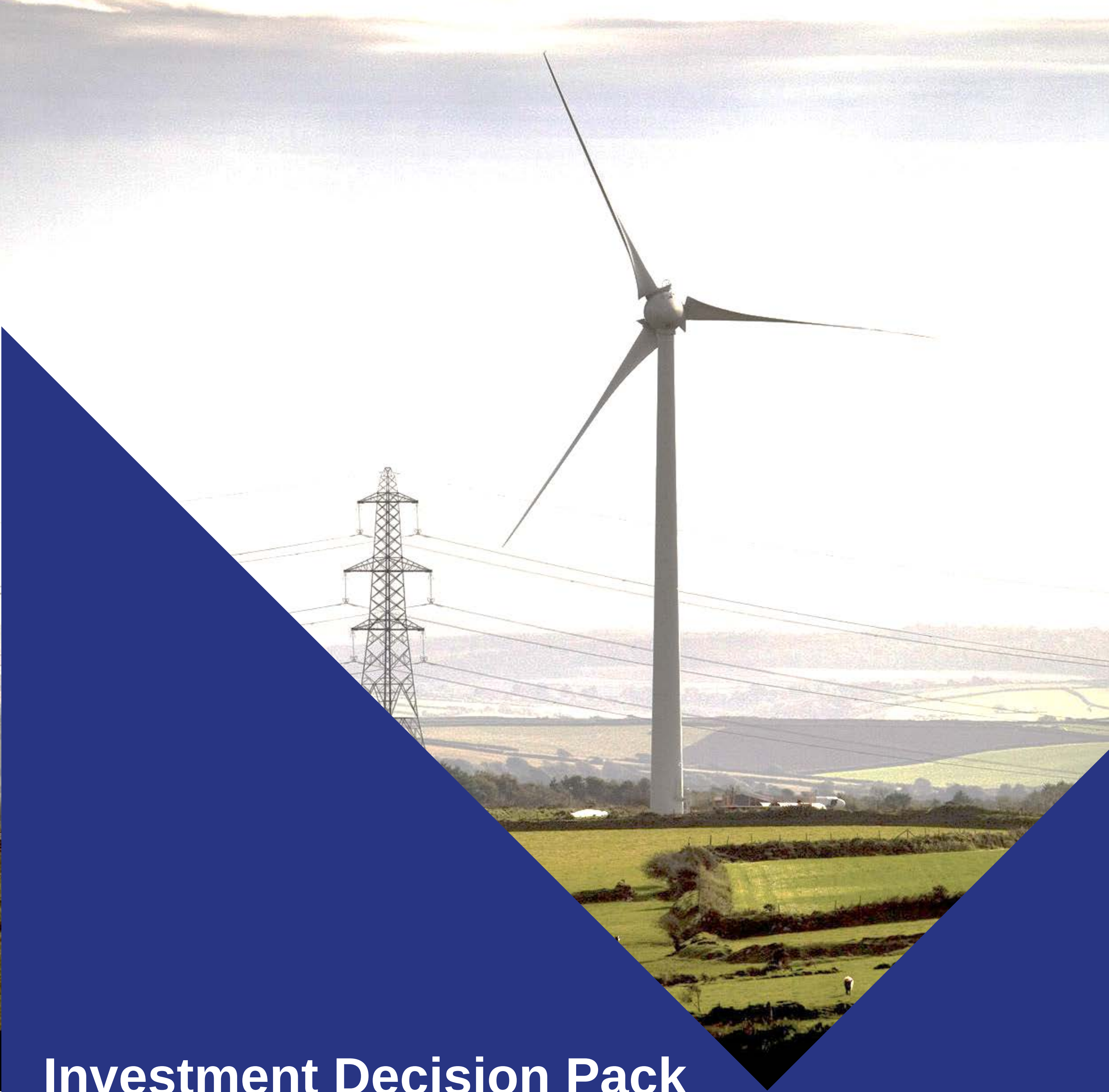

Investment Decision Pack

NGET_A9.19 – Strategic Spares

December 2019

As a part of the NGET Business Plan Submission

Strictly Confidential

nationalgrid

Engineering Justification Paper; Non-Load Related Strategic Spares			
Name of Scheme / Programme / Asset Family	Strategic Spares		
Primary Investment Driver	Maintaining stock of strategic spares for quick response to asset faults and failures		
Reference	A9.18		
Output Asset Types	N/A		
Cost	£45.858m (of which £19.74m is static wound equipment)		
Delivery Year(s)	2021-2026		
Reporting Table	C2.11, C2.2a		
Outputs included in RIIO T1 Business Plan	*No*		
Spend Apportionment	**T1**	**T2**	**T3+**
	£0.142m	**£45.650m**	**£0.067m**

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1. Executive Summary

Our stakeholders have told us that one of their key priorities is for National Grid Electricity Transmission to provide a safe and reliable network. Strategic Spares play a pivotal role in maintaining the current levels of reliability and ensuring future reliability.

