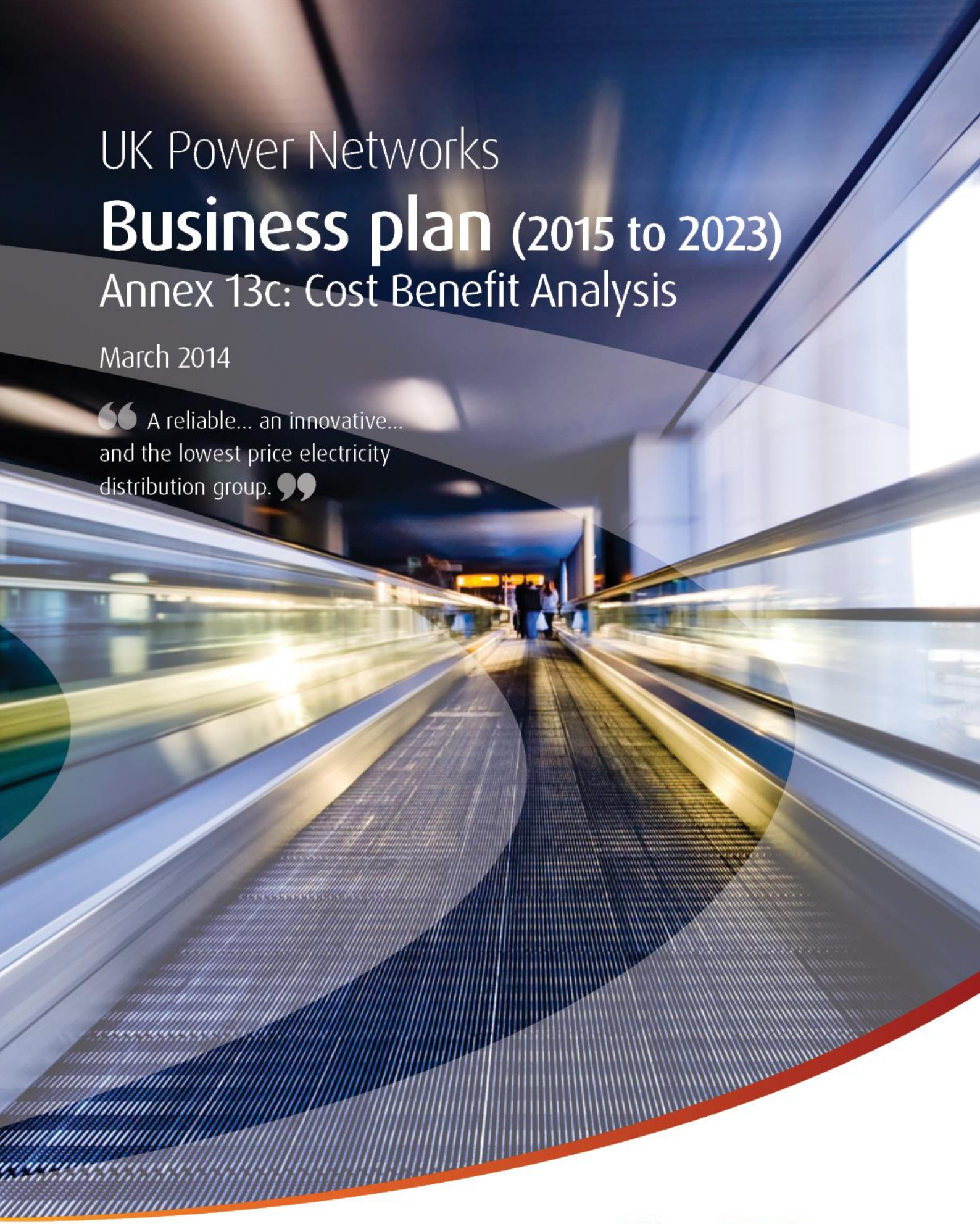

UK Power Networks

Business plan (2015 to 2023)

Annex 13c: Cost Benefit Analysis

March 2014

"A reliable... an innovative... and the lowest price electricity distribution group."

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Delivering your electricity

Contents

This annex has been updated to reflect UK Power Networks' March 2014 business plan. We have a tracked change version for the purpose of informing Ofgem of all revisions to the July 2013 business plan, should this be required.

1 Executive Summary

This document sets out UK Power Networks' use of Cost Benefit Analysis to evaluate and justify our key investment areas, in order to demonstrate a robust and justifiable expenditure plan. Extensive Cost Benefit Analysis (CBA) has been undertaken, based on Ofgem's guidance, to measure and quantify the benefits associated with key areas of our investment plan. Analysis has been focused on the major areas where we are proposing changes from the investment profile in DPCR5.

Our analysis shows that compared to industry volumes we are more efficient than industry average and a fast track equivalent. The CBA analysis on asset replacement shows that UK Power Networks is £216m more efficient on volumes than the industry benchmark (£329m when scaled assuming the results are representative of all expenditure) and £35m more efficient on volumes than the WPD equivalent benchmark (£112m if scaled).

This document describes the process we undertook, setting out the parameters and methodology we used in calculating the benefits, and our approach to treatment of these benefits within the CBAs.

Overall, we have undertaken CBAs on numerous activities that cover over 60% of our investment plans.

Table 1 Expenditure covered by CBAs

	EPN	LPN	SPN	UKPN Total
Total Expenditure Covered by CBAs	£855m	£982m	£526m	£2,063m
% of Capex covered by CBAs	66%	67%	62%	65%
% of Load Related Expenditure covered by CBAs	100%	100%	100%	100%
% of Non-Load Related Expenditure covered by CBAs	45%	46%	45%	46%
% of Asset Replacement/Refurbishment Expenditure covered by CBAs	60%	71%	67%	65%
% Increased expenditure for improved Central London performance	– 100%	100%	100%	100%

To address the comments made by Ofgem on our original submission and address the revised guidance that arose from their assessments of all the DNOs submissions we have comprehensively updated our approach as shown in Table 2.

Table 2 Ofgem Guidance and UK Power Networks' approach

Ofgem Guidance	UK Power Networks' approach
Options need to be realistic and appropriate. 'Do nothing' or 'run to failure scenarios' are not appropriate to compare investment options.	Our Asset Management engineers have reviewed and developed credible scenarios to assess. 'Do nothing' scenarios only exist where this is a real and possible option.
DNOs should consider a range of possible options, rather than limit to a baseline and one other option.	Most CBAs contain at least 3 or 4 options to compare
Benefits need to be realistic and justifiable, with transparent calculations and engineering feasibility.	Benefits are based on a mechanistic approach, using similar methodologies between assets and using established CBRM assumptions where possible, reflecting engineering judgement that is calibrated to historic performance. Calculations have been provided within each CBA model.
Costs and volumes should be easily identifiable and be able to be traced to their relevant RIGs tables.	Each CBA states which RIGs line the costs are taken from, and this document details the exact amount assigned to each line.
The baseline scenario should represent a realistic business scenario. In most cases, this is considered to be current DPCR5 levels of expenditure.	– The baseline scenario is current DPCR5 levels of intervention for most CBAs. In many cases, this option is not considered by UK Power Networks to be a viable long-term approach, but has been used to adhere to Ofgem Guidance. Where this is the optimum approach, we have selected the least negative option.

UK Power Networks has assessed its investments against a DPCR5 equivalent reference case as requested by Ofgem. We do not believe that historic volumes of activity are a good indicator of future investment where condition based asset management is used to make best use of assets and extend their lives by making the most appropriate interventions at the most appropriate time. To illustrate the efficiency of our plans we have tested our investments against two alternative scenarios which we have developed to represent equivalent industry average condition based volumes and WPD equivalent condition based volumes.

1.1 Conclusions

1.1.1 Asset Replacement

We have carried out assessments aimed at identifiable projects covering

- Fluid filled cables
- 132kV, 66kV and 33kV transformers
- 132kV, 66kV, 33kV and 11kV Primary switchgear,
- Overhead line Steel Towers

We have also carried out CBAs on our distribution switchgear and link box replacement programmes.

We have demonstrated that our condition based intervention strategies produce robust investment plans which provide positive benefits for customers and maintain the condition of the distribution networks. We have compared our investment plan to alternative strategies which give intervention volumes comparable to the other UK DNOs and the results are show our plans to be favourable.

The assessments have been summarised and presented in line with RIGs costs in Section 4. Scheme papers have also been provided separately for 30 asset replacement and refurbishment schemes.

1.1.2 Load-Related Reinforcement

We have populated a sample of 30 of our reinforcement projects for RIIO ED1 through the Ofgem CBA model showing supporting the scheme papers we have proved. The scheme papers giving technical options and solution choice have been provided separately for primary substation and EHV/132kV circuit reinforcement projects.

In EPN we have had a significant increase in requests to connect new low carbon generation which has not been seen in LPN and SPN. This is largely due to the availability of land for solar generation projects. We have included CBA to justify investment in EPN of £15.4 million of reinforcement which will increase network capacity for generation connections by 187MVA.

1.1.3 High Value Projects

We have included CBAs for key high value projects providing additional support to the detailed justification documentation supplied separately.

We have demonstrated that the replacement of gas filled cables between Sydenham and Eltham in south east London should be carried out in RIIO-ED1 rather than being deferred until RIIO-ED2

1.1.4 Flood Mitigation

Our proposals to protect at-risk sites from surface water flooding have been tested through CBA to ensure we are providing the most optimal solution.

1.1.5 BT21CN

A CBA has been carried out to show that our proposed solution for BT21CN is the least-cost solution for customers.

1.1.6 ESQCR

Our approach to dealing with the safety issues of presented by overhead lines where there is a high risk of contact by the public has been scrutinised to prove the mix of work we are proposing is optimal for customers.

1.1.7 Loss Reduction

We have used CBA to value the impact of our loss reduction initiative and identify the tipping point for investing in low loss transformers ahead of any limits being imposed by EU directives.

1.1.8 Smart Grid Solutions

We have used CBA to test the parameters we have used to assess the implementation smart technologies will have on our investment plans. These support using

- Demand Side Response (DSR) to defer investment. Separate parameters have been define around 2MVA in deferring reinforcement for at least 3 years in EPN and SPN and 5MVA of DSR deferring reinforcement for 4 years in LPN.
- Partial Discharge testing provides benefits in deferring switchgear replacement
- Smart adaptation of overhead line ratings will allow reinforcement to be managed more effectively
- Equipment to allow real time transformer rating provides benefits in allowing capacity increases to be deferred.

These technologies will allow our investment plans to be better optimised and uncertainties better managed.

1.2 Summary

In order to show how our plans compare to the other DNOs we have presented how our investment plans compare to our industry average condition based replacement volumes in. We have presented the outcomes for RIIO-ED1 as an eight year equivalent to the whole life costs and benefits (45 years) from the CBA assessments.

Table 3 Summary CBA results against Industry average volumes

CBA ED1 Total Benefit £m	kV	EPN	LPN	SPN
Fluid Filled Cable Intervention	132	2.7	5.1	10.1
	66		10.6	
	33	0.7	1.0	3.1
EHV Transformer Intervention	132	5.9	-0.05	2.2
	66		3.9	
	33	25.5	45.5	8.3
Switchgear Intervention	132	0.8	2.1	1.9
	66		0.1	
	33	4.3	3.3	5.0
	11	12.7	7.3	5.8
Link Boxes		0.1	2.2	0.3
Distribution Switchgear		29.7	4.7	11.0
Steel Towers		0.0		0.0
Asset Replacement and Reinforcement		**82.3**	**85.7**	**47.8**
Load Related Expenditure		10.9	4.6	2.6
High Value Projects		2.0	12.6	3.2
Flood Mitigation		8.1	3.2	4.3
ESQCR		2.5		0.6
BT21CN		1.3		1.3
Central London Plan			6.5	
Low Carbon generation		2.7	0.0	0.0
Losses		17.4	17.4	17.4
Smart Grid Strategy		0.0	0.0	0.0
QoS		4.0	0.4	2.5
Total		**131.4**	**130.3**	**79.6**

Table 4 shows the summary outcomes against the industry benchmark scaled to reflect our total capex.

Table 4 CBA Results against equivalent industry condition based replacement

£m Total Benefit in ED1	KV	UKPN	EPN	LPN	SPN
FFC	132	17.9	2.7	5.1	10.1
	66	10.6	0.0	10.6	0.0
	33	4.8	0.7	1.0	3.1
Transformers	132	8.1	5.9	0.0	2.2
	66	3.9	0.0	3.9	0.0
	33	79.3	25.5	45.5	8.3
Switchgear	132	4.8	0.8	2.1	1.9
	66	0.1	0.0	0.1	0.0
	33	12.6	4.3	3.3	5.0
	11	25.8	12.7	7.3	5.8
Link boxes		2.5	0.1	2.2	0.3
Distribution switchgear		45.4	29.7	4.7	11.0
Steel towers		0.0	0.0	0.0	0.0
Total		**215.7**	**82.3**	**85.7**	**47.8**
scaling		65%	65%	65%	67%
Scaled total		**329.0**	**137.1**	**120.6**	**71.3**

Table 5 shows the summary outcomes against our equivalent WPD condition based benchmark.

Table 5 CBA Results against equivalent WPD condition based replacement£m Total Benefit in ED1	KV	UKPN	EPN	LPN	SPN
Transformers	132	9.6	4.6	1.2	3.8
	66	-0.2	0.0	-0.2	0.0
	33	20.4	8.4	9.0	3.1
Switchgear	132	-1.5	-2.7	0.3	0.9
	66	-2.0	0.0	-2.0	0.0
	33	3.9	0.9	0.9	2.1
	11	4.6	1.3	2.0	1.4
Total		**34.9**	**12.5**	**11.1**	**11.3**
scaling		32%	32%	32%	27%
Scaled total		**112.1**	**34.6**	**36.3**	**41.3**

In aggregate for non load UK Power Networks is £216 million more efficient on volumes than the industry benchmark (£329 million when scaled assuming the results are representative of all expenditure) and £35 million more efficient on volumes than the WPD equivalent benchmark (£112 million if scaled). This represents a significant benefit to customers from our asset management approach that was not taken into account in the fast track assessment.

2 Introduction

A Cost Benefit Analysis (CBA) is a systematic way of calculating and comparing benefits and costs of a project. A CBA has two purposes

1. To determine if a project is a sound investment decision
2. To provide a basis for comparing projects or project options considering both the costs and benefits.

For the purposes of assessing our investment plans, and in line with Ofgem's guidance, CBA assessments have been used to consider the costs against the benefits of different intervention approaches. CBA has been focused on areas of investment where there is a marked difference in expenditure between DPCR5 and RIIO-ED1.

All costs and benefits assessments are presented in millions of pounds at 12/13 prices, before the application of our assumptions around on-going efficiency savings and real price effects.

2.1 Ofgem Guidance and Approach

Ofgem has set out their requirements for DNOs to follow in completing this assessment, to ensure a consistent comparison across the industry. Below we have detailed the key points from Ofgem's guidance and what we have done to adhere to this. Our revised CBAs use alternative technical options provided by our asset management teams based on the models used to develop our plans.

Table 6 Ofgem Guidance and UK Power Networks' Approach

Ofgem Guidance	UK Power Networks' Approach
Options need to be realistic and appropriate. 'Do nothing' or 'run to failure scenarios' are not appropriate to compare investment options.	Our Asset Management engineers have reviewed and developed credible scenarios to assess. 'Do nothing' scenarios only exist where this is a real and possible option.
DNOs should consider a range of possible options, rather than limit to a baseline and one other option.	Most CBAs contain at least 3 or 4 options to compare
Benefits need to be realistic and justifiable, with transparent calculations and engineering feasibility.	Benefits are based on a mechanistic approach, using similar methodologies between assets and using established CBRM assumptions where possible, reflecting engineering judgement that is calibrated to historic performance. Calculations have been provided within each CBA model.
Costs and volumes should be easily identifiable and be able to be traced to their relevant RIGs tables.	Each CBA states which RIGs line the costs are taken from, and this document details the exact amount assigned to each line.
The baseline scenario should represent a realistic business scenario. In most cases, this is considered to be current DPCR5 levels of expenditure.	– The baseline scenario is current DPCR5 levels of intervention for most CBAs. In many cases, this option is not considered by UK Power Networks to be a viable long-term approach, but has been used to adhere to Ofgem Guidance. Where this is the optimum approach, we have selected the least negative option.

2.2 Scope

Cost benefit analysis has been completed on the following areas of spend:

- Asset Replacement/refurbishment: Replacing/refurbishing assets maintains the condition of the network, essential to its safe operation and continuing high levels of quality of supply to customers.
- Load Related Reinforcement: The network needs to be constantly reinforced and upgraded to keep up with increases in consumer demand, ensuring a stable and consistent connection for customers.
- High Value Projects: Discretionary replacement projects with abnormally high investment costs.
- Flooding: Flood protection measures protect substations in the event of floods, reducing the possibility of customers losing supply.
- ESQCR: The mitigation overhead line issues that can cause safety issues to the public will decrease the risk of injuries and fatalities.
- BT21CN: Future changes in BT's infrastructure decommission some key telecommunications circuits used in the protection systems for long overhead line networks where circuit breakers at each end must be operated when a fault occurs. Malfunction of protection systems, due to Teleprotection failure, may result in increased damage at the point of fault, risk to personnel and members of the public and extended outages to the network
- Central London Plan: The economic importance of the electricity supply in Central London is greater than elsewhere in the UK. To ensure a resilient and robust network, additional investment and operating costs have been assessed in Central London, above what may normally be considered efficient.
- Low Carbon Generation Reinforcement: Investing in reinforcement to allow more low carbon generation to connect and displace higher carbon generation creating environmental benefits from reduced carbon emissions.
- Low Loss Equipment: Newer, more efficient equipment with lower losses ratings not only provides a financial benefit of the reduced cost of generating the lost energy, but also an environmental benefit, in the associated reduced carbon emissions.
- Smart Grid Solutions: Employing innovative techniques to help manage our network can help us defer investment to a point where we have more information about the future and what is needed.

Table 7 Expenditure covered by CBAs

	EPN	LPN	SPN	UKPN Total
Total Expenditure Covered by CBAs	£855m	£982m	£526m	£2,063m
% of Capex covered by CBAs	66%	67%	62%	65%
% of Load Related Expenditure covered by CBAs	100%	100%	100%	100%
% of Non-Load Related Expenditure covered by CBAs	45%	46%	45%	46%
% of Asset Replacement/Refurbishment Expenditure covered by CBAs	60%	71%	67%	65%

Overall, we these CBA assessments support over 60% of our proposed capital expenditure over RIIO-ED1.

