These defects may in turn result in down-rating of their associated transformers, or an increased risk of overheating with a resultant decrease in asset life and potential in-service failure. Where fitted, we also need to ensure fire deluge systems are in working order to protect the spread of fire to other assets if the transformer were to catch on fire.

Transformer oil deteriorates through oxidation of the oil, which produces water and acids, reduces the resistivity of the oil and, in the extreme, produces sludge. If high levels of acids are allowed to remain in the oil, they will react with cellulose molecules and reduce the mechanical strength of insulating paper. The presence of sludge raises the temperature of the transformer through deposition in oil channels, cooling areas and on the surface of windings. Sludge therefore also causes paper deterioration but, unlike acids, through a thermal rather than chemical pathway. The effect is the same; to reduce the operational life of the transformer as damage to the insulating paper is irreversible. This is addressed through oil reclamation work that is programmed as a cost-efficient alternative to oil replacement. Reclamation involves a mobile processing unit that circulates the oil through several filtering and chemical processes to return the oil operating properties

A1.3 Non-Civils – Cables and Overhead Lines

Cable and Overhead Line work includes repairs and minor replacement of fittings and accessories not addressed in the respective asset justification papers such as leak repairs (Cables), Earthwire linkages and Tower Step Bolts (OHL).

OESBs (Cables and Overhead Lines)

Operational Engineering Safety bulletins (OESB) state the need to undertake activities on the transmission network as a result of an incident or on discovery of a transmission network critical issue though inspection / condition assessment. The T2 spend covers ongoing commitments in substation cable sealing ends.

Cable Repairs

This includes the costs associated with the emergency fault repair and refurbishment of cable joint bays of main interconnected high voltage cables. These faults may be caused by third-party damage which nearly always results in oil loss for oil-filled cables (impacting both network reliability and the environment), and often results in cable faults which will have an extended impact on network security. Third-party damage will typically take several weeks or even months to repair by the replacement and creation of new cable sections.

This also includes the continued implementation of our cable oil leak reduction strategy which will allow faster rectification of major oil leaks. Oil leaks from joints, failure of reinforcing tapes, failure of lead or aluminium sheaths if not addressed by addressing the leaks, could result in environmental incidents that would be prosecutable by the Environment Agency.

In the late 1990’s and early 2000’s modification to insulated sheath power cable systems were conducted to reduce the number of link positions with the ambition to reduce maintenance costs of circuits. Following modification to these circuits, issues with the sheath voltage limiters have been identified. The sheath voltage limiter design in use is not fit for the duty expected of it. At present the sheath voltage limiters do not endure past a few switching operations, even though they can pass the relevant tests. The problem is exacerbated where they are used for voltage control. The scope of these projects is therefore a repeat of the modifications completed in the early 1990's to increase electrical section length, reduce number of link boxes, and reduce maintenance overhead. A secondary objective is to try and avoid the need for these circuits to sit on enhanced maintenance regimes and to cut the number of outages needed and associated costs.

A thorough review of the bonding and earthing will be necessary; and consideration given to the sheath voltage limiters installed.

OHL Repairs

In contrast to the OHL Conductors and Fittings Investment Decision Paper that covers systematic replacement to address condition, this category covers the defect maintenance and fault repair of OHL assets covering all fittings, except for Conductors, when unplanned faults arise. Component potential failure / defects are identified and monitored over a period, the benefit of which is to bring together volumes of associated work into a scheme via the plant status process whilst minimising disruption to the transmission network through outage requirements.

A major fault on the OHL system can occur due to natural phenomenon such as lightning, or because of a system issue. This leads to the need to undertake an unplanned repair under emergency conditions. Typical examples of this type of activity would be the major failure of a steel structure or the dropping of a current carrying conductor which holds the biggest risk to injuring third parties as the assets run through third party land.

OHL Signage and Access Prevention Systems

The condition of signage is reported through the annual foot patrols undertaken by our OHL field operatives. The condition data is used to identify signage that requires immediate rectification along with data used to develop our annual replacement plan. This is a rolling year on year programme containing the same annual volumes.

National Grid Electricity Transmission has a legal obligation under the (Electricity Supply Quality and Continuity Regulations 2002 to maintain the integrity of the access prevention systems installed on OHL towers. Annual foot patrol data identifies systems requiring immediate attention along with OHL tower, conductor and fittings condition data which feeds the ongoing replacement schedule. This is a rolling year on year programme containing the same annual volumes.

A1.4 Portable and Freestanding Assets (PFSA)

This equipment is to allow for routine maintenance, repair and minor replacement activities while ensuring personnel safety. The scope of equipment to be purchased includes but is not limited to:

- Protection & Telecoms testing equipment including Primary Injection Test Sets, fibre microscopes and CT Analysers
- Cable maintenance tools & test equipment – insulated tools sets & cable sheath test system
- Transformer monitoring & test equipment and Switchgear equipment including HD Video scope
- Air blast CB Timing test sets
- Battery related equipment including Battery ground fault testers and Analysers
- Specialist equipment including Tunnel gas testers, magnetic field monitors & Olympus investigation cameras
- Substation Safety equipment including RFI meters and small zip up scaffold towers
- SF_6 related equipment including gas handling plant & upgrades to existing equipment including Mass Flow meters, SF_6 Multi Analyser, Adaptors and Hoses

A1.5 Productive Working Environment

National Grid Electricity Transmission provides operational working accommodation for around [redacted] employees in circa [redacted] substations. Many of these buildings are deteriorating and have limited facilities, which fall below the standards required for a main place of work. For the substation estate, the Property Transformation team have developed a process to upgrade the portfolio by providing appropriate furniture, wall and floor finishes for the operational working environment, known as Productive Work Environment (PWE).

It is planned that main substation sites should receive an appropriate level of refurbishment, in order to improve the working conditions of site staff whilst ensuring compliance with workplace regulations such as Health and Safety (Display Screen Equipment) Regulations 1992. It is our ambition to increase the number of female engineers within the workforce, however, many of the operational sites have limited or no female facilities. This investment alos aims to provide suitable welfare facilities for both female staff and visitors to those sites.