Strategic Spares are a unique type of spare equipment which generally have a long lead time. These types of assets would also lead to significant impact on the reliable operation of the network should they not be available. The requirement for strategic spares holdings for individual asset classes are based on internal policies that are informed by failure rates, spares utilisation, cost and lead time.

The preferred strategy for T2 is to continue with a similar approach to T1 with similar levels of stock. This is based on our current policy and balances cost, risk and performance. The forecast for Strategic Spares spending in T1 across all asset types is £92.4m (£11.55m p.a.) compared to a forecast of £45.86m for T2 (£9.17m p.a.). The reduction largely stems from efforts in T1 to fill gaps in spares holdings. This approach is supported by the options assessment.

2. Introduction

Strategic spares are defined as *"assets or subcomponents which are procured in advance and held in storage* ***solely*** *for immediate deployment to mitigate network events involving commissioned, in-service assets".*

Strategic spares are a very mature resilience measure for utilities, typically consisting of long lead time and high cost items (e.g. High Voltage cable, OHL conductor, circuit breakers, bushings). They are held separately and in addition to other spares in order to mitigate the risk of asset failure or unrepairable faults and defects that could otherwise result in long lead time replacements. We also provide access to our spares catalogues to other utilities and generators which contributes to resilience across the electricity supply industry.

We set initial target Strategic Spares holdings (stock levels) which are published in Policy. These stock levels are optimised using a combination of historic failure rate information and tools such as the commercially available Inventory Optimiser module of the SALVO decision support tool. For higher usage strategic spares, standard inventory management techniques are continually used to optimise the appropriate stock holding.

Our stakeholders have told us that one of their key priorities is for National Grid Electricity Transmission to provide a safe and reliable network. The provision of strategic spares contributes to delivering this priority by providing a solution to the failure of long lead time assets that would otherwise deplete our network, impacting its reliability for electricity consumers. Specifically Strategic spares are intended for use where asset failure is unexpected (i.e. they are not used to replace assets due for replacement due to condition).

3. Background & T1 Overview

National Grid Electricity Transmission keep a stock of suite of spares to suit our asset portfolio, with the prime purpose of managing lead times for replacements. Spares classed as strategic spares (whole assets or significant parts of) typically have lead times of 6-12 months as *Table **1*** outlines. A lack of strategic spares holdings could lead to an increase in network unavailability and consequently a decrease in reliability.

In addition to lead times, strategic spares are held to manage obsolescence (i.e. where manufacturers have stopped supporting equipment due to its age). Transmission equipment typically has lifetimes that are decades longer than suppliers will provide support for, and therefore proactively managing, replenishing and increasing spares stock can ensure that we maximise the useful economic life of our assets.

Table 1. Typical lead times to procure replacement Transmission equipment

Item	Estimated Lead time
Cable	9-24 months
Cable Joints	2-4 months
OHL Conductor	1-4 months
Instrument transformers	6-12 months
Circuit breakers and significant parts	6-9 months
Power transformers	18-24 months
Bushings	6-12 months

Strategic spares are also utilised to manage equipment defects and faults. On average, there are 490 strategic spares issued per year (approximately 9 per week) across all asset types as shown in *Table **2***.

Table 2. Average quantity of strategic spares stock issued per year over the last 10 years (2009-2018)

Asset Type	Average annual spares usage
Cable	1,300m
Cable joints	13
OHL conductor	12,000m
Instrument Transformers	31
Circuit breakers	8
Static Wound Equipment	1.5
Bushings	50

Comparison between spares usage and lead times indicates that lack of availability of spares would quickly become unsustainable as stock would quickly run out, having significant impacts on network availability and thus the ability to carry out network connections, renewal and maintenance.

3.1 T1 performance

We have a well-established stock of strategic spares and there has been significant effort during RIIO-T1 to review stock levels and to identify and fill gaps in Strategic Spares stock (Table 3 shows RIIO-T1 costs and forecast). Consequently, the majority of expenditure in RIIO-T2 will be to replenish Strategic Spares used to replace failed assets and components.

Power Transformer, Reactor and Quad Booster spares (henceforth referred to a Static Wound Equipment (SWE)) are utilised at a rate of 1.5-1.7 units per year depending on the time period that analysis is carried out over. This has been lower in T1 (c.a. 1 unit per year) but the long term average is a better comparator, given that the annual variability of strategic spares deployment is defined by the transmission network asset faults and failures that lead to their deployment, which are not fixed. It is also more appropriate to look over a longer time period when dealing with such long-life assets where Strategic Spares usage is low.