2.2.1 Asset Replacement/Refurbishment

The CBAs are focused on the most significant categories of expenditure, particularly where we are proposing changes from DPCR5 investment levels. We have included CBAs for; fluid filled cables, 11kV Switchgear, EHV and 132kV Switchgears and EHV and 132kV transformers, OHL steel towers, distribution switchgear and link boxes.

Costs for these investments were calculated summating individual project costs (for fluid filled cables, 132kV/EHV/ 11kV Switchgear, 132kV/EHV transformers and steel towers) as this aligns all relevant costs across the associated RIGs tables with the associated benefits. Project costs are mapped to multiple Ofgem cost lines in the data tables to reflect all the works necessary to carry out that project and these costs are presented in the relevant section. Link boxes and distribution switchgear do not have individual projects our Asset Management plan, and so have only been done at an overall level.

The CBAs were grouped by voltage, so that the costs covered by the CBAs could be directly matched to the relevant Ofgem cost mapping lines in the data tables they require us to submit. The asset replacement and refurbishment schemes have been grouped together, so different mixes of work can be tested within the options.

The key costs and benefits that have been compared are as follows

Table 8 Asset Replacement Inputs

Price Control Costs/Benefits	Society Costs/Benefits
Investment Costs	Carbon Emissions
Costs Avoided (Faults, Maintenance costs)	Unsupplied Energy (Loss of supply)
	Oil Leakage
	Network Losses
	Safety improvements

2.2.2 Load Related Reinforcement

Reinforcement projects are essential to ensure the network remains capable of meeting increasing customer demand. We have applied Ofgem's CBA approach to a sample of 30 schemes, 10 in each of our DNOs. Each project has been compared against a number of other technically viable options that have been considered on a project by project basis. This represents 63% of our proposed Load Related Expenditure covered by CBAs. However, individual scheme papers for all of the proposed schemes are also provided as separate documents justifying our load related projects.

2.2.3 Flooding

Flood mitigation schemes in LPN are planned to lessen the effects of surface water flooding on our network. These schemes have been run through CBA to ensure we are undertaking the most cost-effective approach to dealing with the issue. The options considered were to complete traditional flood mitigation schemes (i.e. raise critical equipment above the flood level), to employ reactive measures (dealing with floods as and when they occur in substations), and to construct flood walls around the high risk substation sites.

2.2.4 ESQCR

Eliminating overhead lines where there is a high risk of dangerous contact for the public has a substantial area of expenditure. The CBA has been carried out to demonstrate our assumed mix of structural mitigation (i.e. not simple tree-cutting) is an appropriate response. Whilst there is a hierarchy associated with what measures are used in individual cases, different amounts of structural mitigation responses have been tested to see whether the right assumptions have been made in our plan.

2.2.5 BT21CN

As BT move to update their infrastructure, UK Power Networks needs to find a new solution for the network protection telecommunications that presently use dedicated BT circuits. As BT move to a digital 'IP' based networks these circuits will no longer be available. Five separate options have been considered to achieve this, ranging from a self-build network wholly owned by UK Power Networks, to leasing from a private network owner. Since all options achieve the same outcome, the analysis is a simple least-cost assessment.

2.2.6 Central London Network

We are proposing an additional £11.2 million of costs (£6.9 million of opex and £4.3 million of capex) to ensure the central London networks supplying 162,000 customers in the central business districts are maintained in a manner that delivers a service at the level expected and is consistent with the economic value added in this area, which is 19 time the UK average. We have assessed the costs against the supply improvements at an appropriate value or customer interruptions.

2.2.7 Low Carbon Generation

We have used cost benefit assessment of a number of potential projects to enable additional distributed generation connection to assess which would be included in our RIIO-ED1 business plan. The benefits included were the reduced emissions associated with low carbon generation displacing more traditional generation. Ofgem's recommended traded carbon values were used to quantify this.

In order to estimate the amount of low carbon generation each project would enable, the following parameters were used.

Table 9 Low Carbon Generation Inputs

Parameter	Comments
Capacity of the site	Measured in MVA
– Load Factor -0.4	Used to estimate an average loading
– Power Factor- 1 (At/near unity)	To convert the MVA into MWh

2.2.8 Low Loss Equipment

UK Power Networks has a strategy for managing technical losses as set out in Annex 7: Losses Strategy. A range of opportunistic measures have been planned within our proposed costs, and the CBA model has been used in order to determine the economic benefits.

In addition, a new possible EU directive may lead to new, tougher standards for electrical losses in our distribution transformers. A CBA assessment has been carried out and sensitivities were run to establish a threshold for the price of a new low loss transformer that would produce a positive CBA result. This is essentially a 'tipping point' price, where if these new transformers are below a certain price, installation of them can be considered justifiable, whereas if they turn out to be more expensive, it will not.

2.2.9 Smart Grid Solutions

A number of Smart technologies have been tested through Ofgem's CBA model, looking at whether the use of these technologies to defer conventional investment, provides sufficient justification for their utilisation. The technologies that were considered were:

- Demand Side Response
- Partial Discharge Testing (switchgear)
- Overhead line Ratings
- Real Time Transformer Ratings

2.2.10 Quality of Supply

A detailed discussion of the benefits is included in Annex 6: Quality of Supply. UK Power Networks is no longer seeking ex-ante funding for these improvements but we have included in this CBA to demonstrate that our proposals exhibit clear value for money for customers.

Our proposed investment in Quality of Supply related projects have been assessed against the improvements in forecast CIs and CMLs. The Quality of Supply schemes that were considered are

- Algorithmic Automation
- ASL Programme
- Auto Re-closer Programme
- Switchgear Change Programme
  Improved Operational Response

2.3 Input Parameters

The key parameters that were used for the CBA are shown in Table 10

Table 10 CBA Parameters

Parameter	Value	Comments
Cost of Capital	4.1%	RIIO ED1 UKPN average value based on revised cost of equity
– Discount rate	3.5%	Treasury Green Book/Ofgem guidance
– CI	£15.44	Ofgem's recommended values

Parameter	Value	Comments
– CML	£0.38	Ofgem's recommended values
– Losses £/MWh	£48.42	Ofgem's recommended values
– Oil Leakage £/Litre	£36.08	ARP Model/ Ofgem guidance
– Capitalization rate (split between fast & slow money)	70%	RIIO ED1 UKPN Value
– Asset Life	45 Years	Ofgem Guidance

2.4 Interpretation of Results

In general, the option with the most positive NPV will be judged to be the most cost efficient outcome.

There are some instances where this is not necessarily the outcome that has been chosen as our approach. Where DPCR5 expenditure/volumes as a baseline produces negative results for all the credible options we have considered, then the lease negative solution would be the most efficient outcome. Where this is the case, this has been discussed in the relevant results section.

2.5 Methodology used for Asset Replacement CBAs

For our primary asset replacement CBAs (fluid filled cables, EHV transformers, EHV and 11kV Switchgear), a common methodology has been used to ensure consistency and alignment with our Condition Based Risk Modelling (CBRM). The common methodology has been described below. Where alternative methods have been employed, these are described in the corresponding asset section.

2.5.1 Options Considered

Our Asset Management engineers considered a range of strategies that could be used as a viable alternative intervention strategy. The following four were considered as the most appropriate, and were subsequently put forward for analysis.

2.5.1.1 Baseline - DPCR5 volumes and costs

The DPCR5 volumes are calculated simply by using the current and forecast DPCR5 volumes, pro-rated to the eight year RIIO-ED1 period. Since there are no detailed costs for this scenario, a cost has been calculated based on an average unit cost per volume of work as contained within our RIIO-ED1 projects. This ensures we capture all costs associated with replacement/refurbishment, rather than basing it on a single activity line as used in Ofgem's data tables. UK Power Networks does not believe that this is the most appropriate reference case as condition based asset risk management will address the assets when the need arises. Good asset management practices will make the correct interventions as need arises and rather than relying on a constant investment level over time. We have therefore included two other scenarios comparing our investments to the average levels of investment being driven by the condition based replacement programmes of the industry and the condition based volumes of WPD.

2.5.1.2 Option 1- ED1 condition-based volumes and costs

These costs and volumes are taken from our detailed plan and include all associated costs for the projects. The volumes and interventions are derived from detailed condition based risk modelling and actual asset condition data to inform which assets are in need of intervention. This option therefore contains the most detailed and accurate cost and volume information of all options, and so these costs and volumes are used as the basis for the Unit Cost Indicator (UCI) calculations and alternative expenditures within the other options.

2.5.1.3 Option 2- Industry equivalent average condition based replacement volumes

In order to establish an equivalent strategy to industry average condition based replacement, our asset engineers developed an age-based proxy, using industry average ages of the assets as a signal of when their condition based strategies replace assets. Since we do not know the 'thresholds' for when DNOs deem intervention necessary, the apparent age they intervene from the Ofgem data tables that are shared amongst DNOs, has been used to estimate an industry average proxy age we can apply to our assets. Costs are calculated similarly to the baseline scenario, using a unit cost based on the ED1 condition based plan. Our asset engineers have assessed the impact this would have on the condition of the assets replaced.

2.5.1.4 Option 3– Replace all assets requiring intervention

This option involves replacing all assets where intervention is required, rather than refurbishing. The overall volumes are the same as in the ED1 condition based approach, but at a higher cost since there are more replacements occurring, typically a more costly activity. These costs are also calculated based on the UCI from Option 1. Some CBAs do not contain this option, if for instance option 1 already proposes to replace all assets.

2.5.1.5 Option 4 – WPD equivalent condition based volumes

For a number of assets we have included an option looking comparing the asset replacement and refurbishment proportions (approximately 10% refurbishment, the proportions are shown in the asset volume tables for each scenario) used by WPD and assessed as efficient by Ofgem in their fast-track decision.

2.5.2 Scenario Benefits

Using the volumes derived as per above, benefits associated with each approach are calculated, based on the number of HI4/5 assets each option removes from the network. Only removing assets that are HI4/5 produces any substantial benefits, and so the effect of replacing a HI3 asset has been assigned no benefit. This is consistent with our ARP models which are calibrated against observed failures. Mirroring the assumptions used in the RIGs HI tables, replacement of an asset will move its HI rating to a HI1, whilst refurbishment will move to a HI2. Our models show there to be no significant difference in the average probability of failure between a HI1 and a HI2 asset, meaning there is no substantial difference in benefits between replacement and refurbishment. This is consistent with the observed performance of current assets.

Our engineers compared each volume profile for each option against the baseline scenario, and a delta of the number of HI4/5 assets replaced/refurbished was assessed. For both the DPCR5 condition based, and the ED1 condition based options, they have assumed that all interventions on a HI4/5 asset (i.e. the delta HI4/5 between the baseline and the ED1 condition based scenario is simply the difference in volumes). Within the industry average replacement scenario not all assets that are proposed to be replaced will be a HI4/5 asset. Therefore, in addition to the volume profile, Asset Management engineers have also estimated a HI4/5 intervention profile that is used to calculate the associated strategy benefits, based on our current CBRM modelling.

This HI4/5 delta is multiplied by the difference in the average probability of failure between a HI1 and HI4/5 asset, to get a delta number of failures per annum. For example, should one Proposed Option replace 5 fewer HI4/5s than the baseline scenario, this will produce an increase in the number of asset Failures (PoF) (5*(PoF for HI4/5 - PoF for HI1)). This change in the number of failures has then been split across the different failure modes, Minor, Significant, Major, and Failure to operate, weighted according to their historic relative occurrences. This is consistent with the methodologies used within our asset risk model. All of these calculations are provided within each CBA for clarity.

We have assumed that all investments post RIIO-ED1 make no further change to condition.

2.5.2.1 CIs/CMLs

The failure rate from the HI4/5 deltas also allows an increase/decrease in the number of customer interruptions (CIs) and customer minutes lost (CMLs) to be calculated. This is based on our asset risk models and assesses the probabilities of different magnitudes of failure. Each asset type within the CBRM model uses a different assumption of the number of customers interrupted per failure, based on the average number of customers connected to each asset and the levels of redundancy in the networks. These are detailed within the corresponding asset section. The CMLs are then calculated by assuming that each of those customers would be off supply for a varying amount of time, depend on the failure mode. These again vary between the asset classes, as an assumed failure for 11kV switchgear will not cause the same length of loss of supply as a 132kV transformer.

2.5.2.2 Safety Consequences

Again using assumptions based in our CBRM models, the increased/decreased number of failures in each option are used to estimate how many of these will cause injury/fatalities. Each asset type is calibrated differently to assume that, given a failure occurs; there is a given probability of that failure causing an injury or fatality. This probability is simply multiplied by the increase/decrease in the number of failures as estimated by our Asset Management engineers.

2.5.2.3 Faults and Maintenance Costs

Each additional failure on the network has fault repair costs, as well as potentially increased maintenance costs, associated with it. Our engineers have mirrored the assumptions used in our risk modelling process to estimate the additional costs of repair and maintenance following an asset failure.

3 11kV Switchgear

3.1 Summary

We are proposing to spend over £117m over the RIIO-ED1 period across EPN, LPN and SPN on replacement or refurbishment of our 11kV Switchgear assets.

Each CBA has a number of options that produce different volumes of work, and therefore different levels of expenditure, with varying benefits associated with each approach. Refer to further on in this chapter for a description of each scenario and the methodology used.

The options considered, and their associated volumes, are shown in Table 11.

Table 11 CBA Option Volumes

CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average Replacement	Replace All	WPD Equivalent
EPN Replacement	295	759	1,803	851	875
EPN Refurbishment	44	92	0	0	86
LPN Replacement	232	363	1257	485	650
LPN Refurbishment	106	122	0	0	64
SPN Replacement	139	289	900	571	505
SPN Refurbishment	45	282	0	0	50

These volumes form the basis for all our approaches, with which alternative costs and benefits are calculated, as per in the 'Approach' section below.

Table 12 CBA Outcome

CBA Whole life Benefit £m	EPN	LPN	SPN	Total
DPCR5 Baseline	-31.00	-5.99	-14.84	-51.83
Average Industry condition equivalent	71.29	40.93	32.68	144.90
WPD condition equivalent	7.15	11.02	7.89	26.06

The table above shows the CBA outcomes of our RIIO-ED1 plan relative to the other scenarios assessed. These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

Against the DPCR5 volumes the CBAs show a negative outcome, reflecting the higher volume of work we are proposing in RIIO-ED1, which we believe is fully justified on condition.

The CBAs for 11kV Switchgear show positive benefits over our industry average condition and WPD condition scenarios indicating our volumes are efficient compared to other benchmarks.

3.2 Approach

For 11kV Switchgear, five different approaches were considered as viable intervention strategies, as described previously. These were

- DPCR5 Equivalent Volumes
- Condition-based intervention
- Industry average replacement
- Replace all assets requiring intervention
- WPD equivalent levels of Intervention

3.2.1 Options Volumes and costs

3.2.1.1 Baseline - DPCR5 volumes and costs

Using the methodology described above, the following costs and volumes were used for the baseline scenario.

Table 13 11kV Switchgear costs and volumes-baseline

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 11kV Switchgear	339	£20.42
LPN 11kV Switchgear	338	£12.34
SPN 11kV Switchgear	184	£9.18

3.2.1.2 Option - ED1 condition-based volumes and costs

These costs form the basis for which the costs in other scenarios are calculated.

Table 14 11kV Switchgear costs and volumes - ED1 condition based

CBA Model	Estimated Volumes	Estimated Costs	UCIs used in other options (£k/unit)
EPN 11kV Switchgear	759 Replace 92 Refurbish	£42.93m Replace £1.40m Refurbish £19.71m Civil Works	Replacement: £55.6k Refurbishment:£15.3k Civil Works:£23.1k
LPN 11kV Switchgear	363 Replace 122 Refurbish	£15.90m Replace £1.71m Refurbish £5.81m Civil Works	Replacement: £43.8 Refurbishment:£14.0 Civil Works:£12.0k
SPN 11kV Switchgear	289 Replace 282 Refurbish	£16.82m Replace £4.47m Refurbish £8.30m Civil Works	Replacement: £58.2k Refurbishment:£15.9k Civil Works:£14.5k

These costs map to the following RIGs lines

Table 15 EPN RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£12.34	£29.27	42%
CV3	33	Switchgear	6.6/11kV CB (GM) Primary	£19.11	£19.11	100%
CV3	38	Switchgear	6.6/11kV RMU	£2.90	£24.24	12%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	83	Transformer	33kV Transformer (GM)	£1.15	£19.36	6%
CV3	85	Protection	Batteries at 33kV Substations	£1.19	£3.58	33%
CV5	19	6.6/11kV CB (GM) Primary	Refurbishment - Switchgear	£1.40	£90.00	2%
CV6	16	Civil Works At 33kV & 66kV Substations		£0.28	£6.68	4%
CV6	30	Plinths and Groundworks		£0.33	£2.12	15%
CV6	31	Building		£19.11	£27.11	70%
CV8	7	Site security	EHV Substations	£2.79	£8.94	31%
CV8	13	Earthing upgrades	Locations	£0.38	£2.01	19%
CV105	6	Substation RTUs, marshalling kiosks, receivers		£2.36	£38.68	6%

Table 16 LPN RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£2.63	£10.38	25%
CV3	33	Switchgear	6.6/11kV CB (GM) Primary	£11.37	£11.37	100%
CV3	38	Switchgear	6.6/11kV RMU	£0.50	£22.78	2%
CV3	83	Transformer	33kV Transformer (GM)	£0.43	£2.58	17%
CV3	85	Protection	Batteries at 33kV Substations	£0.17	£0.83	21%
CV5	19	6.6/11kV CB (GM) Primary	Refurbishment - Switchgear	£1.71	£122.00	1%
CV6	28	Building		£0.29	£1.54	19%
CV6	30	Plinths and Groundworks		£0.06	£0.36	17%
CV6	31	Building		£5.46	£5.65	97%
CV8	7	Site security	EHV Substations	£0.41	£1.84	22%
CV8	13	Earthing upgrades	Locations	£0.05	£0.83	7%
CV105	6	Substation RTUs, marshalling kiosks, receivers		£0.34	£28.78	1 %

Table 17 SPN RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£4.62	£20.24	23%
CV3	33	Switchgear	6.6/11kV CB (GM) Primary	£7.87	£7.97	99%
CV3	38	Switchgear	6.6/11kV RMU	£1.40	£33.64	4%
CV3	51	Protection	Batteries at GM HV Substations	£0.11	£3.68	3%
CV3	83	Transformer	33kV Transformer (GM)	£0.50	£13.89	4%
CV3	85	Protection	Batteries at 33kV Substations	£0.38	£2.53	15%
CV5	19	6.6/11kV CB (GM) Primary	Refurbishment - Switchgear	£4.47	£294.00	2%
CV6	27	Plinths and Groundworks		£0.01	£1.58	0.5%
CV6	28	Building		£0.28	£0.70	40%
CV6	30	Plinths and Groundworks		£0.23	£1.53	15%
CV6	31	Building		£8.15	£8.64	94%
CV6	33	Plinths and Groundworks		£0.00	£1.28	0%
CV8	6	Site security	HV Substations	£0.04	£5.60	1%
CV8	7	Site security	EHV Substations	£1.17	£4.05	29%
CV8	13	Earthing upgrades	Locations	£0.17	£0.68	24%
CV101	8	Secondary network	HV to HV	£0.17	£2.31	7%
CV105	6	Substation RTUs, marshalling kiosks, receivers		£1.03	£29.83	3%

Using this method, all costs associated with these projects are taken into account, rather than just the primary RIGs lines that drive the intervention.

3.2.1.3 Option - Industry Equivalent Average Condition Based Volumes

The industry equivalent average replacement volumes have been estimated by using industry average asset age as a proxy for when other DNOs replace their assets based on condition. Since we don't know the 'thresholds' for when DNOs deem intervention necessary, age has been used to estimate this, using the age profile data tables that are shared amongst DNOs. For 11kV Switchgear, an average industry age of 56 years has been used. Costs have been estimated using the unit costs described above.

Table 18 11kV Switchgear costs and volumes - Industry equivalent volumes

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 11kV Switchgear	1,803	£142.08
LPN 11kV Switchgear	1,257	£70.12
SPN 11kV Switchgear	900	£65.47

3.2.1.4 Option – Replace all assets requiring intervention

This option involves replacing all assets where intervention is required, rather than refurbishing. The overall volumes are the same as in the ED1 condition based approach, but at a higher cost since there are more replacements occurring, typically a more costly activity. Costs have been estimated using the unit costs described above.

Table 19 11kV Switchgear costs and volumes - Replace All

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 11kV Switchgear	851	£67.06
LPN 11kV Switchgear	485	£27.06
SPN 11kV Switchgear	571	£41.54

3.2.1.5 Option – WPD Equivalent Condition Based Volumes

Since WPD has been fast tracked by Ofgem, having assessed their investment plans as efficient, we have tested whether we should we undertake the equivalent volumes of work. We have calculated the volumes for this scenario by replacing or refurbishing the same percentage of our asset base as WPD have proposed in their business plan that was accepted by Ofgem.

Table 20 11kV Switchgear costs and volumes- WPD Equivalent

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 11kV Switchgear	961	£72.25
LPN 11kV Switchgear	714	£37.93
SPN 11kV Switchgear	555	£38.25

3.2.2 Scenario Benefits

The benefits for 11kV Switchgear are calculated as per the methodology described above, using the difference in the number of HI4/5 assets being replaced by each strategy. The average probability used for a HI4/5 asset is 1.68%, 1.97%, 1.26% for EPN, LPN and SPN respectively. The average probability of failure for a HI1/2 asset is 0.35% across all three DNOs.

3.2.2.1 CIs/CMLs

The increase/decrease in the number of customer interruptions (CIs) and customer minutes lost (CMLs) is obtained using the average number of customers connected to each asset which gives 1,402 customers interrupted per failure. The CMLs are then calculated by assuming that each of those customers would be off supply for an amount of time depending on the failure mode as defined in our asset management models. A minor failure would cause a loss of supply for three minutes, a significant failure would be 30 minutes, and a major failure would cause customers to be off supply for 75 minutes. These combine to produce a weighted average CML per CI of 7.63 minutes. These produce an assumption that, for every failure of an asset, this will cause 1,402 CIs and 10,697 CMLs.

3.2.2.2 Safety Consequences

Again using assumptions based in our asset management models, the increased/decreased number of failures in each option are used to estimate how many of these will cause injury/fatalities. The table below shows the probability that, given a failure has already occurred, this will have safety repercussions.

Table 21 Assumptions on probability of injury/fatality

	Minor failure	Significant failure	Major failure	Failure to operate
Probability of minor injury	0.1	0.2	0.5	0.2
Probability of major injury	0.01	0.02	0.05	0.02
Probability of fatality	0.001	0.002	0.005	0.002

When the different failure modes are combined and weighted by their historic occurrences, each additional asset failure causes, 0.0127 major injuries, and 0.00127 fatalities per annum.

3.2.2.3 Faults and Maintenance Costs

Each additional failure on the network has fault repair costs, as well as potentially increased maintenance costs, associated with it. The following values taken from our asset management models have been used to estimate the additional costs of repair and maintenance following an asset failure.

Table 22 Assumptions on Faults and Maintenance Costs

Minor failure	Significant failure	Major failure	Failure to operate
£5,000	£30,000	£120,000	£5,000

3.2.3 Sensitivities

In the case of 11kV Switchgear, the only sensitivity run was on the customer time off supply in LPN, increasing it from 7.63 minutes to 30 minutes to test the strength of our assumption that, on average, most losses of supply will only be for an extremely short amount of time. When the sensitivity ran on LPN proved to make very little difference in the outcome of the CBA, it was decided not to run similar sensitivities on the other DNOs.

3.3 Results

3.3.1 CBA Results

Table 23 EPN 11kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£20.63	-£25.17	-£28.12	-£31.00
Industry Equivalent Average Condition Based Volumes	-£65.97	-£81.47	-£91.79	-£102.29
Replace all	-£22.09	-£27.19	-£30.52	-£33.79
WPD Equivalent Condition Based Volumes	-£25.33	-£30.94	-£34.59	-£38.15

Table 24 LPN 11kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£4.27	-£5.05	-£5.55	-£5.99
Sensitivity on ED1 condition based	-£4.05	-£4.71	-£5.11	-£5.43
Industry Equivalent Average Condition Based Volumes	-£30.83	-£37.76	-£42.33	-£46.92
Sensitivity on Industry Equivalent Average Condition Based Volumes	-£30.29	-£36.97	-£41.35	-£45.68
Replace all	-£5.67	-£7.00	-£7.86	-£8.70
WPD Equivalent Condition Based Volumes	-£11.74	-£14.11	-£15.62	-£17.01

Table 25 SPN 11kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£10.15	-£12.22	-£13.56	-£14.84
Industry Equivalent Average Condition Based Volumes	-£31.13	-£38.16	-£42.81	-£47.53
Replace all	-£15.85	-£19.65	-£22.15	-£24.65
WPD Equivalent Condition Based Volumes	-£15.16	-£18.45	-£20.60	-£22.73

3.3.2 Discussion

The chosen option (highlighted in orange in Table 23, Table 24 and Table 25) is the ED1 condition based replacement for all DNOs. Our CBA assessment shows that our condition based programme provides a more positive CBA than an industry average or WPD equivalent programme of work.

The results are all negative because the DPCR5 volumes have been used as the baseline to adhere to Ofgem guidance. A strategy based on these volumes is not considered as a reasonable strategy to maintain asset condition, particularly in the long term.

Switchgear replacement or refurbishment is based on condition as detailed in Section 3 of the Asset Stewardship Reports. For all three licence areas the intervention volumes in ED1 have increased compared to DPCR5. The two main reasons for this are:

- An increasing deterioration in operating mechanism performance evidenced by rising circuit breaker trip times and the number of circuit breakers failing to clear a fault.
- A rise in the number of circuit breakers with poor insulation performance resulting in unsustainable levels of partial discharge activity.

Where possible, refurbishment remains the preferred option, but there are some circumstances where this is either not feasible due to non-availability of components or skills or uneconomic due to the extent of the work involved.

4 EHV Transformers

4.1 Summary

We are proposing to spend over £153 million over the RIIO-ED1 period across EPN, LPN and SPN on intervention of our 11kV Switchgear assets.

Each CBA has a number of options that produce different volumes of work, and therefore different levels of expenditure, with varying benefits associated with each approach. Refer to further on in this chapter for a description of each scenario and the methodology used.

The options considered, and their associated volumes, are shown below.

Table 26 CBA Option Volumes

	CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average Replacement	Replace All	WPD Equivalent Volumes
EPN	132kV Replacement	8	22	49	27	41
	132kV Refurbishment	13	5	0	0	5
	33kV Replacement	42	43	372	66	147
	33kV Refurbishment	21	23	0	0	1
LPN	132kV Replacement	0	20	21	24	29
	132kV Refurbishment	30	4	0	0	4
	66kV Replacement	10	11	47	12	11
	66kV Refurbishment	0	1	0	0	0
	33kV Replacement	6	11	103	11	29
	33kV Refurbishment	6	0	0	0	0
SPN	132kV Replacement	21	10	23	19	28
	132kV Refurbishment	10	9	0	0	4
	33kV Replacement	35	35	147	66	80
	33kV Refurbishment	5	31	0	0	1

These volumes form the basis of the costs and benefits for all our approaches, as per the Approach section.

Table 27 CBA Outcomes 132kV transformer

132kV Transformer Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline	-15.64	-9.48	12.45	-12.66
Average Industry condition equivalent	33.09	-0.28	12.55	45.36
WPD condition equivalent	25.95	6.72	21.58	54.25

Table 28 CBA Outcomes 66kV transformer

66kV Transformer Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline		-1.44		-1.44
Average Industry condition equivalent		21.69		21.69
WPD condition equivalent		-1.05		-1.05

Table 29 CBA Outcomes 33kV transformer

33kV Transformer Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline	-0.89	-13.30	-3.91	-18.10
Average Industry condition equivalent	143.41	255.91	46.66	445.98
WPD condition equivalent	47.26	50.47	17.20	114.92

Table 27, Table 28 and Table 29 show the CBA outcomes of our RIIO-ED1 plan relative to the other scenarios assessed. These values are for the full 45 year CBA period and are converted to an eight year straight line equivalent for the executive summary and stakeholder facing documents.

The results show our plans are robust when compared to the industry average condition based replacement volumes or the WPD condition based volumes, with LPN 66kV transformers only being marginally negative to the WPD condition equivalent.

The negative results compared to the baseline reflect the different mix of replacement and refurbishment inherent in our RIIO-ED1 plan. Increases in transformer replacement have been limited by the use of refurbishments to extend the serviceable life of the assets in the current period and our strategy continues to favour refurbishment where this is technically justified.

Additional justification for our chosen approach can be seen in the Asset Strategy Report provided along with this document as part of the business plan submission. A further discussion of the results is further in this chapter.

4.2 Approach

For EHV transformers, five different approaches were considered as viable intervention strategies as described earlier in the document. These were:

- DPCR5 equivalent volumes
- Condition-based intervention, including both replacement and refurbishment where viable
- Industry average replacement
- Replace all assets requiring intervention
- WPD Equivalent volumes

4.2.1 Options Volumes and costs

4.2.1.1 Baseline - DPCR5 volumes and costs

Using the methodology as described earlier, the following inputs are used in the model:

Table 30 EHV Transformer costs and volumes - Baseline

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Transformer	21	£14.64
EPN 33kV Transformer	63	£25.79
LPN 132kV Transformer	30	£6.61
LPN 66kV Transformer	10	£6.80
LPN 33kV Transformer	12	£20.57
SPN 132kV Transformer	31	£29.54
SPN 33kV Transformer	40	£19.43

4.2.1.2 Option - ED1 condition-based volumes and costs

These costs and volumes are taken from our Asset Management proposed plan, and form the basis of all other costs used in the alternative scenarios.

Table 31 EHV Transformer costs and volumes - ED1 Condition Based

CBA Model	Estimated Volumes	Estimated Costs	UCIs used in other options (£k/Unit)
EPN 132kV Transformer	22 Replace 5 Refurbish	£28.29m Replace £0.75m Refurbish £3.07m Civil Works	Replacement: £1,285k Refurbishment: £150k Civil Works: £114k
EPN 33kV Transformer	43 Replace 23 Refurbish	£19.02m Replace £3.39m Refurbish £4.30m Civil Works	Replacement: £442k Refurbishment: £148k Civil Works: £65k
LPN 132kV Transformer	20 Replace 4 Refurbish	£14.44m Replace £0.67m Refurbish £1.28m Civil Works	Replacement: £722k Refurbishment: £167k Civil Works: £53k
LPN 66kV Transformer	11 Replace 1 Refurbish	£7.27m Replace £0.29 Refurbish £0.23m Civil Works	Replacement: £661k Refurbishment: £189k Civil Works: £19k
LPN 33kV Transformer	11 Replace	£31.45m Replace £2.10m Civil Works	Replacement: £2,858k Refurbishment: £189k (based on LPN 66kV) Civil Works: £191k
SPN 132kV Transformer	10 Replace 9 Refurbish	£12.30m Replace £1.38m Refurbish £1.34m Civil Works	Replacement: £1,230k Refurbishment: £154k Civil Works: £70k
SPN 33kV Transformer	35 Replace 31 Refurbish	£16.44m Replace £4.48m Refurbish £3.75m Civil Works	Replacement: £470k Refurbishment: £144k Civil Works: £57k

For transparency, these costs map to the following RIGs lines:

Table 32 EPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	48	Transformer	6.6/11kV Transformer (GM)	£0.04	£11.32	0%
CV3	70	Switchgear	33kV CB (Air Insulated Busbars)(OD) (GM)	£0.05	£3.88	1%
CV3	83	Transformer	33kV Transformer (GM)	£0.50	£19.36	3%
CV3	89	Overhead Tower Line	132kV OHL (Tower Line) Conductor	£0.91	£37.41	2%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.37	£0.74	51%
CV3	100	Switchgear	132kV Switchgear - Other	£0.69	£0.75	91%
CV3	101	Transformer	132kV Transformer	£23.73	£23.73	100%
CV5	32	33kV Transformer (GM)	Refurbishment - Transformer	£3.39	£3.42	99%
CV6	33	Plinths and Groundworks		£1.95	£2.38	82%
CV6	34	Building		£0.19	£8.08	2%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV6	35	Enclosures and Surrounds		£0.93	£1.74	54%
CV8	8	Site security	132kV Substations	£0.83	£10.16	8%
CV8	13	Earthing upgrades	Locations	£1.17	£2.01	58%

Table 33 EPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£0.90	£29.27	3%
CV3	48	Transformer	6.6/11kV Transformer (GM)	£0.56	£11.32	5%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£0.33	£12.09	3%
CV3	83	Transformer	33kV Transformer (GM)	£15.63	£19.36	81%
CV5	32	33kV Transformer (GM)	Refurbishment - Transformer	£3.39	£3.42	99%
CV6	30	Plinths and Groundworks		£1.42	£2.12	67%
CV6	32	Enclosures and Surrounds		£2.88	£3.24	89%
CV8	7	Site security	EHV Substations	£1.61	£8.94	18%

Table 34 LPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	**29**	Cable	6.6/11kV UG Cable	£0.40	£10.38	4%
CV3	**48**	Transformer	6.6/11kV Transformer (GM)	£0.12	£8.90	1%
CV3	**83**	Transformer	33kV Transformer (GM)	£0.07	£2.58	3%
CV3	**96**	Switchgear	132kV CB (Air Insulated Busbars)(ID) (GM)	£0.05	£1.02	5%
CV3	**97**	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.11	£1.86	6%
CV3	**100**	Switchgear	132kV Switchgear - Other	£0.30	£2.48	12%
CV3	**101**	Transformer	132kV Transformer	£12.95	£40.96	32%
CV5	42	66kV Transformer	Refurbishment - Transformer	£0.19	£0.19	100%
CV5	52	132kV Transformer	Refurbishment - Transformer	£0.21	£0.67	32%
CV6	33	Plinths and Groundworks		£0.81	£2.42	34%
CV6	34	Building		£0.08	£2.57	3%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV6	35	Enclosures and Surrounds		£0.39	£1.18	33%
CV8	8	Site security	132kV Substations	£0.36	£2.85	13%
CV8	13	Earthing upgrades	Locations	£0.08	£0.83	10%

Table 35 LPN 66kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£0.06	£10.38	1%
CV3	48	Transformer	6.6/11kV Transformer (GM)	£0.01	£8.90	0%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£0.01	£8.54	0%
CV3	70	Switchgear	33kV CB (Air Insulated Busbars)(OD) (GM)	£0.01	£0.33	3%
CV3	83	Transformer	33kV Transformer (GM)	£0.06	£2.58	2%
CV3	84	Transformer	66kV Transformer	£6.04	£6.04	100%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.01	£1.86	0%
CV5	42	66kV Transformer	Refurbishment - Transformer	£0.19	£0.19	100%
CV6	30	Plinths and Groundworks		£0.05	£0.36	13%
CV6	31	Building		£0.02	£5.65	0%
CV6	32	Enclosures and Surrounds		£0.16	£0.48	34%
CV8	7	Site security	EHV Substations	£0.03	£1.84	1%
CV8	13	Earthing upgrades	Locations	£0.02	£0.83	2%
CV101	11	Primary network (n-1)	EHV to EHV	£0.97	£2.88	34%
CV105	6	Substation RTUs, marshalling kiosks, receivers		£0.07	£28.78	0%

Table 36 LPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£0.11	£10.38	1%
CV3	48	Transformer	6.6/11kV Transformer (GM)	£0.12	£8.90	1%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£0.06	£8.54	1%
CV3	70	Switchgear	33kV CB (Air Insulated Busbars)(OD) (GM)	£0.02	£0.33	7%
CV3	83	Transformer	33kV Transformer (GM)	£1.73	£2.58	67%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£1.30	£61.26	2%
CV3	96	Switchgear	132kV CB (Air Insulated Busbars)(ID) (GM)	£0.02	£1.02	2%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.16	£1.86	9%
CV3	100	Switchgear	132kV Switchgear - Other	£0.33	£2.48	13%
CV3	101	Transformer	132kV Transformer	£23.08	£40.96	56%
CV6	30	Plinths and Groundworks		£0.18	£0.36	51%
CV6	32	Enclosures and Surrounds		£0.31	£0.48	65%
CV6	33	Plinths and Groundworks		£0.94	£2.42	39%
CV6	34	Building		£0.09	£2.57	4%
CV6	35	Enclosures and Surrounds		£0.44	£1.18	37%
CV8	7	Site security	EHV Substations	£0.20	£1.84	11%
CV8	8	Site security	132kV Substations	£0.40	£2.85	14%
CV8	13	Earthing upgrades	Locations	£0.56	£0.83	68%
CV101	13	Primary network (n-1)	132 kV to HV	£1.96	£31.53	6%

Table 37 SPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£0.09	£20.24	0.44%
CV3	48	Transformer	6.6/11kV Transformer (GM)	£0.03	£10.44	0%
CV3	70	Switchgear	33kV CB (Air Insulated Busbars)(OD) (GM)	£0.02	£0.02	100%
CV3	83	Transformer	33kV Transformer (GM)	£0.18	£13.89	1%
CV3	89	Overhead Tower Line	132kV OHL (Tower Line) Conductor	£0.39	£11.79	3%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.16	£1.22	13%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	100	Switchgear	132kV Switchgear - Other	£0.30	£1.30	23%
CV3	101	Transformer	132kV Transformer	£10.34	£10.34	100%
CV5	32	33kV Transformer (GM)	Refurbishment - Transformer	£4.48	£4.48	100%
CV5	52	132kV Transformer	Refurbishment - Transformer	£0.25	£1.38	18%
CV6	30	Plinths and Groundworks		£0.01	£1.53	1%
CV6	33	Plinths and Groundworks		£0.83	£1.28	65%
CV6	34	Building		£0.08	£3.71	2%
CV6	35	Enclosures and Surrounds		£0.41	£0.73	57%
CV8	7	Site security	EHV Substations	£0.04	£4.05	1%
CV8	8	Site security	132kV Substations	£0.32	£9.74	3%
CV8	13	Earthing upgrades	Locations	£0.41	£0.68	60%

Table 38 SPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	29	Cable	6.6/11kV UG Cable	£0.69	£20.24	3%
CV3	48	Transformer	6.6/11kV Transformer (GM)	£0.37	£10.44	4%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£0.34	£10.86	3%
CV3	83	Transformer	33kV Transformer (GM)	£11.61	£13.89	84%
CV5	32	33kV Transformer (GM)	Refurbishment - Transformer	£4.48	£4.48	100%
CV6	29	Enclosures and Surrounds		£0.05	£0.29	19%
CV6	30	Plinths and Groundworks		£1.15	£1.53	75%
CV6	32	Enclosures and Surrounds		£2.28	£2.59	88%
CV8	7	Site security	EHV Substations	£1.32	£4.05	32%
CV10 1	10	Primary network (n-1)	EHV to HV	£0.88	£30.84	3%

Using this method, all costs associated with these projects are taken into account, rather than just the primary RIGs lines that drive the intervention.