Table 3. Comparison of spend, forecast and allowances in T1

Spares Type	Allowance	Spend in first 6 years of T1	Forecast for remainder of T1	Total forecast spend	Variance to allowance
SWE Strategic Spares	£71m	£31.72m	£17.24m	£48.96m	£22.04m
Other Strategic Spares	£43.7	£31.86	£11.58m	£43.44m	£0.26
Total	£114.7m	£63.58m	£28.82m	£92.40m	£22.3m

*Figure **1*** shows the actual spend in T1 up to and including 2018/19. The forecast for the remaining 2 years (19/20 and 20/21) are made up of the "flat" forecast shown later for T2 and additional planned expenditure due to known stock replenishment needs (as per our RIIO-T1 spares strategy). A 'flat' baseline forecast is appropriate given the unpredictability of spares deployment and is also reflected in our RIIO-T2 forecasts.

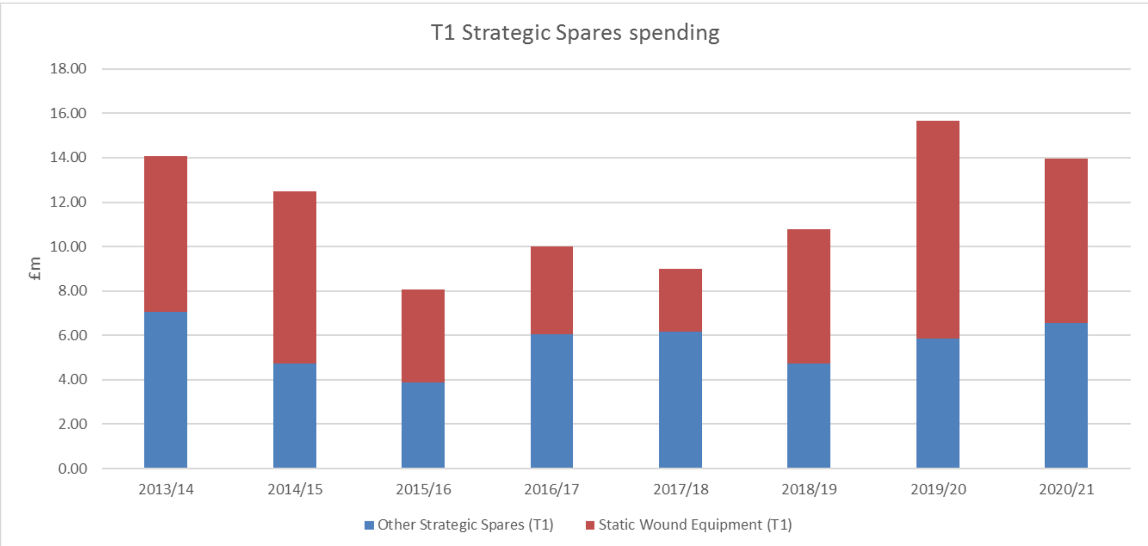

Figure 1. Expenditure on strategic spares in T1 (including forecast for 19/20 and 20/21)

4. RIIO T2 Strategy

Our strategy for T2 is to continue managing spares using the same principles, tools and techniques that we have used throughout T1. This approach is supported by the Cost Benefit Analysis and options assessment in Section 5 below and is in line with our current policy.

To date in RIIO-T1 a concerted focus has been made to identify and replenish any gaps in our Strategic Spares holding. We will continue to manage our strategic spares holding throughout the remainder of the RIIO-T1 period so that in the RIIO-T2 period the majority of expenditure will be for the replenishment of stock that is used to respond to failures.

Given the random nature of asset failures it is not possible to predict precisely what spares will be utilised or purchased. This is demonstrated by our RIIO-T1 performance to date (Section 3) where actual to date plus forecast RIIO-T1 end figures identify that expenditure will be within RIIO-T1 allowance, expenditure across strategic spares categories within this allowance have been disproportionate to those expected – driven by the nature of network challenges that have required their deployment.

For this reason, with the exception of SWE spares, forecasts have been made based on average (mean) spares replenishment cost figures from the first 6 years of T1, rather than a bottom up assessment based on spares unit costs. In addition, costs related to the deployability of strategic spares have also been included in the forecast.

SWE spares forecast expenditure has been based on the need to replace 1 off 400kV transformer per year through T2.