4.2.1.3 Option - Industry Equivalent Average Condition Based Volumes

The industry equivalent average replacement volumes have been estimated by using an industry average asset age as a proxy for when other DNOs replace their assets based on condition. Since we don't know the condition 'thresholds' for when DNOs deem intervention necessary, age has been used to estimate this, using the Age profile data tables that are shared amongst DNOs. For 132kV Transformers, an average asset age of 61 years has been used, whilst 66kV and 33kV both use 59 years. Costs are calculated similarly to the baseline scenario, using a unit cost based on the ED1 condition based plan.

Table 39 EHV Transformer costs and volumes - Industry equivalent volumes

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Transformer	49	£68.58
EPN 33kV Transformer	372	£188.83
LPN 132kV Transformer	21	£16.29
LPN 66kV Transformer	47	£21.96
LPN 33kV Transformer	103	£314.10
SPN 132kV Transformer	23	£29.90
SPN 33kV Transformer	147	£77.39

4.2.1.4 Option – Replace all assets requiring intervention

This option involves replacing all assets where intervention is required, rather than refurbishing. The overall volumes are the same as in the ED1 condition based approach, but at a higher cost since there are more replacements occurring, typically a more costly activity.

Table 40 EHV Transformer costs and volumes - Replace All

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Transformer	27	£37.79
EPN 33kV Transformer	66	£33.50
LPN 132kV Transformer	24	£18.61
LPN 66kV Transformer	12	£8.16
LPN 33kV Transformer	11	£33.54
SPN 132kV Transformer	19	£15.02
SPN 33kV Transformer	66	£24.67

4.2.1.5 Option – WPD Equivalent Condition Based Volumes

Since WPD has been fast-tracked by Ofgem, having assessed their investment plans as efficient, we have tested the outcome should we undertake the equivalent volumes of work. We have calculated the volumes for this scenario by replacing the same percentage of our asset base as WPD have proposed in their business plan that was accepted by Ofgem.

Table 41 EHV Transformer costs and volumes - WPD Equivalent

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Transformer	46	£58.70
EPN 33kV Transformer	148	£74.83
LPN 132kV Transformer	33	£23.37
LPN 66kV Transformer	11	£7.48
LPN 33kV Transformer	29	£88.44
SPN 132kV Transformer	32	£37.30
SPN 33kV Transformer	81	£42.32

4.2.2 Scenario Benefits

The benefits for EHV Transformers are calculated as per the methodology previously described, using the difference in the number of HI4/5 assets being replaced by each strategy. The average probability of failures for each HI class is shown below.

Table 42 Probabilities of Failure

	HI4/5 Asset	HI1/2 Asset
132kV	8.34%	1.70%
66kV	8.29%	1.60%
33kV	8.29%	1.60%

This change in the number of failures has then been split across the different failure modes, Minor, Significant, and Major, weighted according to their historic relative occurrences. All of these calculations are provided within each CBA for clarity.

4.2.2.1 CIs/CMLs

Our Asset Management engineers have assessed the number of CIs by taking the average number of customers per transformer, and assuming only a certain percentage of customers will lose supply following equipment failure (85% for 33kV, 65% for 66kV, and 50% for 132kV). It is then assumed that two transformers will need to be off supply in order for a failure to impact customers. Our CBRM modelling assumes that there is a 5% chance that a transformer will fail at the same time another is off load being out for maintenance (equivalent to an 18 day outage).

The CMLs are then calculated by assuming that each of those customers would be off supply for a varying amount of time, depending on the failure mode. A minor failure would cause a loss of supply for 180 minutes, a significant failure would be 240 minutes, and a major failure would cause customers to be off supply for 480 minutes. These combine to produce a weighted average CML per CI of 207 minutes. Thus, the following CI and CMLs would occur per additional failure (weighted by failure mode):

Table 43 Probabilities of Failure

	CIs per failure	CML per failure
EPN 132kV	344	71,180
EPN 33kV	167	34,476
LPN 132kV	512	106,145
LPN 66kV	314	81,647
LPN 33kV	516	106,770

	CIs per failure	CML per failure
SPN 132kV	535	110,677
SPN 33kV	315	65,235

4.2.2.2 Safety Consequences

Based in our CBRM modelling, the increased/decreased number of failures in each option are used to estimate how many of these will cause injury/fatalities. The table bellows show that probability that, given a failure has already occurred, this will have safety repercussions.

Table 44 Probability of injury/fatality

	Minor failure	Significant failure	Major failure
Probability of minor injury	0.01	0.02	0.1
Probability of major injury	0.001	0.002	0.01
Probability of fatality	0.0001	0.0002	0.001

When the different failure modes are combined and weighted by their historic occurrences, an additional asset failure causes 0.00165 major injuries and 0.000165 fatalities per annum.

4.2.2.3 Faults and Maintenance Costs

Each additional failure on the network has fault repair costs, as well as potentially increased maintenance costs, associated with it. The following data from our asset management models have been used to estimate the additional costs of repair and maintenance following an asset failure.

Table 45 Faults and Maintenance Costs

	Minor failure	Significant failure	Major failure
Opex	£5,000	£25,000	£125,000
Capex	£0	£75,000	£750,000

4.2.3 Sensitivities

In the case of EHV Transformers, sensitivities were run for EPN 33kV, LPN 132kV and LPN 66kV, increasing the assumed time off supply from 207 minutes to 360 minutes. This was just to test the strength of our assumption used in CBRM modelling. This proves to make very little difference in the outcome of the CBAs.

4.3 Results

4.3.1 CBA Results

Table 46 EPN 132V Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£10.16	-£12.49	-£14.04	-£15.64
Industry Equivalent Average Condition Based Volumes	-£31.20	-£38.62	-£43.59	-£48.73
Replace all	-£13.43	-£16.54	-£18.62	-£20.76
WPD Equivalent Condition Based Volumes	-£26.88	-£33.10	-£37.27	-£41.59

Table 47 EPN 33kV Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£0.56	-£0.70	-£0.80	-£0.89
Sensitivity on ED1 condition based	-£0.55	-£0.69	-£0.78	-£0.87
Industry Equivalent Average Condition Based Volumes	-£89.93	-£112.86	-£128.28	-£144.30
Replace all	-£4.14	-£5.24	-£5.98	-£6.75
WPD Equivalent Condition Based Volumes	-£31.07	-£38.27	-£43.11	-£48.16

Table 48 LPN 132kV Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£6.04	-£7.48	-£8.46	-£9.48
Sensitivity on ED1 Condition Based	-£6.11	-£7.59	-£8.59	-£9.65
Industry Equivalent Average Condition Based Volumes	-£5.75	-£7.18	-£8.16	-£9.19
Sensitivity on Industry Average Condition Based Volumes	-£5.93	-£7.43	-£8.47	-£9.58
Replace all	-£7.39	-£9.14	-£10.31	-£11.54
WPD Equivalent Condition Based Volumes	-£10.28	-£12.77	-£14.44	-£16.19

Table 49 LPN 66kV Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£1.40	-£1.43	-£1.44	-£1.44
Sensitivity on ED1 condition based	-£1.39	-£1.42	-£1.43	-£1.42
Industry Equivalent Average Condition Based Volumes	-£15.14	-£18.53	-£20.80	-£23.14
Replace all	-£1.36	-£1.48	-£1.55	-£1.61
WPD Equivalent Condition Based Volumes	-£0.32	-£0.36	-£0.38	-£0.40

Table 50 LPN 33kV Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£8.85	-£10.75	-£12.01	-£13.30
Industry Equivalent Average Condition Based Volumes	-£173.65	-£214.12	-£241.23	-£269.22
Replace all	-£9.71	-£11.55	-£12.78	-£14.03
WPD Equivalent Condition Based Volumes	-£41.33	-£50.84	-£57.20	-£63.77

Table 51 SPN 132kV Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£8.17	£10.00	£11.22	£12.45
Industry Equivalent Average Condition Based Volumes	£0.59	£0.33	£0.13	-£0.10
Replace all	£2.96	£3.43	£3.73	£4.01

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
WPD Equivalent Condition Based Volumes	-£5.70	-£7.12	-£8.08	-£9.13

Table 52 SPN 33kV Transformer Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£2.67	-£3.21	-£3.57	-£3.91
Industry Equivalent Average Condition Based Volumes	-£31.95	-£39.84	-£45.12	-£50.57
Replace all	-£8.27	-£10.22	-£11.51	-£12.83
WPD Equivalent Condition Based Volumes	-£13.88	-£16.95	-£19.00	-£21.10

4.3.2 Discussion

The chosen option (highlighted in orange in the above tables) is the ED1 condition based replacement for all DNOs. Whilst in most cases this is more negative than the baseline scenario reflecting the increased proportion of asset replacement our condition data indicates is necessary, the chosen option is usually the 'least negative' option from the remaining choices, including the industry average and WPD equivalent options. LPN's 66kV transformers show a less negative result than the WPD alternative volumes which is due to a difference in volume of a single additional transformer refurbishment.

The ED1 plan has been developed using a bottom up method utilising all available condition data, including oil sample analysis results, defects, environmental and loading data in addition to consideration of the specific make and model of transformers and tap changers, as detailed in the Asset Stewardship Reports. Increases in transformer replacement have been limited by the use of refurbishments to extend the serviceable life of the assets. Where possible, refurbishment is the preferred option, but there are some circumstances where this is either not feasible due to the internal condition of the transformer or uneconomic due to the extent of the work involved. The internal condition of the transformer, assessed by analysing oil samples, can show:

- Degradation of the paper insulation identified through formaldehyde content
- Identification of developing faults identified using dissolved gas analysis to determine the temperatures reached by faults ranging from discharge activity to electrical arcing.

Although the LPN 132kV transformers are also very slightly negative compared to the industry average replacement scenario, the difference is very marginal. Therefore, we have decided to remain with the strategy that is in line with the rest of our transformer intervention approach. LPN's 66kV transformers show a less negative result in the WPD alternative volumes which is due to a difference in volume of a single additional transformer refurbishment, so we consider that these CBA assessments support our proposed investment plans.

5 EHV Switchgear

5.1 Summary

We are proposing to spend over £129 million over the RIIO-ED1 period across EPN, LPN and SPN on intervention of our EHV Switchgear assets.

Each CBA has a number of options that produce different volumes of work, and therefore different levels of expenditure, with varying benefits associated with each approach. Refer to previous chapters for a description of each scenario and the methodology used.

The options considered, and their associated volumes, are shown below.

Table 53 CBA Option Volumes

	CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average Replacement	WPD Equivalent Volumes
EPN	132kV Replacement	72	61	68	42
	132kV Refurbishment	0	0	0	6
	33kV Replacement	264	255	476	304
	33kV Refurbishment	0	0	0	2
LPN	132kV Replacement	16	26	60	32
	132kV Refurbishment	0	0	0	4
	66kV Replacement	32	35	37	3
	66kV Refurbishment	0	0	0	0
	33kV Replacement	56	10	265	88
	33kV Refurbishment	0	0	0	1
SPN	132kV Replacement	40	26	42	33
	132kV Refurbishment	0	0	0	5
	33kV Replacement	72	17	347	168
	33kV Refurbishment	0	8	0	1

These volumes form the basis of the costs and benefits for all our approaches, as per the Approach section.

Table 54 CBA Outcomes 132kV

132kV Switchgear Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline	8.19	-4.20	9.04	13.04
Average Industry condition equivalent	4.44	11.78	10.63	26.85
WPD condition equivalent	-15.13	1.82	4.82	-8.49

Table 55 CBA Outcomes 66kV

66kV Switchgear Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline		-1.67		-1.67
Average Industry condition equivalent		0.67		0.67
WPD condition equivalent		-11.52		-11.52

Table 56 CBA Outcomes 33kV

33kV Switchgear Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline	1.16	3.26	4.16	8.58
Average Industry condition equivalent	24.21	18.63	28.14	70.98
WPD condition equivalent	5.02	5.10	12.00	22.12

Table 54, Table 55 and Table 56show the CBA outcomes of our RIIO-ED1 plan relative to the other scenarios assessed. These values are for the full 45 year CBA period and are converted to an eight year straight line equivalent for the executive summary and stakeholder facing documents.

All the CBA assessments show our proposed RIIO-ED1 plans to be better than the alternative industry average condition scenario.

There is one scenario for LPN 66kV switchgear where the CBAs produce a negative result to the baseline and WPD equivalent condition based scenario, but here the results are comparable to the industry average. The LPN plan includes replacement works at one site, Hackney, which accounts for 33 of the 35 replacements. Further detail for this scheme can be found in the scheme justification paper.

For EPN the 132kV switchgear is showing a negative result compared to the WPD equivalent condition volume scenario, but is more positive than the baseline or industry average scenarios.

All the CBAs for 33kV switchgear show our RIIO-ED1 proposals to have positive benefits over the other investment options.

5.2 Approach

For EHV Switchgear, four different approaches were considered as viable intervention strategies as described earlier in the document. These were:

- DPCR5 equivalent volumes
- Condition-based intervention
- Industry average replacement
- WPD equivalent volumes

The ‘replace all assets that require intervention’ option has not been applied here, as only SPN 33kV Switchgear have any refurbishment proposed.

5.2.1 Options Volumes and costs

5.2.1.1 Baseline - DPCR5 volumes and costs

Using the methodology as described earlier, the following inputs are used in the model:

Table 57 EHV Transformer costs and volumes-Baseline

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Switchgear	72	£64.1
EPN 33kV Switchgear	264	£33.1
LPN 132kV Switchgear	16	£6.6
LPN 66kV Transformer	32	£12.5
LPN 33kV Switchgear	56	£4.4
SPN 132kV Switchgear	40	£29.7
SPN 33kV Switchgear	72	£6.9

5.2.1.2 Option - ED1 condition-based volumes and costs

These costs and volumes are taken from our Asset Management proposed plan, and form the basis of all other costs used in the alternative scenarios.

Table 58 EHV Transformer costs and volumes- ED1 Condition Based

CBA Model	Estimated Volumes	Estimated Costs	UCIs used in other options (£k/Unit)
EPN 132kV Switchgear	61	£45.57m Replace £8.74m Civil Works	Replacement: £747k Civil Works: £143k
EPN 33kV Switchgear	255	£23.07m Replace £8.87m Civil Works	Replacement: £90k Civil Works: £35k
LPN 132kV Switchgear	26	£8.32m Replace £2.39m Civil Works	Replacement: £320k Civil Works: £92k
LPN 66kV Switchgear	35	£12.77m Replace £0.90m Civil Works	Replacement: £365k Civil Works: £26k
LPN 33kV Switchgear	10	£0.73m Replace £0.07m Civil Works	Replacement: £72k Civil Works: £7k
SPN 132kV Switchgear	26	£14.89m Replace £4.40m Civil Works	Replacement: £572k Civil Works: £169k
SPN 33kV Switchgear	17 Replace 8 Refurbish	£1.28m Replace £0.45m Refurbish £0.50m Civil Works	Replacement: £76k Refurbishment: £56k Civil Works: £20k

For transparency, these costs map to the RIGs lines **Table 59**

Table 59 EPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	83	Transformer	33kV Transformer (GM)	£0.21	£19.36	1%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£16.97	£27.41	62%
CV3	96	Switchgear	132kV CB (Air Insulated Busbars)(ID) (GM)	£0.38	£0.38	100%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.32	£0.74	44%
CV3	98	Switchgear	132kV CB (Gas Insulated Busbars)(ID) (GM)	£27.36	£27.47	100%
CV3	100	Switchgear	132kV Switchgear - Other	£0.06	£0.75	8%
CV6	33	Plinths and Groundworks		£0.42	£2.38	18%
CV6	34	Building		£7.53	£8.08	93%
CV6	35	Enclosures and Surrounds		£0.79	£1.74	45%
CV8	13	Earthing upgrades	Locations	£0.26	£2.01	13%

Table 60 EPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£2.10	£12.09	17%
CV3	69	Switchgear	33kV CB (Air Insulated Busbars)(ID) (GM)	£0.69	£0.69	99%
CV3	70	Switchgear	33kV CB (Air Insulated Busbars)(OD) (GM)	£3.58	£3.88	92%
CV3	71	Switchgear	33kV CB (Gas Insulated Busbars)(ID) (GM)	£13.86	£13.86	100%
CV3	73	Switchgear	33kV Switch (GM)	£0.05	£0.08	64%
CV3	74	Switchgear	33kV Switchgear - Other	£0.05	£0.08	63%
CV3	83	Transformer	33kV Transformer (GM)	£1.33	£19.36	6%
CV3	85	Protection	Batteries at 33kV Substations	£0.19	£3.58	5%
CV3	102	Protection	Batteries at 132kV Substations	£0.01	£0.68	1%
CV3	104	Protection	Pilot Wire Underground	£0.07	£1.83	4%
CV6	30	Plinths and Groundworks		£0.30	£2.12	14%
CV6	31	Building		£8.01	£27.11	30%
CV6	32	Enclosures and Surrounds		£0.27	£3.24	8.%
CV6	34	Building		£0.29	£8.08	4%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV6	35	Enclosures and Surrounds		£0.01	£1.74	1%
CV105	6	Substation RTUs, marshalling kiosks, receivers		£0.60	£38.68	2%

Table 61 LPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	83	Transformer	33kV Transformer (GM)	£0.15	£2.58	6%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£0.84	£61.26	1%
CV3	96	Switchgear	132kV CB (Air Insulated Busbars)(ID) (GM)	£0.96	£1.02	94%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£1.54	£1.86	83%
CV3	98	Switchgear	132kV CB (Gas Insulated Busbars)(ID) (GM)	£3.75	£3.75	100%
CV3	100	Switchgear	132kV Switchgear - Other	£1.03	£2.48	41%
CV6	33	Plinths and Groundworks		£0.44	£2.42	18%
CV6	34	Building		£1.80	£2.57	70%
CV6	35	Enclosures and Surrounds		£0.16	£1.18	13%
CV8	13	Earthing upgrades	Locations	£0.05	£0.83	6%

Table 62 LPN 66kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	78	Switchgear	66kV CB (Air Insulated Busbars)(OD) (GM)	£6.93	£6.95	100%
CV3	79	Switchgear	66kV CB (Gas Insulated Busbars)(ID) (GM)	£4.14	£4.14	100%
CV3	83	Transformer	33kV Transformer (GM)	£0.06	£2.58	2%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£1.42	£61.26	2%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£0.02	£1.86	1%
CV3	100	Switchgear	132kV Switchgear - Other	£0.15	£2.48	6%
CV6	33	Plinths and Groundworks		£0.14	£2.42	6%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV6	34	Building		£0.59	£2.57	23%
CV6	35	Enclosures and Surrounds		£0.16	£1.18	14%
CV8	13	Earthing upgrades	Locations	£0.05	£0.83	6%

Table 63 LPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£0.06	£8.54	1%
CV3	69	Switchgear	33kV CB (Air Insulated Busbars)(ID) (GM)	£0.14	£0.23	59%
CV3	70	Switchgear	33kV CB (Air Insulated Busbars)(OD) (GM)	£0.30	£0.33	90%
CV3	83	Transformer	33kV Transformer (GM)	£0.05	£2.58	2%
CV6	30	Plinths and Groundworks		£0.07	£0.36	18%

Table 64 SPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	83	Transformer	33kV Transformer (GM)	£0.14	£13.89	1%
CV3	89	Overhead Tower Line	132kV OHL (Tower Line) Conductor	£0.16	£11.79	1%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£1.58	£17.48	9%
CV3	97	Switchgear	132kV CB (Air Insulated Busbars)(OD) (GM)	£1.06	£1.22	87%
CV3	98	Switchgear	132kV CB (Gas Insulated Busbars)(ID) (GM)	£11.12	£11.12	100%
CV3	99	Switchgear	132kV CB (Gas Insulated Busbars)(OD) (GM)	£0.12	£0.12	100%
CV3	100	Switchgear	132kV Switchgear - Other	£0.60	£1.30	46%
CV6	33	Plinths and Groundworks		£0.45	£1.28	35%
CV6	34	Building		£3.63	£3.71	98%
CV6	35	Enclosures and Surrounds		£0.32	£0.73	43%
CV8	13	Earthing upgrades	Locations	£0.10	£0.68	15%

Table 65 SPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£0.19	£10.86	2%
CV3	69	Switchgear	33kV CB (Air Insulated Busbars)(ID) (GM)	£0.05	£0.05	100%
CV3	71	Switchgear	33kV CB (Gas Insulated Busbars)(ID) (GM)	£0.87	£0.87	100%
CV3	83	Transformer	33kV Transformer (GM)	£0.06	£13.89	1%
CV3	85	Protection	Batteries at 33kV Substations	£0.02	£2.53	1%
CV3	104	Protection	Pilot Wire Underground	£0.01	£0.73	1%
CV5	33	33kV CB (GM)	Refurbishment - Switchgear	£0.44	£0.44	100%
CV6	31	Building		£0.48	£8.64	6%
CV6	32	Enclosures and Surrounds		£0.02	£2.59	1%
CV8	7	Site security	EHV Substations	£0.04	£4.05	1%
CV105	6	Substation RTUs, marshalling kiosks, receivers		£0.04	£29.83	0%

Using this method, all costs associated with these projects are taken into account, rather than just the primary RIGs lines that drive the intervention.

5.2.1.3 Option - Industry Equivalent Average Condition Based Volumes

The industry equivalent average replacement volumes have been estimated by using industry average asset age as a proxy for when other DNOs replace their assets based on condition. Since we don't know the condition 'thresholds' for when DNOs deem intervention necessary, age has been used to estimate this, using the Age profile data tables that are shared amongst DNOs. For 132kV Switchgear, an average asset age of 50 years has been used, whilst 66kV and 33kV both use 52 years. Costs are calculated similarly to the baseline scenario, using a unit cost based on the ED1 condition based plan.

Table 66 EHV Switchgear costs and volumes- Industry equivalent volumes

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Switchgear	68	£60.54
EPN 33kV Switchgear	476	£59.63
LPN 132kV Switchgear	60	£24.72
LPN 66kV Switchgear	37	£14.45
LPN 33kV Switchgear	265	£21.02
SPN 132kV Switchgear	42	£31.15

CBA Model	Estimated Volumes	Estimated Costs £m
SPN 33kV Switchgear	347	£33.13

5.2.1.4 Option – WPD Equivalent Condition Based Volumes

Since WPD has been fast-tracked by Ofgem, having assessed their investment plans as efficient, we have tested the outcome should we undertake the equivalent volumes of work. We have calculated the volumes for this scenario by replacing the same percentage of our asset base as WPD have proposed in their business plan that was accepted by Ofgem.

Table 67 EHV Switchgear costs and volumes- WPD equivalent volumes

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV Switchgear	48	£38.25
EPN 33kV Switchgear	306	£38.15
LPN 132kV Switchgear	36	£13.55
LPN 66kV Switchgear	3	£1.17
LPN 33kV Switchgear	89	£6.99
SPN 132kV Switchgear	38	£25.32
SPN 33kV Switchgear	169	£16.12

5.2.2 Scenario Benefits

The benefits for EHV Transformers are calculated as per the methodology described previously, using the difference in the number of HI4/5 assets being replaced by each strategy. The average probability of failures for each HI class is shown below.

Table 68 Assumed Probabilities of Failure

	HI4/5 Asset	HI1/2 Asset
EPN 132kV	7.65%	1.03%
EPN 33kV	6.37%	0.88%
LPN 132kV	4.22%	1.03%
LPN 66kV	5.50%	1.03%
LPN 33kV	3.48%	0.88%
SPN 132kV	6.41%	1.03%
SPN 33kV	4.24%	0.88%

This change in the number of failures has then been split across the different failure modes, Minor, Significant, and Major, weighted according to their historic relative occurrences. All of these calculations are provided within each CBA for clarity.

5.2.2.1 CIs/CMLs

Our Asset Management engineers have assessed the number of CIs by taking the average number of customers per switchgear, and assuming only half of the customers connected to the asset will be off supply following a failure. Our CBRM modelling assumes that there is a 5% chance that failure of a piece of switchgear will cause load to be at risk.

The CMLs are then calculated by assuming that each of those customers would be off supply for a varying amount of time, depending on the failure mode. A minor failure would cause a loss of supply for 180 minutes, a significant failure would be 240 minutes, and a major failure would cause customers to be off supply for 480 minutes. A failure to operate would cause customers to be off supply for only 30 minutes. These combine to produce a weighted average CML per CI of 184 minutes. Thus, the following CI and CMLs would occur per additional failure (weighted by failure mode):

Table 69 CI and CML per failure

	CIs per failure	CML per failure
132kV	278	51,042
66kV	278	51,042
33kV	59	10,930

5.2.2.2 Safety Consequences

Again using our CBRM modelling, the increased/decreased number of failures in each option are used to estimate how many of these will cause injury/fatalities. The table bellows show that probability that, given a failure has already occurred, this will have safety repercussions.

Table 70 Probability of injury/fatality

	Minor failure	Significant failure	Major failure	Failure to operate
Prob. of minor injury	0.05	0.1	0.5	0.1
Prob. of major injury	0.005	0.01	0.05	0.01
Prob. of fatality	0.0005	0.001	0.005	0.001

When the different failure modes are combined and weighted by their historic occurrences, an additional asset failure causes 0.0073 major injuries and 0.00073 fatalities per annum. Only these instances are used to calculate benefits in the CBA model.

5.2.2.3 Faults and Maintenance Costs

Each additional failure on the network has fault repair costs, as well as potentially increased maintenance costs, associated with it. The following taken from our asset management models have been used to estimate the additional costs of repair and maintenance following an asset failure.

Table 71 Faults and Maintenance Costs

Minor failure	Significant failure	Major failure	Failure to Operate
– **£10,000**	£105,000	£325,000	£10,000

5.2.3 Sensitivities

In the case of EHV Switchgear, a sensitivity was only run for LPN 33kV, increasing the assumed time off supply from 184 minutes to 360 minutes. This was just to test the strength of our assumption used in CBRM modelling. This proves to make very little difference in the outcome of the CBAs, and so no further sensitivities were run on the other CBAs.

5.3 Results

5.3.1 CBA Results

Table 72 EPN 132V Switchgear Results

£m CBA model output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£5.04	£6.38	£7.27	£8.19
Industry Equivalent Average Condition Based Volumes	£2.76	£3.20	£3.48	£3.75
WPD Equivalent Condition Based Volumes	£15.43	£18.81	£21.05	£23.32

Table 73 EPN 33kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£0.70	£0.89	£1.03	£1.16
Industry Equivalent Average Condition Based Volumes	-£15.01	-£18.45	-£20.74	-£23.05
WPD Equivalent Condition Based Volumes	-£2.55	-£3.11	-£3.48	-£3.85

Table 74 LPN 132kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£3.12	-£3.60	-£3.90	-£4.20
Industry Equivalent Average Condition Based Volumes	-£10.24	-£12.68	-£14.31	-£15.98
WPD Equivalent Condition Based Volumes	-£3.99	-£4.86	-£5.44	-£6.02

Table 75 LPN 66kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£1.50	-£1.58	-£1.63	-£1.67
Industry Equivalent Average Condition Based Volumes	-£1.91	-£2.11	-£2.23	-£2.34
WPD Equivalent Condition Based Volumes	£6.58	£7.99	£8.92	£9.85

Table 76 LPN 33kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£2.11	£2.60	£2.92	£3.26
Industry Equivalent Average Condition Based Volumes	£2.07	£2.55	£2.87	£3.19
Industry Average	-£10.10	-£12.34	-£13.84	-£15.37
WPD Equivalent Condition Based Volumes	-£1.28	-£1.53	-£1.69	-£1.84

Table 77 SPN 132kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£5.77	£7.17	£8.10	£9.04
Industry Equivalent Average Condition Based Volumes	-£1.20	-£1.37	-£1.48	-£1.59
WPD Equivalent Condition Based Volumes	£2.82	£3.42	£3.82	£4.23

Table 78 SPN 33kV Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£2.69	£3.32	£3.73	£4.16
Industry Equivalent Average Condition Based Volumes	-£15.45	-£19.06	-£21.48	-£23.98
WPD Equivalent Condition Based Volumes	-£5.16	-£6.30	-£7.07	-£7.84

5.3.2 Discussion

The chosen option (highlighted in orange in the above tables) is the ED1 condition based replacement for all DNOs. In the case of LPN 132V and 66kV switchgear this is more negative than the baseline scenario.

In the case of LPN 132kV switchgear the RIIO-ED1 plan has 26 replacements and 8 refurbishments compared to 16 replacements in the DPCR5 plan (scaled up to 8 years). The plan includes the replacement of 12 circuit breakers at Barking in conjunction with EPN and National Grid.

In the case of LPN 66kV switchgear the RIIO-ED1 plan has 35 replacements compared to 32 replacements in the DPCR5 plan scaled up to 8 years. The plan includes replacement works at two sites, one of which is Hackney, which accounts for 33 of the 35 replacements. Further detail for this scheme can be found in the scheme justification paper.

In two instances, EPN 132kV and LPN 66kV switchgear, the WPD equivalent volumes are much lower than our RIIO-ED1 or DPCR5 volumes and are giving a more positive CBA as a result. In all instances, our ED1 plans have been developed using a bottom up method based on the condition, age, and model of each circuit breaker in the population rather than based on previous investment levels.

A full discussion of the chosen strategy is included in our EHV Switchgear Asset Stewardship Reports for EPN, LPN and SPN.

6 Fluid Filled Cables

6.1 Summary

We are proposing to spend over £111m over the RIIO-ED1 period across EPN, LPN and SPN on replacement of our fluid filled underground cables with solid cables.

Each CBA has a number of options that produce different volumes of work, and therefore different levels of expenditure, with varying benefits associated with each approach. Refer to previous chapters for a description of each scenario and the methodology used.

The options considered, and their associated volumes (in km), are shown below.

Table 79 CBA Option Volumes

	CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average Replacement
EPN	132kV Replacement	8.75	11.4	0.31
	33kV Replacement	29.92	11.6	25.21
LPN	132kV Replacement	4.16	34.8	1.15
	66kV Replacement	0.64	18.2	65.44
	33kV Replacement	0	16.4	15.31
SP[redacted]	132kV Replacement	7.68	10.5	51.81
	33kV Replacement	16.96	23.2	54.78

These volumes form the basis of the costs and benefits for all our approaches, as per the 'Approach' section below.

Table 80 CBA Outcome

132kV FFC Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline	-1.77	-15.13	-3.17	-20.07
Average Industry condition equivalent	15.22	28.51	57.02	100.76

66kV FFC Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline		-1.87		-1.87
Average Industry condition equivalent		59.50		59.50

33kV FFC Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
DPCR5 Baseline	14.49	16.19	4.70	35.38

Average Industry condition equivalent	3.68	5.63	17.41	26.72

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

The CBA assessment for 132kV FFC cable against the DPCR5 baseline shows that while we are doing more volume than in DPCR5 our assessment indicates that our plan is favourable to the industry average condition based position. EPN and SPN are only marginally negative.

Overall only LPN shows a negative result compared to the baseline. The oil filled cable leakage rate in LPN is currently twice the national average. The strategy during ED1 selected by UK Power Networks is to reduce this leakage rate by 28% over the period to begin to bring it in line with the rest of the industry. To achieve this cable circuits have been selected for replacement based on current leakage, age, construction type and condition.

6.2 Approach

For EHV Switchgear, four different approaches were considered as viable intervention strategies as described earlier in the document. These were:

- DPCR5 Equivalent Volumes
- Condition-based intervention
- Industry average replacement
- WPD equivalent

The 'replace all assets that require intervention' option has not been applied here, as we do not refurbish any fluid filled cable, instead we always replace with solid cable.

6.2.1 Options Volumes and costs

6.2.1.1 Baseline - DPCR5 volumes and costs

Using the methodology as described earlier, the following inputs are used in the model:

Table 81 EHV Transformer costs and volumes-Baseline

CBA Model	Estimated Volumes	Estimated Costs £m
EPN 132kV FFC	8.75	£9.34
EPN 33kV FFC	29.92	£9.11
LPN 132kV FFC	4.16	£4.86
LPN 66kV FFC	0.64	£0.87
LPN 33kV FFC	0	£0.00
SPN 132kV FFC	7.68	£10.10
SPN 33kV FFC	16.96	£5.49

6.2.1.2 Option - ED1 condition-based volumes and costs

These costs and volumes are taken from our Asset Management proposed plan, and form the basis of all other costs used in the alternative scenarios.

Table 82 Fluid Filled Cables costs and volumes- ED1 Condition Based

CBA Model	Estimated Volumes	Estimated Costs £m	UCIs used in other options (£k/Unit)
EPN 132kV FFC	11.4	£12.16	Replacement: £1,067k
EPN 33kV FFC	11.6	£3.53	Replacement: £305k
LPN 132kV FFC	34.8	£40.63	Replacement: £1,168k
LPN 66kV FFC	18.2	£24.75	Replacement: £1,360k
LPN 33kV FFC	16.4	£8.40	Replacement: £512k
SPN 132kV FFC	10.5	£13.81	Replacement: £1,316k
SPN 33kV FFC	23.2	£7.51m	Replacement: £324k

For transparency, these costs map to the following RIGs lines:

Table 83 EPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£8.29	£27.41	30%
CV3	93	Cable	132kV UG Cable (Oil)	£3.87	£5.70	68%

Table 84 EPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£1.55	£12.09	13%
CV3	63	Cable	33kV UG Cable (Oil)	£1.98	£5.68	35%

Table 85 LPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£39.13	£61.26	64%
CV3	93	Cable	132kV UG Cable (Oil)	£9.24	£9.65	96%

Table 86 LPN 66kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	65	Cable	66kV UG Cable (Non Pressurised)	£18.72	£31.48	59%
CV3	66	Cable	66kV UG Cable (Oil)	£1.04	£1.04	100%

Table 87 LPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£5.55	£8.54	65%
CV3	63	Cable	33kV UG Cable (Oil)	£0.11	£2.66	4%

Table 88 SPN 132kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	92	Cable	132kV UG Cable (Non Pressurised)	£8.29	£27.41	30%
CV3	93	Cable	132kV UG Cable (Oil)	£3.87	£5.70	68%

Table 89 SPN 33kV RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line	%
CV3	62	Cable	33kV UG Cable (Non Pressurised)	£12.36	£17.48	71%
CV3	63	Cable	33kV UG Cable (Oil)	£1.46	£3.37	43%

Using this method, all costs associated with these projects are taken into account, rather than just the primary RIGs lines that drive the intervention.