This has been determined as follows:

- Historic failure rate for SWE of 1.5 p.a.
- c.a. 50% of failures relate to poor condition assets (i.e. already planned) resulting in a 0.75 p.a. SWE spares requirement
- This has been inflated by 0.25 p.a. (total of 1 p.a.) to account for the possibility of a Quad Booster failure (and resulting higher cost), rather than a transformer failure
- Forecast cost for 1 p.a. reduced by c.a. 20% to account for emergency nature of works (reduced scope of works compared to routine transformer replacements).

The availability of spares avoids disruption of planned work by ensuring that resources earmarked for other projects do not have to be diverted for emergency replacements.

This approach is described in the “Baseline” option below and amounts to a forecast average expenditure of £9.17m p.a. compared to a forecast £11.55m p.a. in T1.

5. Optioneering

Three options for the management of strategic spares have been considered:

- Baseline - Keep current stock levels (or similar) in line with current policy
- Option 1 - Run down stock by not replacing spares that have been used in RIIO-T2
- Option 2 - Increase stock levels for more comprehensive coverage (above current policy)

5.1 Baseline – maintain stock levels in line with current policy

In this option the primary driver for most of the expenditure in T2 will be related to the replacement of strategic spares that are utilised within the T2 period to mitigate sudden and large asset failures that would otherwise be subject to long lead time replacements (stock replenishment). These stock levels have been optimised using a combination of historic failure rate information and tools such as the Inventory Optimiser module of the SALVO decision support tool. The exact output of this differs per asset type where interchangeability, availability and lead times may vary greatly.

For example, interchangeability between instrument transformers means that for each "type" of instrument transformer a standard strategic spare can be held to cover a number of individual design types. In addition, Instrument Transformers are an asset type where we have good usage statistics and this gives increased confidence in the correct stock level. The stock level is continually reviewed in line with standard stock management practises. A further example of spares optimisation across design types is air insulated switchgear.

An example: Optimisation of SF6 Air Insulated Switchgear (AIS) Strategic Spares

For 132kV, 275kV and 400kV AIS SF6 switchgear National Grid currently has 69 different types of circuit breaker installed making up a total population of 1300. The strategic spares requirement consists of whole 3 phase circuit breakers for 9 circuit breakers designs, and single phase assemblies for a further 11 designs. In the event of the failure of more than one phase of these 11 designs then the solution is likely to be full replacement with one of the 9 designs mentioned above.

The strategic spare holding for the remaining 49 designs are either nil or combinations of components such as Operating Mechanisms, Interrupter Heads and support columns. Any fault or failure that cannot be repaired using available components will result in full replacement using one of the 9 designs as above.

Similarly, we do not hold complete spares for air blast or bulk oil circuit breakers as the strategic spares in the event of a failure are AIS or dead tank designs.

In contrast, XLPE cable spares are very specific to a particular installation(s) and need to be held to match specific cable installations on our transmission network (particularly at 275kV & 400kV) as there is little compatibility between manufacturers. Also, lead times and minimum order quantities for this technology are high (typically minimum of 12 months).

Ongoing upkeep of Strategic Spares is also necessary to ensure their usability when required, particularly in an emergency. There are 2 main areas of cost that have been included in this option relating to spares care:

- Bushing check test: electrical testing of all strategic spare bushings holdings on a 7-year cycle
- Cable drum turning and renewal: Cable drums are required to be turned to prevent settling of the cable (stretching and decompression under its own weight). In addition, on a condition basis, wooden drums require replacing with steel drums, because wooden drums are not designed for long term storage.

A breakdown of the cost elements associated with this option is indicated in *Table **4*** and a comparison of the forecast compared to T1 costs is shown in *Figure **2***.

Table 4. Forecast and breakdown of expenditure for the baseline option

Item	Description	Total
Forecast stock replenishment	Forecast cost of replenishment of strategic spares for asset types including overhead lines, switchgear, cables, bushings and instrument transformers based on historic expenditure	£20m
Bushing check test	Cost associated with 7 yearly electrical testing of spare bushings	£1.50m
Cable Drum turning and renewal	Cost associated with the turning cable drums and replacing wooden drums with steel	£1.50m
Unsupported equipment management	Forecast cost of proactively increasing spares holdings for equipment where manufacturer support is withdrawn	£3.15m
SWE spares	Spare SWE units – 1 p.a.	£19.74m
Total		**£45.86m***

***Note – the sum of individual components will not exact the total (£45.86m) as a result of rounding in the figures.**

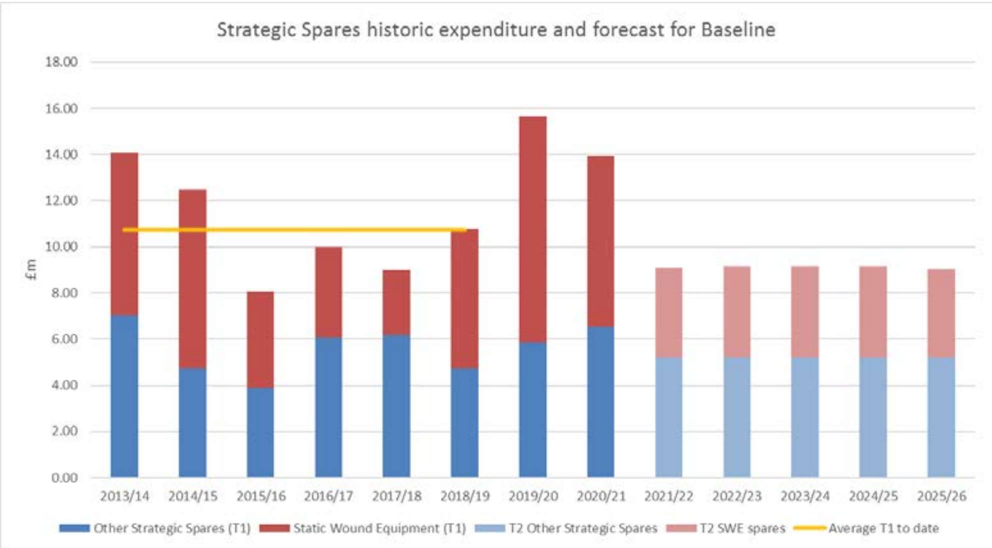

Figure 2. Historic and forecast Strategic Spares expenditure for the baseline option

<u>Forecast Stock Replenishment</u>

Forecast stock replenishment is £4m p.a. on average. This is based on historic averages and historic performance (i.e. assumes that failure rates will remain consistent).

<u>Bushing check test</u>

All strategic spares bushings require a 7 yearly electrical test in order to meet National Grid technical specifications and policies and ensure that they are fit for purpose. This is expected to cost c.a. £300k p.a.

<u>Cable drum care and renewal</u>

All cable drums require lifetime management activities such as turning, pressure checks and in some cases, drum replacement. Many older cable drums are wood which is not designed for external storage and replacement with steel drums is required

<u>Unsupported Equipment Management</u>

This element is to provide sufficient funding (c.a. £0.63m p.a.) to increase spares holdings for assets that are obsolete and no longer supported by suppliers. For modern switchgear this can typically happen once an asset is approximately 20 years old. The funding will be used to either procure additional spares from suppliers at the last available moment (as required) or to refurbish and store existing "grey spares".

SWE Spares

Based on analysis of SWE failure rates this element forecasts a total expenditure of £19.74m on SWE failures (accounting for assets that are not already in the T2 or T3 plan - c.a. 1 unit p.a.). In any particular year the value could be higher or lower depending on the nature and number of failures and the specific type of equipment that fails. This forecast is a central case (built on historic rates) to cover the most likely eventualities.

5.2 Option 1 - Run down stock by not replacing spares that have been used in T2

This option does not replace spares as they are used during T2 to address short term network requirements for (otherwise) long-lead assets. Rather stock levels are run down over the RIIO-T2 period. Immediate consequences of this strategy in T2 may not be felt as the existing stock would sustain the business for 2-3 years. However, within 3-5 years the lack of availability of certain strategic spares could result in significant network constraint and reliability issues.

One way of understanding the impact of this is to look at the difference that it would have to one of our key reliability metrics: Average Circuit Unreliability (ACU). ACU measures the amount of network unavailability when a circuit or part of the system is switched out for the repair of unreliable assets. Further explanation of the measure can be found in our recently published document "Managing Electricity Transmission Network Reliability".

Looking at tables 1 & 2 shows that c.a. 100 spares are issued per year where the lead time for ordering replacements is 6-12 months.

If we conservatively assume that 45 of these spares are required to resolve defects or faults where the equipment is no longer operable or must be switched out of service on safety grounds then it is possible to estimate the impact on ACU.

When calculating ACU we use a list of all transmission circuits with the amount of time that they have been out of service due to equipment unreliability. Under this scenario, rather than assuming that the network would be planned with a greater number of outages (planned + now additional unplanned outages from a lack of strategic spares in this scenario), we have assumed that unplanned outages would cause cancellation of planned work (see Figure 3 and explanation below). We have therefore taken the most recent ACU figures and, for the number of circuits that would be impacted by the lack of strategic spares assumption (45), increased the circuit outage duration to 6 months (i.e. the minimum lead time for acquiring spare assets no longer held in stock under this option).