6.2.1.3 Option - Industry Equivalent Average Condition Based Volumes

The industry equivalent average replacement volumes have been estimated by using industry average asset age as a proxy for when other DNOs replace their assets based on condition. Since we don't know the condition 'thresholds' for when DNOs deem intervention necessary, age has been used to estimate this, using the Age profile data tables that are shared amongst DNOs. For all fluid filled cables, an industry average asset age of 69 years has been used. Costs are calculated similarly to the baseline scenario, using a unit cost based on the ED1 condition based plan.

Table 90 EHV Switchgear costs and volumes- Industry equivalent volumes

CBA Model	Estimated Volumes	Estimated Costs £m
– EPN 132kV Transformer	0.31	£0.33
EPN 33kV Transformer	25.21	£7.68
LPN 132kV Transformer	1.15	£1.34
LPN 66kV Transformer	65.44	£88.99
LPN 33kV Transformer	15.31	£7.85
SPN 132kV Transformer	51.81	£68.17
SPN 33kV Transformer	54.78	£17.73

6.2.2 Scenario Benefits

The majority of the benefits for Fluid Filled Cables are calculated as per the methodology described above, using the difference in the number of HI4/5 assets being replaced by each strategy. The average probability of failures for each HI class is shown below.

Table 91 Probabilities of Failure

	HI4/5 Asset	HI1/2 Asset
– **EPN 132kV**	0.39%	0.11%
EPN 33kV	0.67%	0.11%
LPN 132kV	0.68%	0.11%
LPN 66kV	0.61%	0.11%
LPN 33kV	0.51%	0.11%
SPN 132kV	0.54%	0.11%
SPN 33kV	0.54%	0.11%

This change in the number of failures has then been split across the different failure modes, Minor, Significant, and Major, weighted according to their historic relative occurrences. All of these calculations are provided within each CBA for clarity.

6.2.2.1 CIs/CMLs

Whilst our Asset Management engineers calculated some CI and CML benefits using similar methodology as described in a previous chapter, these benefits are not included in the CBA assessment as our engineers did not feel they would accurately reflect what is seen in real life. When a fluid filled cable fails, it is extremely uncommon for it to result in an electrical failure that causes loss of supply to customers. Therefore this has been removed from our assessment of fluid filled cables.

6.2.2.2 Safety Consequences

Using assumptions based in our CBRM modelling, the increased/decreased number of failures in each option are used to estimate how many of these will cause injury/fatalities. The table bellows show the probability that given a failure has already occurred; this will have safety repercussions, which is much less likely than other assets.

Table 92 Probability of injury/fatality

	Minor failure	Significant failure	Major failure
Prob. of minor injury	0.001	0.002	0.002
Prob. of major injury	0.0001	0.0002	0.0002
Prob. of fatality	0.00001	0.00002	0.00002

When the different failure modes are combined and weighted by their historic occurrences, an additional asset failure causes 0.0018 minor injuries, 0.00018 major injuries, and 0.000018 fatalities per annum.

6.2.2.3 Faults and Maintenance Costs

Each additional failure on the network has fault repair costs, which can be extremely high, particularly in the event of a major failure. The following assumptions have been used to estimate the additional costs of repair and maintenance following an asset failure.

Table 93 Faults and Maintenance Costs

Minor failure	Significant failure	Major failure
£5,000	£40,000	£1,020,000

6.2.2.4 Oil Leakage

We have a robust calculation for oil leakage associated with our planned targeted programmes. Our Asset Management engineers have calculated an unconstrained oil leakage profile using CBRM modelling software to estimate the oil leakage should we not replace any sections of cable. They have also calculated an oil leakage profile based on our proposed ED1 condition-based approach. The detail for how they have calculated this is included in the Underground Cable Asset Stewardship Reports for EPN, LPN and SPN. For the alternative scenarios, a 'per km' leakage rate is used to calculate an oil leakage profile, multiplying the following leakage rates by the proposed volumes in each option. These leakage rates are taken from the CV12- Environmental Reporting data tables we are submitting to Ofgem as part of this submission.

Table 94 Leakage rates per km

	Per unit Leakage (Litres)
EPN 132kV	5,000
EPN 33kV	1,500
LPN 132kV	5,000
LPN 66kV	5,000
LPN 33kV	1,500
SPN 132kV	5,000
SPN 33kV	1,500

6.2.3 Sensitivities

In the case of fluid filled cables, sensitivities were run on LPN 66kV, SPN 132kV and SPN 33kV, testing our assumptions on oil leakage. The sensitivity tests whether a 10% reduction in the benefits gained has any significant effect on the outcome. Whilst the change is not insignificant, it doesn't have any meaningful bearing on the outcome of the CBAs.

6.3 Results

6.3.1 CBA Results

Table 95 EPN 132V FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£0.98	-£1.32	-£1.55	-£1.77
Industry Equivalent Average Condition Based Volumes	-£3.99	-£8.38	-£11.99	-£16.99

Table 96 EPN 33kV FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
ED1 Condition Based	£7.02	£9.78	£11.87	£14.49
Industry Equivalent Average Condition Based Volumes	£4.61	£6.82	£8.55	£10.80

Table 97 LPN 132kV FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£11.47	-£13.57	-£14.65	-£15.13
Industry Equivalent Average Condition Based Volumes	-£14.54	-£24.75	-£32.84	-£43.64

Table 98 LPN 66kV FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£4.70	-£3.44	-£2.07	£0.39
Sensitivity on ED1 condition based	-£5.69	-£4.88	-£3.86	-£1.87
Industry Equivalent Average Condition Based Volumes	-£45.13	-£52.87	-£57.55	-£61.38

Table 99 LPN 33kV FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£5.40	£9.03	£12.01	£16.19
Industry Equivalent Average Condition Based Volumes	£3.47	£5.80	£7.76	£10.56

Table 100 SPN 132kV FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£2.77	-£2.99	-£3.11	-£3.17
Sensitivity on ED1 Condition Based	-£2.78	-£3.03	-£3.17	-£3.25
Industry Equivalent Average Condition Based Volumes	-£37.86	-£47.07	-£53.39	-£60.19

Table 101 SPN 33kV FFC Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£1.59	£2.64	£3.51	£4.70
Sensitivity on ED1 Condition Based	£1.32	£2.24	£3.00	£4.05
Industry Equivalent Average Condition Based Volumes	-£7.53	-£9.64	-£11.10	-£12.70

6.3.2 Discussion

The chosen option (highlighted in orange in the above tables) is the ED1 condition based replacement for all DNOs.

The CBA assessment for 132kV FFC cable against the DPCR5 baseline shows that while we are doing more volume than in DPCR5 our assessment indicates that our plan is favourable to the industry average condition based position. EPN and SPN are only marginally negative.

The oil filled cable leakage rate in LPN is currently twice the national average. The strategy during ED1 selected by UK Power Networks is to reduce this leakage rate by 28% over the period to bring it in line with the rest of the industry. To achieve this cable circuits have been selected for replacement based on current leakage, age, construction type and condition.

A full discussion of the chosen strategy is included in our Underground Cable Asset Stewardship Reports for EPN, SPN and LPN.

7 Distribution Assets

7.1 Summary

This section covers our Link Box and Distribution Switchgear assets. We are proposing to spend £75m on our Link Box replacement program over RIIO-ED1, and £133m on replacement of our Distribution Switchgear. Our Asset Management engineers have looked at a number of approaches that could be adopted as our decision making strategy, which are described more below.

Table 102 Link Boxes Option Volumes

CBA Model	DPCR5 Equivalent	ED1 Condition Based	Reduce to Ofgem Benchmarking	ARM Model-based replacement
EPN Link Boxes	1584	4000	3500	6470
LPN Link Boxes	4456	7200	4512	5968
SPN Link Boxes	1704	3200	2733	2096

Table 103 Distribution Switchgear Option Volumes

CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average	Mid-point between Industry average and UKPN
EPN Dist. Switchgear	2024	3664	6488	6400
LPN Dist. Switchgear	3024	1496	1848	1856
SPN Dist. Switchgear	6352	6224	9360	8192

These volumes form the basis of the costs and benefits for all our approaches, as per the 'Approach' section below.

Table 104 CBA Outcome

Dist. Assets Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
Link Boxes	2.08	12.50	6.15	61.81
Distribution Switchgear	86.16	-23.06	-1.29	-0.01

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

The CBAs for link boxes return positive results for our proposed plans when compared to the DPCR5 baseline as shown above. The EPN Link Boxes CBA our future asset risk model (ARM) alternative option is the only option more positive than our proposed investments. This option justifies higher volumes than we are proposing however we believe that the ED1 volumes are deliverable and will allow us to manage the risk appropriately.

For distribution switchgear both our proposals for both LPN and SPN are to do less volume than in DPCR5. The CBA results indicate that the benefits of increased volumes outweigh the costs of investment which is generating a negative result for LPN and SPN i.e. justifying higher volumes than we are proposing in our plans.

7.2 Approach

7.2.1 Options Volumes and costs

7.2.1.1 Link Boxes Volumes and Costs

The 4 possible approaches our Asset Management engineers considered for Link Boxes are as follows:

- DPCR5 Equivalent Volumes - In order to adhere to Ofgem's guidance, the baseline scenario is set as the equivalent DPCR5 volumes, pro-rated to the eight year RIIO-ED1 period.
- ED1 Condition based - A continuation of our current strategy, replacing assets based on condition in order to keep a stable level of asset risk over the period. This option utilises a 'Stocks and Flows' model to predict asset condition. Please refer to the Asset Stewardship Report for more detail on this.
- Reduce volumes to Ofgem Benchmarking result - Following the initial submission of DNO business plans, Ofgem ran each DNOs costs and volumes through a benchmarking model to establish which DNOs had submitted efficient costs. Within the model, they look at how far away a DNO is from an 'efficient' set of volumes. It is these volumes we have used in this option, to test whether this constitutes the most beneficial strategy.
- ARM Model based replacement - A new statistical model is being tested within our Asset Management team that is being considered to replace the 'Stocks and Flows' model currently used. We have tested this model to see whether its outputs produce viable alternatives to our current models.

The costs for the 'ED1 condition based' approach have been taken from our Asset Management proposed project plan (the NAMP), which details the costs of each individual project. These costs then form the basis of all the other scenarios, scaling the ED1 condition based costs according to the relative difference in volumes in each of the scenarios.

Table 105 Link Boxes Option Volume and Costs

CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average	Mid-point between Industry average and UKPN
EPN Link Box Volumes	1584	4000	3500	6470
EPN Link Box Costs	£8.04m	£20.30m	£17.76m	£32.83m
LPN Link Box Volumes	4456	7200	4512	5968
LPN Link Box Costs	£23.61m	£38.15m	£23.91m	£31.62m
SPN Link Box Volumes	1704	3200	2733	2096
SPN Link Box Costs	£8.73m	£16.39m	£14.00m	£10.74m

The costs are all taken from the Ofgem Data Table 'CV3-Asset Replacement', Row 19 'LV UGB & LV Pillars (OD not at Substation)'.

7.2.1.2 Distribution Switchgear

The four possible approaches our Asset Management engineers considered for Distribution Switchgear are as follows:

- DPCR5 Equivalent Volumes- In order to adhere to Ofgem's guidance, the baseline scenario is set as the equivalent DPCR5 volumes, pro-rated to the eight year RIIO-ED1 period.
- ED1 Condition based - A continuation of our current strategy, replacing assets based on condition in order to keep a stable level of asset risk over the period. This option utilises our industry-standard condition based risk modelling to predict when assets require intervention.

- Industry Average Replacement volumes- We have looked at replicating the industry average condition based threshold for when assets require intervention, using average asset age as a proxy for this, as the actual thresholds for when intervention is required is not known. The assumed ages used are 53 years for RMUs, 44 years for Secondary CBs, and 50 years for switches.
- Mid-point between industry average and UK Power Networks average - A scenario has been proposed that looks at a mid-point between the industry average replacement volumes, using average asset age as a proxy for this, and UK Power Networks average asset age. This equates to 51 years for RMUs, 50 years for Secondary CBs, and 50 years for Switches.

The costs for the 'ED1 condition based' approach have been taken from our Asset Management proposed project plan (the NAMP), which details the costs of each individual project. These costs then form the basis of all the other scenarios, scaling the ED1 condition based costs according to the relative difference in volumes in each of the scenarios.

Table 106 Distribution Switchgear Option Volume and Costs

CBA Model	DPCR5 Equivalent	ED1 Condition Based	Industry Average	Mid-point between Industry average and UKPN
EPN Distribution Switchgear Volumes	2024	3664	6488	6400
EPN Distribution Switchgear Costs	£30.98m	£56.09m	£99.32m	£70.41m
LPN Distribution Switchgear Volumes	3024	1496	1848	1856
LPN Distribution Switchgear Costs	£61.05m	£30.20m	£37.31m	£37.47m
SPN Distribution Switchgear Volumes	6352	6224	9360	8192
SPN Distribution Switchgear Costs	£47.57m	£46.61m	£70.10m	£61.35m

The 'ED1 Condition based' costs are aligned to the following lines in Ofgem's data tables:

Table 107 EPN Distribution Switchgear RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	34	Switchgear	6.6/11kV CB (GM) Secondary	23.71	23.71	100%
CV3	37	Switchgear	6.6/11kV Switch (GM)	0.73	0.73	100%
CV3	38	Switchgear	6.6/11kV RMU	21.34	24.24	88%
CV6	27	Plinths and Groundworks		1.27	1.59	80%
CV6	28	Building		3.21	4.03	80%
CV6	29	Enclosures and Surrounds		0.20	0.25	80%
CV105	6	Substation RTUs, marshalling kiosks, receivers		5.64	38.68	15%

Table 108 LPN Distribution Switchgear RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	34	Switchgear	6.6/11kV CB (GM) Secondary	1.10	1.10	100%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	37	Switchgear	6.6/11kV Switch (GM)	0.61	0.61	100%
CV3	38	Switchgear	6.6/11kV RMU	22.29	22.78	98%
CV6	27	Plinths and Groundworks		0.03	0.04	68%
CV6	28	Building		0.86	1.54	56%
CV105	6	Substation RTUs, marshalling kiosks, receivers		5.31	28.78	19%

Table 109 SPN Distribution Switchgear RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	34	Switchgear	6.6/11kV CB (GM) Secondary	2.69	2.69	100%
CV3	37	Switchgear	6.6/11kV Switch (GM)	1.90	1.90	100%
CV3	38	Switchgear	6.6/11kV RMU	32.20	33.64	96%
CV6	27	Plinths and Groundworks		1.25	1.58	79%
CV6	28	Building		0.34	0.70	48%
CV6	29	Enclosures and Surrounds		0.18	0.29	64%
CV105	6	Substation RTUs, marshalling kiosks, receivers		8.05	29.83	27%

7.2.2 Scenario Benefits

7.2.2.1 CI/CMLs

The CI/CML benefits are calculated in a similar fashion to the other asset replacement CBAs, in that the difference in the number of HI4/5s replaced in each scenario is used to calculate an increase in the number of failures, from which CIs and CMLs are derived.

An average failure rate is established for each DNO, which is calculated by dividing the average number of failures per annum by the number of HI4/5s on the network. It is assumed that all assets that fail are HI4/5.

Table 110 Failure Rates

CBA	Assumed Failure Rate of HI4/5 assets
EPN Link Boxes	3.9%
LPN Link Boxes	3.5%
SPN Link Boxes	5.6%
EPN Dist. Switchgear	16%
LPN Dist. Switchgear	7.2%
SPN Dist. Switchgear	3.9%

The ‘ED1 condition based’ approach aims to keep the number of HI4/5s on the network constant throughout RIIO-ED1, which means that the volumes being replaced in that approach is equal to the number of assets that turn into HI4/5s each year. Using this information, the number of HI4/5s left on the network for each strategy can then be assessed. The failure rates calculated above are then applied to produce an increase in the number of failures per annum.

These failures are translated into CIs and CMLs by using the average CIs and CMLs per incident, as reported in our 12-13 IIS returns to Ofgem. The values used are stated below.

Table 111 CIs and CMLs

CBA	CIs per Failure	CMLs per CI
EPN Link Boxes	36	209 minutes
LPN Link Boxes	69	286 minutes
SPN Link Boxes	36	286 minutes
EPN Dist. Switchgear	157	125 minutes
LPN Dist. Switchgear	117	163 minutes
SPN Dist. Switchgear	160	135 minutes

7.2.2.2 Fault and Maintenance Costs

For each of these failures calculated above, there will be increased faults and maintenance costs associated with this. The unit costs used are as follows:

Table 112 Fault and Maintenance Unit Costs

CBA	Fault UCI (£k)	Maintenance UCI (£k)
EPN Link Boxes	£4.2k	N/A
LPN Link Boxes	£5.9k	N/A
SPN Link Boxes	£4.2k	N/A
EPN Dist. Switchgear	£12k	£0.5k
LPN Dist. Switchgear	£15k	£1k
SPN Dist. Switchgear	£12k	£0.5k

7.2.2.3 Safety benefits

Link boxes have the added risk of major injuries, particularly because they are often in very public areas. Asset management engineers have used historic occurrences of injuries caused by link boxes to establish a probability of injury when a link box fails. There has been only 1 incident of a link box causing injury when it fails in the last 7 years, out of a total of 1,623 link box failures. Therefore, the probability of a major injury is 0.06% (1/1623).