Based on the estimates above analysis shows that this approach to managing strategic spares is likely to give rise to at least a 50% increase in Average Circuit Unreliability (ACU) by the start of T3 under this option.

In addition to the impact on ACU extended outages on circuits reduce the ability to do work on adjacent circuits which has further knock on consequences to future reliability.

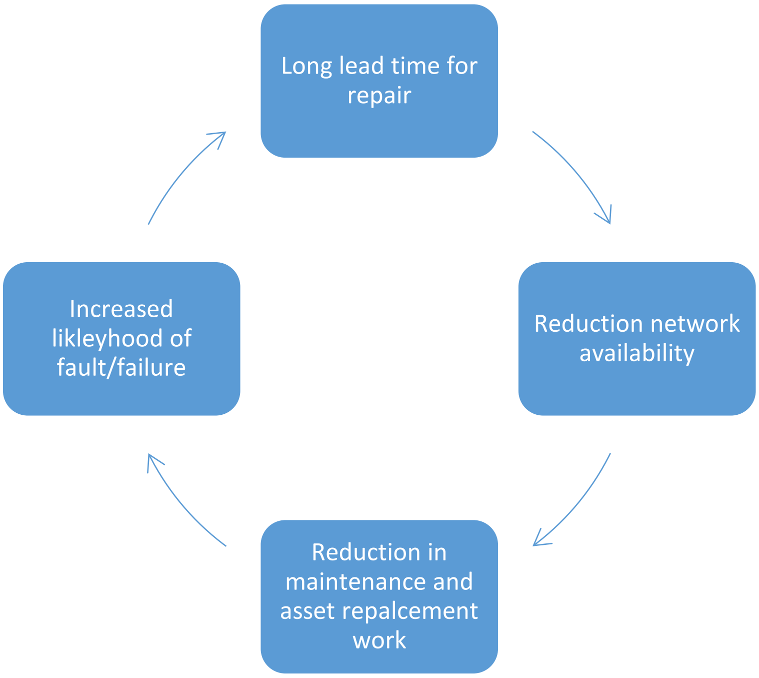

Figure 3. Feedback loop showing how lack of availability of spares leads to worsening reliability state.

Ultimately the cost of this option will rise as spares will need to be procured directly as they are required, so while there is a short-term reduction in cost this will only last 1-3 years. This can be seen in Table 5 where the line items consistent with Table 4 show the same or lower RIIO-T2 estimated costs. However, on top of this there will be the resulting increase in system constraint costs indicated above, plus the cost of re-planning existing work that cannot be fulfilled on a less reliable network. Figure 3 shows how managing the network in this manner creates a feedback loop of increasingly worsening reliability and inability to deliver asset replacement and new connection commitments, reflecting the importance of maintaining network reliability incrementally, for which strategic spares can play an important role.