7.3 Results

7.3.1 CBA Results

Table 113 EPN Link Boxes Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£2.79	-£1.71	-£0.34	£2.08
Ofgem Benchmarking volume	-£2.17	-£1.29	-£0.18	£1.76
ARM Model	-£5.53	-£3.29	-£0.47	£4.47

Table 114 LPN Link Boxes Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£0.64	£3.99	£7.31	£12.50
Industry Average	£0.01	£0.08	£0.15	£0.26
ARM Model	£0.38	£2.23	£4.08	£6.95

Table 115 SPN Link Boxes Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£0.00	£1.68	£3.41	£6.15
Industry Average	£0.06	£1.24	£2.45	£4.37
ARM Model	£0.02	£0.46	£0.92	£1.65

Table 116 EPN Distribution Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£22.07	£41.19	£59.28	£86.16
Industry Average	-£47.01	-£60.06	-£69.67	-£80.93
Mid-point between Industry average and UKPN	-£32.33	-£43.03	-£51.44	-£62.04

Table 117 LPN Distribution Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	£1.65	-£4.77	-£11.75	-£23.06
Industry Average	-£9.17	-£20.70	-£32.16	-£49.69
Mid-point between Industry average and UKPN	-£9.22	-£20.75	-£32.20	-£49.70

Table 118 SPN Distribution Switchgear Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
ED1 Condition Based	-£0.17	-£0.48	-£0.80	-£1.29
Industry Average	-£27.92	-£39.73	-£49.66	-£63.05
Mid-point between Industry average and UKPN	-£25.42	-£37.68	-£48.30	-£63.00

7.3.2 Discussion

The CBAs support our plans over industry standard replacement volumes for both Link Box replacement and Distribution Switchgear replacement.

For EPN Link boxes there appears to be a more positive investment scenario, using the Asset Replacement Modelling software to determine replacement volumes. This option supports higher volumes of linkbox replacement than we are proposing in RIIO-ED1; however we are comfortable that our plans are both deliverable and will allow us to manage the asset risk.

For distribution switchgear both our proposals for both LPN and SPN are to do less volume than in DPCR5. The CBA results indicate that the benefits of increased volumes outweigh the costs of investment which is generating a negative result for LPN and SPN i.e. justifying higher volumes than we are proposing in our plans.

8 Steel Tower Conductor

8.1 Summary

We are proposing to spend £80m over RIIO-ED1 on replacement of our Overhead Line Steel Tower assets in EPN and SPN.

Our engineers in asset management have compared a couple of different approaches that could be used to effectively manage these assets. The options used, and associated volumes for each approach, are summarised below.

Table 119 Steel Towers Option Volumes

CBA Model	ED1 Condition Based	Age-based equivalent volumes	Replace as soon as assets get to condition 4
EPN Steel Towers	706km	706km	1581km
SPN Steel Towers	271km	271km	276km

These volumes form the basis of the costs and benefits for all our approaches, as per the 'Approach' section below.

Table 120 CBA Outcome

Steel Towers Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
Steel Towers	0.01		0.01	0.01

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

The CBA results against our DPCR5 baseline are marginally positive compare to the age based equivalent volumes and much more positive than replacing all condition 4 based assets, which would be the lowest risk option.

8.2 Approach

8.2.1 Options Volumes and costs

There are three different strategies that were considered by our Asset Management engineers, described below:

- Baseline Scenario: ED1 Condition Based Replacement- As with other strategies, this approach replaces assets based on their condition, using analysis of the conductor's previous Cormon tests, and an understanding of the stages of conductor degradation to predict when intervention is necessary.
- Age-based equivalent volumes- If we were to replace the same volume of assets as in the baseline scenario, but choose the assets based on age, we would replace all conductors over 69 years of age. This creates an increase in risk associated with failure.
- Replace as soon as asset gets to condition 4- Our engineers have analysed the point at, on average, a piece of conductor reaches condition rating 4 (please refer to the Asset Stewardship Report for details on condition ratings) is 55 years of age. Thus, a possible option is to replace all assets when they get

here. This eliminates much of the uncertainty of when an asset will require intervention that exists within the baseline; analysis of the Cormon tests are a good indicator, but there could be assets which require intervention before the Cormon test indicates we should.

The costs for the 'ED1 condition based' approach have been taken from our Asset Management proposed project plan (the NAMP), which details the costs of each individual project. These costs then form the basis of all the other scenarios, scaling the ED1 condition based costs according to the relative difference in volumes in each of the scenarios. Since the baseline scenario and the 'age based equivalent volumes' propose to replace the same amount of conductor, the costs in both scenarios are the same.

Table 121 Link Boxes Option Volume and Costs

CBA Model	ED1 Condition Based	Age-based equivalent volumes	Replace as soon as assets get to condition 4
EPN Steel Tower Volumes	706	706	1581
EPN Steel Tower Costs	£57.59m	£57.59m	£128.96m
SPN Steel Tower Volumes	271	271	276
SPN Steel Tower Costs	£22.42m	£22.42m	£22.83m

The costs for the baseline scenario are mapped to the following RIGs lines in Ofgem's data tables:

Table 122 EPN Steel Tower OHL RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	56	Overhead Tower Line	33kV OHL (Tower line) Conductor	4.85	4.85	100%
CV3	58	Overhead Tower Line	33kV Fittings	0.13	0.13	100%
CV3	89	Overhead Tower Line	132kV OHL (Tower Line) Conductor	36.51	37.41	98%
CV3	90	Overhead Tower Line	132kV Tower	2.35	2.35	100%
CV3	91	Overhead Tower Line	132kV Fittings	8.61	8.61	100%
CV5	29	33kV Tower	Refurbishment - Tower	4.75	4.75	100%
CV5	49	132kV Tower	Refurbishment - Tower	0.01	0.01	100%
CV5	50	132kV Tower	Refurbishment - Tower painting	0.13	5.59	2%
CV5	51	132kV Tower	Refurbishment - Tower Foundation	0.25	0.25	100%

Table 123 SPN Steel Tower OHL RIGs line Mapping

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	52	Overhead Pole Line	33kV OHL (Pole Line) Conductor	1.06	4.49	24%
CV3	53	Overhead Pole Line	33kV Pole	0.06	2.11	3%
CV3	56	Overhead Tower Line	33kV OHL (Tower line) Conductor	0.31	0.31	100%

Table	Line No	Description		Total Assessed £m	Total RIGs Line £m	%
CV3	89	Overhead Tower Line	132kV OHL (Tower Line) Conductor	11.24	11.79	95%
CV3	90	Overhead Tower Line	132kV Tower	2.08	2.08	100%
CV3	91	Overhead Tower Line	132kV Fittings	5.57	5.57	100%
CV5	29	33kV Tower	Refurbishment - Tower	0.90	0.90	100%
CV5	49	132kV Tower	Refurbishment - Tower	-0.08	-0.08	100%
CV101	14	Primary network (n-1)		1.27	16.89595	7%

8.2.2 Scenario Benefits

Due to the nature of Steel Tower Conductors, and the fact that an asset failure is extremely rare (except in severe weather events), it was deemed by our Asset Management engineers that there is not enough data on which to base any assumptions for benefits of replacement. Whilst our engineers could say for certain there would be an increase in risk for certain strategies, quantifying this risk was not possible.

Therefore, we have used a 'non-zero' value of £1,000 per annum to describe this increase in risk associated with the two age based options, under the assumption that this is the very minimum value that the increase in risk would be, whilst it's far more likely to be even more than this.

8.3 Results

8.3.1 CBA Results

Table 124 EPN Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario-Condition Based	N/A	N/A	N/A	N/A
Age based equivalent volume	-£0.01	-£0.01	-£0.01	-£0.01
Replace as soon as asset reaches Condition 4	-£42.72	-£52.48	-£59.01	-£65.74

Table 125 SPN Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario-Condition Based	N/A	N/A	N/A	N/A
Age based equivalent volume	-£0.01	-£0.01	-£0.01	-£0.01
Replace as soon as asset reaches Condition 4	-£0.26	-£0.32	-£0.35	-£0.39

8.3.2 Discussion

Both CBAs confirm that our chosen approach is the most positive within both EPN and SPN. Whilst it is very marginal in the 'age based equivalent volume', this is because of the use of a very small non-zero value to represent the increase in risk, which in reality is likely to be much higher. By replacing on an age basis, there would undoubtedly be condition 4 conductors left on the network. This is expected to be approximately 10% of the network from analysis of previous Cormon tests. Whilst it is difficult to estimate the value of this risk with any level of certainty, we conclude that this is a higher risk strategy than the baseline, for the same level of investment. Therefore this strategy is rejected.

Please refer to our EPN & SPN Wood Poles, Narrow Based Steel Towers & Conductors Asset Stewardship Reports.

9 Load Related Investment and High Value Projects

9.1 Summary

We are proposing 177 load-related projects (excluding High Value Projects) within RIIO-ED1, spending c. £500m. We have chosen a representative sample of the projects to undertake cost benefit analysis, selecting 10 schemes from each of our DNOs to test, in addition to our High Value Projects, as justification for our plan.

Table 126 Load Related Schemes

Load Related Whole Life Benefit CBA Project Name	£m v next best option
Red Lodge	3.96
Stowmarket Grid	4.69
Guildford Grid	1.88
White City New 132-11kV Substation	1.73
Trowse 132-33kV	6.12
Highfield 33kV	2.06
Rye House-Harlow West 132kV Tower Line	4.50
Maldon South Woodham Primary	0.51
Bramford	2.58
Bainton new GSP	27.09
March Grid 132-33kV Grid Substation	3.64
Horningsea-Fulbourn	5.87
Gravesend	2.47
Moulsecoombe	1.09
Broadoak Group 33kV Reinforcement	6.74
Littlehampton T1T2 33kV	2.00
Canterbury Town 33-11kV	0.88
Merrow 33-11kV Reinforcement	0.65
King Henry's Walk	2.91
Hearn St	8.20
Weybridge	0.71
Epsom 33-11kV substation reinforcement	0.87

Load Related Whole Life Benefit CBA Project Name	£m v next best option
Lodge Rd- Carnaby St	1.17
Marden Tee 132kV Switching station	3.95
New 132-11kV Substation in Hoxton Area	3.72
Eglinton	2.39
Waterloo Road- Replant as 132-11kV	3.52
Lithos Road 66-11kV-ITC	2.52
Hatchard Road	3.88
Verney Rd	0.75
North London (King Henry's Walk, Hearn Street and Waterloo Road)	15.69

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

We believe all of the selected schemes have CBAs that justify all of our Load-Related Expenditure. Whilst only a sample of projects have been assessed through CBAs, we have also provided individual scheme papers for all of our proposed schemes, which are provided as part of the suite of documents in this business plan submission. We have provided an additional CBA in support of the North London upgrade to 132kV showing that the equivalent reinforcement and asset renewal at 66kV would be more expensive if carried out over the same period.

High Value Projects Whole Life Benefit CBA Project Name	£m v next best option
High Value Project- VNEB	53.30
High Value Project- PO Route	15.42
High Value Project- Eaton Socon	11.30
High Value Project- West End	16.55
High Value Project- Eltham Sydenham	0.94

We have carried out CBAs on the high value projects showing they are the least cost alternative or provide resilience benefits in the case of the Eltham – Sydenham gas cables.

9.2 Approach

9.2.1 Options Volumes and costs

Our Asset Management engineers have provided in the Load-Related Scheme papers a list of alternative options that were considered in selecting an appropriate reinforcement strategy. The CBAs have been produced to reflect what is in these papers.

These costs are estimates based on similar previous schemes, and are unique to each project. Please refer to the individual scheme papers for further information on each.

In all instances the proposed investment has been used as the baseline as there is not equivalent DPCR5 expenditure.

9.2.2 Scenario Benefits

Since solid benefits for each individual project could not be calculated to a comfortable degree of certainty, most of these CBAs look only at the costs of each option. Where we have proposed to select an approach that is not the most positive CBA, this is justified within the project's scheme paper with other grounds for undertaking. This is usually due to unfeasible or unnecessary work that would need to be carried out in alternative options that cannot be quantified for use in a CBA.

9.3 Results

9.3.1 CBA Results EPN

Table 127 Red Lodge CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Construct a strategically located 33kV bus bar near Red Lodge to form a source of capacity from Burwell Grid	-	-	-	-
Make provision for a Primary substation only at Red Lodge	-£2.81	-£3.29	-£3.64	-£3.96

Table 128 Stowmarket Grid CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish a new 132kV switchboard at Stowmarket Grid	-	-	-	-
Lay additional 132kV circuits	-£3.21	-£3.83	-£4.27	-£4.69

Table 129 Trowse 132-33kV CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install a 3rd 132/33kV transformer at Trowse Grid	-	-	-	-
Convert St Stephens Primary to direct transformation	-£4.22	-£5.02	-£5.58	-£6.12
Establish a new Grid Substation on a reserved site to the northeast of Norwich (Norwich East)	-£12.82	-£15.31	-£17.03	-£18.72
Establish a new Grid Substation on a reserved site to the east of Norwich (Bungalow Lane)	-£4.54	-£5.40	-£6.00	-£6.59
Establish a new Grid Substation on a reserved site to the east of Norwich (Bungalow Lane)	-£10.91	-£13.03	-£14.48	-£15.92

Table 130 Highfield 33kV CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Reinforce Highfield Primary Substation.	-	-	-	-
Reinforce Highfield and Roundwood Road Primary substations	-£1.71	-£2.01	-£2.23	-£2.44

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Create a new Primary Substation	-£1.45	-£1.71	-£1.89	-£2.06

Table 131 Rye House-Harlow West 132kV Tower Line CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Separate Harlow West / Epping 132kV circuits	-	-	-	-
Establishing a new 132/33kV Grid Substation	-£3.18	-£3.74	-£4.13	-£4.50

Table 132 Maldon South Woodham Primary CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Build a new Primary Substation to support Sth Woodham	-	-	-	-
Reinforce at Sth Woodham Primary substation	-£0.35	-£0.42	-£0.47	-£0.51

Table 133 Bramford CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Replace the existing 132kV switchgear	-	-	-	-
Create a new 400kV/132kV Grid supply point at Melis, equipped with 2x240MVA Super Grid transformers	-£1.70	-£2.07	-£2.33	-£2.58

Table 134 Bainton New GSP CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish a new Grid Supply Point	-	-	-	-
Install additional 132kV circuits from Walpole (overhead line)	-£18.52	-£22.11	-£24.64	-£27.09
Install additional 132kV circuits from Walpole (underground cables)	-£39.46	-£47.15	-£52.57	-£57.82

Table 135 March Grid 132-33kV Substation CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Replace Grid Transformers	-	-	-	-
Build a new Grid Substation	-£2.58	-£3.03	-£3.34	-£3.64

Table 136 Horningsea- Fulborn CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Construct a new 132kV switching station at Horningsea	-	-	-	-
Establish a fourth Grid site from an alternative 132kV network (Wymondley/Pelham)	-£4.22	-£4.91	-£5.40	-£5.87

9.3.2 CBA Results LPN

Table 137 King Henry's Walk CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Upgrade King Henry's Walk to 132kV	-	-	-	-
Replace the existing transformers with larger 66/11kV units and 11kV switchboard	-£4.12	-£4.87	-£5.39	-£5.89
Establish Demand Side Response Contracts	£1.56	£1.93	£2.19	£2.45

The amount of demand side response required within RIIO-ED1 would be more than we believe can be maintained in the area. We have also demonstrated that the overall scheme to upgrade the King Henry's Walk, Hatchard Road and Hearn Street 66kV network to 132kV showing that the overall plan offers least cost and benefits from reduced losses as shown in

Table 140 North London 66kV to 132kV upgrade CBA.

Table 138 Hearn St CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Upgrade Hearn Street to a 132/11kV substation	-	-	-	-
Replace the existing transformers with larger 66/11kV units and 11kV switchboard	-£8.32	-£9.86	-£10.91	-£11.95

Table 139 Hatchard Road CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Upgrade Hatchard Road to a 132/11kV substation	-	-	-	-
Replace the existing transformers with larger 66/11kV units and 11kV switchboard	-£14.30	-£17.02	-£18.86	-£20.69
Establish Demand Side Response Contracts	-£1.56	-£1.77	-£1.91	-£2.04

Table 140 North London 66kV to 132kV upgrade CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Upgrade to 132kV	£9.84	£12.23	£13.91	£15.69
Maintain at 66kV reinforce King Henry's Walk, Hatchard Road and HearnSt and replace 66kV circuits and switchgear				

Table 141 White City New 132-11kV Substation CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Build a new 132/11kV main Substation	-	-	-	-
Reinforce Bulwer Street substation	-£1.05	-£1.34	-£1.53	-£1.73

Table 142 Lodge Road- Carnaby Street CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install 4 x 66kV XLPE circuits in the new deep cable tunnel between Lodge Road and Duke Street	-	-	-	-
Install 4 x XLPE circuits open cut between Lodge Road and Duke Street	-£0.82	-£0.96	-£1.07	-£1.17

Table 143 Waterloo Road- Replant as 132-11kV CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install a new 132/11kV substation	-	-	-	-
Reinforce existing site	-£2.66	-£3.03	-£3.28	-£3.52

Table 144 Lithos Road 66-11kV- ITC CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install 2 additional 15MVA 66/11kV transformers and associated circuits and switchgear	-	-	-	-
Install one additional 15MVA 66/11kV transformer and associated circuit and switchgear	£1.90	£2.32	£2.60	£2.88
Replace the existing transformers with 4x22.5MVA 66/11kV and double bank the existing 66kV circuits	-£1.81	-£2.12	-£2.32	-£2.52

A single transformer solution, whilst marginally lower cost has been rejected on ground of load balance and operational complexity. The substation is designed to operate with four transformers operating as two pairs of transformers, where the loss of one transformer results in three operating in parallel at which point fault current ratings are reached. Configuring load to ensure balanced operation with a fifth transformer is difficult to achieve so the preferred scenario is to add a further pair operating in a similar manner to the substations current mode of operation.