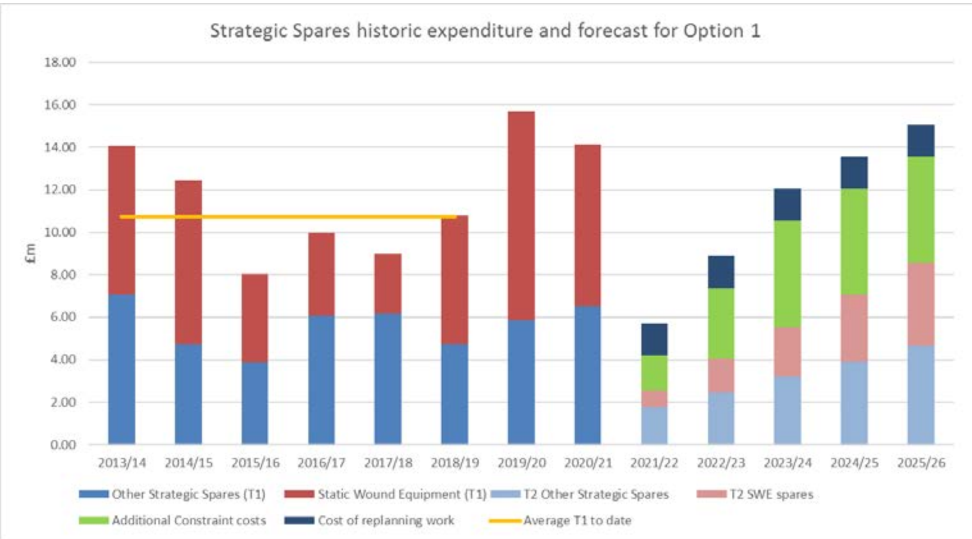

Figure 4. Historic and forecast costs for Option 1

*Figure **4*** and *Table **5*** show and describe the main elements of cost for this option. Strategic spare replenishment costs ramp up over 3-5 years as stocks run out and spares need to be procured directly at the time of a fault or failure. At the same time constraint costs associated with extended outages increase. There is also a cost included for the costs of replanning work (maintenance and capital work) as a result of not being able to achieve the required outages. This has been estimated as a fixed annual cost based on demobilising a single major scheme and remobilising at a later date. As spares deplete further there will be an increased impact and need to replan more work. For the purposes of this analysis we assume that under this option, as re-planning work due to unplanned long term outages becomes more common, we would become increasing efficient at this activity. Therefore, whilst volumes of unplanned work increase, we use a fixed annual cost to represent the total cost of re-planning work.

Table 5. Description of cost elements making up forecast for Option 1 for T2

Item	Description	Total
Forecast stock replenishment	Reactive ordering of replacement equipment as spares holding depletes - Forecast cost of replenishment of strategic spares for asset types including overhead lines, switchgear, cables, bushings and instrument transformers. Calculated by Pro-rating the cost of replenishment from the Baseline option	£10.23m
Bushing check test	Cost associated with 7 yearly electrical testing of spare bushings	£1.5m
Cable Drum turning and renewal	Cost associated with the turning cable drums and replacing wooden drums with steel	£1.5m
Unsupported equipment management	Forecast cost of proactively increasing spares holdings for equipment where manufacturer support is withdrawn	£3.15m
SWE spares	Spare SWE units	£11.76m
Additional Constraint costs	Additional system constraints as a result of 50% increase in ACU	£20m
Cost of replanning work	Costs associated with the need to replan schemes and maintenance as a result of 50% increase in ACU. Based on cost of demobilising and remobilising 1 scheme per year. This is based on an historic example	£7.5
Total		**£55.64m**

The estimated cost of this option is £55.64m.

5.3 Option 2 - Increase stock levels for full coverage (above current policy)

We have identified areas where we could hold additional spares such as Gas Insulated Switchgear, OHLs, AIS switchgear and cables. This option consists of replenishment of strategic stock as they are used, but this is not an optimal approach - additional spares would be purchased and stored to ensure full coverage regardless of risk.

Increasing minimum stock levels across all asset types could, in some instances, increase reliability. However, to be effective it would need to be carried out across all asset types. Strategic Spares with high usage already have optimised stock levels based on their usage and understandings of lead times. Where the unavailability of strategic spares present issues it is largely due to equipment obsolescence or unique designs (e.g. GIS or bushings). Therefore, ensuring complete strategic spares coverage would require a significant increase in strategic spares holdings. This is estimated to cost £50-80m. This estimate has been built up from the items in *Table **6***. These figures are estimates only and quotations would be required to cost this in detail..

Table 6. Increased spares coverage

Item	Cost estimate	Comment
Gas Insulated Switchgear (GIS)	£40m	GIS is highly bespoke to installation with little interchangeability and therefore holding comprehensive spares requires a review of every installation
Instrument Transformers	£0.5m	Increase spares holding to cover more variants or increase stock holding of existing variants
Air Insulated Switchgear	£2m	Increase spares holding to hold full 3 phase strategic spares for more designs over and above current optimised position.
Transformers (or other SWE)	£10m	Buy and store an additional 3-4 transformers to cover additional variants
Overhead Lines	£1m	Increase stock of spare conductor types and associated fittings. Increase stock of tower steelwork and temporary masts
Cables	£20m	Purchase spare cable for circuits where need for spares has been risk assessed out due to short lengths.
Total	**£73.5**	

In addition to the purchase cost of additional spares additional storage facilities will need to be constructed and staff employed to manage these facilities. All this to only marginally increase reliability. Logistically, the addition of more spares means that storage and management is required. Given our RIIO-T1 Strategy to review and replenish strategic spares stocks has not indicated such additional spares holdings, it is unlikely to provide the optimum solution.

Table 7. Description of cost elements making up forecast for Option 2 for T2

Item	Description	Total
Forecast stock replenishment	Forecast cost of replenishment of strategic spares for asset types including overhead lines, switchgear, cables, bushings and instrument transformers	£20m
Bushing check test	Cost associated with 7 yearly electrical testing of spare bushings	£1.5m
Cable Drum turning and renewal	Cost associated with the turning cable drums and replacing wooden drums with steel	£1.5m
Unsupported equipment management	Forecast cost of proactively increasing spares holdings for equipment where manufacturer support is withdrawn	£3.15m
SWE spares	Spare SWE units – 1.5 p.a.	£19.74m
Increased stock levels	Increasing stock levels across major asset types for full coverage	£73.5m
Total		**£119.39m**

*Table **7*** and *Figure **5*** describe the cost elements and forecast phasing for this option. The forecast is flat but in reality procurement timescales and construction/procurement of new storage facilities may mean that there are peaks and troughs in the profile. Compared to the proposed option of maintaining current spares holdings,

Figure 4 shows that Option 2 adds £73.5m of cost over RIIO-T2; an additional £14.7m per year of the Price Control period.

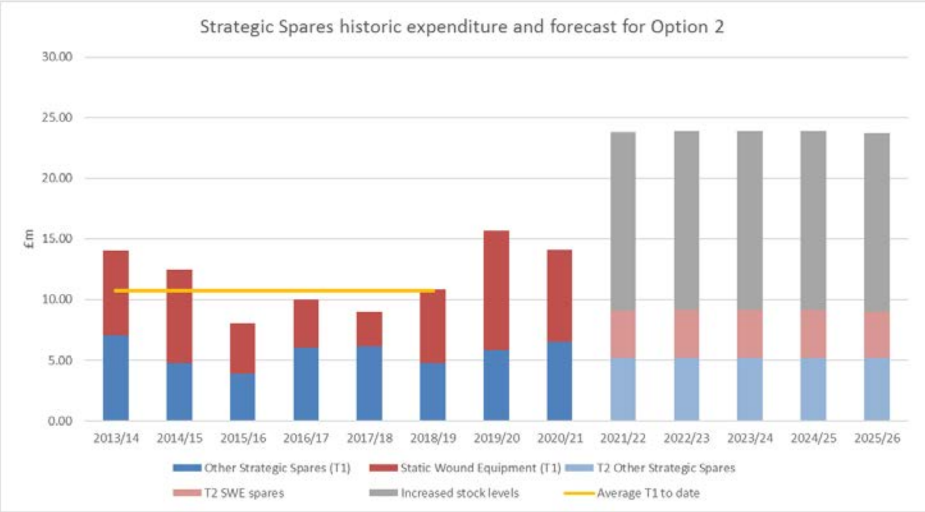

Figure 5. Historic and forecast costs for Option 2

The estimated cost of this option is £119.39m.

6. Detailed Analysis & CBA

Based on the cost assessment and CBA the preferred option is to maintain stock levels in line with current policy (baseline option) as it delivers the maximum reliability for the lowest cost.

The forecast of strategic spares expenditure has been built up by analysing the spending on strategic spare replenishment in the first 6 years of T1. Assuming that equipment faults and failures remain constant into T2 it is therefore expected that expenditure on replacing strategic spares will be broadly consistent.

The forecast for spare transformers is based on historic usage and forecast of 1.5 transformer failures per year.

7. Key Assumptions, Risk and Contingency

Assumptions

There are 2 primary assumptions:

1. Commodity prices remain broadly similar or rise no faster than inflation
2. Failure rates remain similar

Risks

There is a risk that:

1. **Commodity prices rise faster than RPI** - Fundamentally maintaining a stock of Strategic Spares is about purchasing equipment, all of which is made using a variety of commodities (copper, aluminium, steel etc.). Significant fluctuations in the values of these commodities will translate to a price impact.
2. **Failure rates are higher than expected** - The forecast has been developed assuming a similar aggregate equipment fault and failure rate to that in T1. Should this be different in T2 this will have an impact on the number of Strategic Spares used and consequently the total cost of replenishment.
3. **Higher value assets fail than the average costs outlined in our plan** - There is an assumption that the distribution of the value of Strategic Spares used will remain broadly consistent. However, if we were to see an increase in the need for higher value spares on average, this will impact on the overall cost.

Contingency

Strategic Spares are themselves held to respond to contingencies. The primary contingencies affecting strategic spares themselves are outlined in the Risks section above. Additionally, one might be concerned with the loss off spares storage facilities through fire, although this is appropriately covered by insurance arrangements.

A risk to the plan could be a higher than predicted SWE failure rate or the failure of higher cost SWE assets (e.g. Quad Boosters) due to the significantly higher unit cost. No additional funding has been factored in to cover this.

8. Conclusion

A range of options have been considered and it is clear that the optimum option that balances cost, risk and performance is the Baseline Option. This option maintains spending on Strategic Spares at broadly current rates in line with existing policies. This ensures that Strategic Spares stocks are maintained to respond swiftly to the most common failures and faults. This assumes a flat spend of £9.17m p.a. in our T2 submission. In reality the spend profile will be determined by the number and type of in year faults and failures, but given its unpredictability is forecast as a flat, average profile based on historic information.

9. Outputs included in RIIO T1 Plans

N/A