Table 145 Eglinton CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish a 2 x 66MVA substation at Eglinton	-	-	-	-
Establish 132/11kV 3 x 33MVA substation at Eglinton	-£1.65	-£1.97	-£2.18	-£2.39
Establish a 2 x 66MVA substation at Belvedere	-£1.95	-£2.32	-£2.57	-£2.82

Table 146 Verney Road CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install 2 additional 22.5MVA 66/11kV transformers and associated circuits and switchgear	-	-	-	-
Install one additional 22.5MVA 66/11kV transformer and associated circuit and switchgear	£0.29	£0.34	£0.39	£0.42
Replace the existing transformers with 4x33.3MVA 66/11kV units, double bank the existing 66kV circuits	-£0.52	-£0.61	-£0.68	-£0.75

Table 147 New 132-11kV Substation in Hoxton Area CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Build a new 132/11kV main Substation	-	-	-	-
Replace existing 33kV incoming circuits	-£2.62	-£3.08	-£3.41	-£3.72

9.3.3 CBA Results SPN

Table 148 Weybridge CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Replace the transformers with two new 20/40MVA Units, install two new 33kV circuits, and replace the 11kV switchboard offline	-	-	-	-
Install a third 12/24MVA transformer and a new 3.8km 33kV underground circuit; in addition replace the existing 33kV fluid filled cable circuits and 11kV switchboard	-£0.53	-£0.60	-£0.66	-£0.71

Table 149 Merrow 33-11kV Reinforcement CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Add a 3rd Transformer, 33kV Underground Cable Circuit and Replace the 11kV Switchboard	-	-	-	-
Uprate 12/24MVA transformers to 20/40MVA units, install a new 33kV underground Circuit, double bank with existing, and replace the 11kV switchboard	-£0.48	-£0.55	-£0.60	-£0.65

Table 150 Guildford Grid CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install (n-2) support at Guildford Grid at 132kV from Leatherhead	-	-	-	-
Install (n-2) support at Guildford Grid at 132kV from Woking Sentrum	-£1.43	-£1.63	-£1.75	-£1.88

Table 151 Littlehampton T1-T2 33kV CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Replace and uprate the composite feeder circuits between Worthing Grid 'A' and Littlehampton	-	-	-	-
Install 4th section 11kV switchboard and 12MVA transformer	-£1.43	-£1.68	-£1.84	-£2.00
Negotiate demand side response (DSR) contracts with customers	£3.38	£4.01	£4.43	£4.85

Table 152 Canterbury Town 33-11kV CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install 1 x 12/24MVA 33/11kV transformer, 1 x 33kV feeder circuit and a 24 panel 11kV switchboard	-	-	-	-
Replace the existing transformers with 3 x 20/40MVA 33/11kV transformers	-£0.61	-£0.72	-£0.80	-£0.88

Table 153 Gravesend CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install an additional 12/24MVA 33/6.6kV transformer	-	-	-	-
Replace the 2 existing transformers with 2x20/40MVA and overlay the existing FFC circuits	-£1.75	-£2.06	-£2.26	-£2.47

Table 154 Moulsecoombe CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Install a 2nd 9km 132kV circuit from Southern Cross and add a 2nd 90MVA grid transformer at Moulsecoombe	-	-	-	-
Replace the existing 2x7km of 132kV FFC from Brighton-Fishersgate to Brighton-Local using open cut trench installation	-£4.14	-£4.90	-£5.45	-£5.96
Install 1x7km of 132kV solid XLPE cable from Brighton-Fishersgate to Brighton-Local using open cut trench installation as above and double bank the existing 2x132kV FFC	-£0.83	-£0.94	-£1.02	-£1.09

Table 155 Broadoak Group 33kV Reinforcement CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Convert the 33kV switching station to a 132/33kV grid substation and run the PRC circuits at 132kV	-	-	-	-
Overlay 2x8km of 132kV cable on the composite tower line and continue to run the PRC route at 33kV	-£4.77	-£5.62	-£6.18	-£6.74

Table 156 Epsom 33-11kV Substation Reinforcement CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Replace the existing 2x11.5/23MVA transformers with larger 2x20/40MVA units	-	-	-	-
Install an additional 12/24MVA transformer, 5kmx33kV U/G circuit and associated switchgear	-£0.56	-£0.69	-£0.78	-£0.87

Table 157 Marden Tee 132kV Switching Station CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish a new outdoor mesh corner 132kV switching station at Marden tee-point.	-	-	-	-
Establish a new indoor 132kV switching station at Marden tee-point.	-£2.80	-£3.29	-£3.62	-£3.95

9.4 High Value Projects

CBAs have been populated for our high value projects.

Table 158 High Value Project-VNEB CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish a new Battersea 2x66MVA 132/11kV main substation	-	-	-	-
Incremental expansion of existing substation sites	-£29.59	-£35.53	-£39.47	-£43.48

Table 159 High Value Project- PO Route CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish new 400/132kV Grid Supply Point (GSP) at Little Horsted	-	-	-	-
Replace Route PO with a new Lewis - Polegate 132kV double circuit underground cable connection	-£10.98	-£13.83	-£15.75	-£17.73
Establish a new 132kV Grid Substation at Broadoak and install a new 132kV double circuit connection to Lewis	-£9.43	-£11.96	-£13.66	-£15.42

Table 160 High Value Project- Eaton Socon CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
New GIS at Eaton Socon with connection of 3rd SGT	-	-	-	-
New 132kV GIS at Little Barford and 3rd SGT tail from Eaton Socon	-£7.78	-£9.29	-£10.29	-£11.30

Table 161 High Value Project- West End CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Establish a new West End 3x33MVA 66/11kV main substation	-	-	-	-
Incremental expansion of existing substation sites	-£11.50	-£13.67	-£15.10	-£16.55

Table 162 High Value Project- Eltham Sydenham Gas Cables CBA

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Reinforce network in ED1	-	-	-	-
Defer 5 years - restoration using generation in 4 days	-£105.95	-£106.22	-£106.46	-£106.81
Defer 5 years - full QoS impact of rota disconnection	-£0.08	-£0.35	-£0.59	-£0.94

Replacement of the gas cables at Eltham/Sydenham brings with it a reduced probability of failure. Because of the nature of gas cables, there is a significantly higher risk of failure once one circuit already fails, and this is reflected in the model with an increase risk multiplier of 6 (i.e. the circuit is 6 times more likely to fail than previously). Recent experience with the replacement of gas cables in SPN indicates that this is a reasonable assumption. In this instance a gas cable was taken out of service for replacement and the second circuit failed almost immediately; supply loss being averted only because alternative supply arrangements have been put in place before the first circuit was taken out of service.

The baseline scenario in this case is to replace the cables during RIIO-ED1, with the options testing whether a deferral of 5 years into RIIO-ED2 is justifiable, given an increased probability of failure from delaying.

We have demonstrated that the replacement of gas filled cables between Sydenham and Eltham in south east London should be carried out in RIIO-ED1 rather than being deferred until RIIO-ED2.

9.4.1 Discussion

The CBAs prove to show most of our chosen approaches as being least cost. There are, however, some schemes where more beneficial options have been rejected in favour of another. A detailed discussion of each and justification for the adopted solution is included in the scheme papers.

10 Flood Mitigation

We are proposing to spend £15m over RIIO-ED1 on protection of our substation sites particularly at risk of flooding. This amounts to 74 additional sites being protected against the effects of flooding by the end of RIIO-ED1.

Our engineers in asset management have proposed three different approaches that could be adopted in order to deal with the risk of flooding. In all options, the CBAs focus on the 74 sites that are particularly at risk, 38 in EPN, 16 in LPN, and 20 in SPN, and just consider alternative approaches to dealing with those sites.

Table 163 CBA Outcome

Flood Mitigation Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
Flood Mitigation	45.64	17.79	24.05	87.48

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

All three CBAs indicate (as shown above) that our chosen approach to protecting or moving only vital equipment is the more cost effective than building flood walls or trying to exclude water from the whole site. The results were all very positive compared to the consequences of flooding causing a loss of supplied considering a 1:200 flood risk. We consider these CBAs help justify our expenditure in this area. For further detail and justification, please refer to our Substation Flood Protection Strategy.

10.1 Approach

10.1.1 Options Volumes and costs

There are three different strategies that were considered by our Asset Management engineers, described below:

- Baseline Scenario: Employ conventional industry flood mitigation techniques to eliminate the impact of flooding on customer supplies.
- Employ a reactive response: Undertake no flood mitigation measures in RIIO-ED1, instead deciding to respond to flooding should it occur. This eliminates the substantial upfront costs required, and means substations are only targeted when absolutely necessary.
- Completely eliminate the threat of flooding across sites at risk by enclosing every site in a flood wall.

The costs for the baseline scenario are taken from our Asset Management proposed project plan (the NAMP), which details the costs of each individual project. The costs for the reactive response are based on observed costs that occurred when our Tooley Street substation became flooded, including the clean-up costs and refitting that emerged. In total, the clean-up costs amounted to £40,150, and the cost of refitting the substation came to £2.09m. These costs are then multiplied by the probability of a flood occurring, which is assumed at 1/200 per site.

The ‘enclose in a flood wall’ option has been estimated based on predicted costs at Peterborough Central Grid, where a flood wall was proposed to be built at a cost of £1.5m

The assumed ‘per site’ costs, as well as total costs, are shown below:

Table 164 Flooding Option Volume and Costs

CBA Model	ED1 Condition Based	Reactive Operational response	Enclose sites in a flood wall
EPN Flooding 'per site' costs	N/A	£2.13m	£1.5m
EPN Flooding total costs	£7.52m	£3.24m	£57m
LPN Flooding 'per site' costs	N/A	£2.13m	£1.5m
LPN Flooding total costs	£3.73m	£1.36m	£24m
SPN Flooding 'per site' costs	N/A	£2.13m	£1.5m
SPN Flooding total costs	£3.81m	£1.70m	£30m

The costs for the baseline scenario are entirely mapped to Ofgem's data tables 'CV11- Resilience', line 24 'Total Flood Mitigation Schemes'

10.1.2 Scenario Benefits

The only benefits calculated within the CBAs are the customer interruptions and customer minutes lost within the 'Reactive response' scenario. Since the baseline scenario and the 'enclose all sites in a flood wall' scenario both achieve the same aim (i.e. they both eliminate the risk of interruptions to customer's supply), there is no difference in the benefits between the two scenarios.

To estimate the CI losses if we were to employ a reactive response, the number of customers connected to all of the proposed substations we are looking at, was multiplied by the probability of a flood occurring (1/200 per site, which translates to 38/200 for EPN, 16/200 for LPN, and 20/200 for SPN) at any one of the at risk sites we are examining. Customers were assumed to be off supply for a 24 hour period. This produced the following CIs and CMLs as detailed in the workbook:

Table 165 Flooding CIs and CMLs for reactive response

DNO	CI per annum	CML per annum
EPN	83,204	119,814,091
LPN	11,362	16,361,816
SPN	7,340	10,569,600

10.1.3 Sensitivities

Sensitivities were run for all DNOs, testing the strength of some of the assumptions made. When looking at the 'reactive response' scenario, we have run a sensitivity on the assumed time off supply, reducing it from 24 hours to 12 hours. Whilst this makes a large impact upon this scenario, it does not have any effect on the outcome of our decisions.

Another sensitivity has been run on the costs of enclosing all the sites in a flood wall. We have tested the effects of reducing the costs to 80% of the original assumption. Again, whilst making a considerable impact on the NPV of this option, it does not adversely affect our decisions.

10.2 Results

10.2.1 CBA Results

Table 166 EPN Flood Mitigation Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Reactive Response	-£271.73	-£271.14	-£270.74	-£270.33

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Sensitivity to Reactive Response	-£138.42	-£137.82	-£137.43	-£137.02
Enclose in a Flood Wall	-£29.69	-£36.45	-£40.98	-£45.64
Sensitivity to Enclose in a Flood Wall	-£22.87	-£28.07	-£31.55	-£35.14

Table 167 LPN Flood Mitigation Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Reactive Response	-£36.09	-£35.79	-£35.58	-£35.37
Sensitivity to Reactive Response	-£17.89	-£17.58	-£17.38	-£17.16
Enclose in a Flood Wall	-£11.61	-£14.20	-£15.95	-£17.79
Sensitivity to Enclose in a Flood Wall	-£8.86	-£10.84	-£12.17	-£13.58

Table 168 SPN Flood Mitigation Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Reactive Response	-£22.84	-£22.56	-£22.37	-£22.18
Sensitivity to Reactive Response	-£11.08	-£10.80	-£10.61	-£10.42
Enclose in a Flood Wall	-£15.59	-£19.17	-£21.57	-£24.05
Sensitivity to Enclose in a Flood Wall	-£12.00	-£14.76	-£16.61	-£18.52

10.2.2 Discussion

All CBAs show our chosen approach to be the most positive. This option provides the right balance between protecting customer supplies in the event of flooding, and keeping costs to a minimum.

In LPN most sites are indoor and therefore the most important comparison is between our baseline RIIO-ED 1 proposals and the reactive response. The CBAs demonstrate that the costs and impacts of a reactive response give significantly negative result compared to our investment proposals.

Please refer to our Substation Flood Protection Strategy for more detailed discussion of our proposals.

11 ESQCR

11.1 Summary

We are proposing to spend £45m in EPN, and £26m in SPN on climbable tree and overhead line clearance issues which require a response under the Electricity Safety Quality and Continuity Regulations (ESQCR). This expenditure covers occasions where trees that are proximate to our network cause safety concerns cannot be dealt with through simple tree-cutting measures. Instead structural mitigation is required, whether through shrouding, diversions, reconductoring, or even undergrounding the cables. The options proposed by our Asset Management engineers consider alternative mixes of work that could be used when approaching this issue.

Table 169 CBA Outcome

ESQCR Whole Life Benefit CBA £m	EPN	SPN	Total
ESQCR	14.25	3.59	17.84

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

Our CBAs show that the mix of solutions selected is the least cost for addressing the anticipated volumes of assets that are expected to require intervention to address clearance issues.

11.2 Approach

11.2.1 Options Costs

There three options considered by our Asset Management engineers for our RIIO-ED1 plan were different mixes of structural mitigation on climbable tree issues, as described below:

- Baseline Scenario: Structural Mitigation for 60% of LV issues, 10% of HV, and 10% of 132kV issues. This was the original assumption in our original RIIO-ED1 business plan submission for SPN. Alternative approaches have been tested to judge whether there are more effective options.
- Option 1: Structural Mitigation for 100% of LV issues, 3% of HV, and 3% of 132kV issues
- Option 2: Structural Mitigation for 60% of LV issues, 3% of HV, and 3% of 132kV issues

Asset Management engineers estimate that the volume of structural mitigation will decrease by 3% per annum in every scenario, as the opportunities for non-compliance with the regulations are eliminated from the network. The costs for these scenarios were all based on a set of assumed unit costs based on each activity, as shown below:

Table 170 Cost Calculations for EPN

Scheme Name	Assumed UCI (£k/unit)	Baseline Scenario Volumes	Baseline Scenario Costs (£m)	Option 1 Volumes	Option 1 Costs (£m)	Option 2 Volumes	Option 2 Costs (£m)
Climbable Tree risk mitigation - LV Shrouding Permanent	1.0	441	0.44	748	0.75	441	0.44
Climbable Tree risk mitigation - LV (Diversions)	2.2	441	0.99	748	1.68	441	0.99
Climbable Tree Risk Mitigation - LV (Reconductoring)	2.2	5,388	12.08	8,980	20.13	5,388	12.08
Climbable Tree risk mitigation - Rebuild	2.2	1,799	4.03	2,995	6.71	1,799	4.03
Climbable Tree Risk Mitigation - LV (Undergrounding)	2.2	895	2.01	1,499	3.36	895	2.01
Re-Establish Statutory Clearances - LV Shrouding Permanent	1.0	406	0.41	406	0.41	406	0.41
Re-Establish Statutory Clearances - LV (Diversions)	2.2	406	0.91	406	0.91	406	0.91
Re-Establish Statutory Clearances - LV (Reconductoring)	2.2	4,959	11.12	4,959	11.12	4,959	11.12
Re-Establish Statutory Clearances - LV (Rebuild)	2.2	1,651	3.70	1,651	3.70	1,651	3.70
Re-Establish Statutory Clearances - LV (Undergrounding)	2.2	828	1.86	828	1.86	828	1.86
Climbable Tree risk mitigation - HV (Diversions)	3.5	1,166	4.08	364	1.27	364	1.27
Climbable Tree Risk Mitigation - HV (Reconductoring)	3.5	128	0.45	40	0.14	40	0.14
Climbable Tree Risk Mitigation - HV (Rebuild)	3.5	695	2.43	204	0.71	204	0.71
Climbable Tree risk mitigation - HV (Undergrounding)	10.0	364	3.64	120	1.20	120	1.20
Re-Establish Statutory Clearances - HV (Diversions)	3.5	164	0.57	164	0.57	164	0.57
Re-Establish Statutory Clearances - HV (Reconductoring)	3.5	32	0.11	32	0.11	32	0.11
Re-Establish Statutory Clearances - HV (Rebuild)	3.5	332	1.16	332	1.16	332	1.16
Re-Establish Statutory Clearances - HV (Undergrounding)	10.0	64	0.64	64	0.64	64	0.64
Climbable Tree risk mitigation - EHV (Diversions)	7.7	188	1.45	72	0.55	72	0.55
Climbable Tree Risk Mitigation - EHV (Rebuild)	7.7	134	1.03	48	0.37	48	0.37
Climbable Tree risk mitigation - EHV (Undergrounding)	22.5	64	1.44	24	0.54	24	0.54
Re-Establish Statutory Clearances - EHV (Diversions)	7.7	8	0.06	8	0.06	8	0.06

Scheme Name	Assumed UCI (£k/unit)	Baseline Scenario Volumes	Baseline Scenario Costs (£m)	Option 1 Volumes	Option 1 Costs (£m)	Option 2 Volumes	Option 2 Costs (£m)
Re-Establish Statutory Clearances- EHV (Rebuild)	7.7	16	0.12	16	0.12	16	0.12
Total		**20,569**	**54.73**	**24,708**	**58.09**	**18,702**	**45.00**

Table 171 Cost Calculations for SPN

Scheme Name	Assumed UCI (£/unit)	Baseline Scenario Volumes	Baseline Scenario Costs (£m)	Option 1 Volumes	Option 1 Costs (£m)	Option 2 Volumes	Option 2 Costs (£m)
Climbable Tree risk mitigation - LV Shrouding Permanent	1.0	419	0.42	703	0.70	419	0.42
Climbable Tree risk mitigation - LV (Diversions)	2.2	419	0.92	703	1.55	419	0.92
Climbable Tree Risk Mitigation - LV (Reconductoring)	2.2	5,104	11.23	8,515	18.74	5,104	11.23
Climbable Tree risk mitigation - Rebuild	2.2	1,702	3.75	2,835	6.24	1,702	3.75
Climbable Tree Risk Mitigation - LV (Undergrounding)	2.2	853	1.88	1,418	3.12	853	1.88
Re-Establish Statutory Clearances - LV Shrouding Permanent	1.0	134	0.13	134	0.13	134	0.13
Re-Establish Statutory Clearances - LV (Diversions)	2.2	134	0.29	134	0.29	134	0.29
Re-Establish Statutory Clearances - LV (Reconductoring)	2.2	1,670	3.68	1,670	3.68	1,670	3.68
Re-Establish Statutory Clearances - LV (Rebuild)	2.2	568	1.25	568	1.25	568	1.25
Re-Establish Statutory Clearances - LV (Undergrounding)	2.2	284	0.63	284	0.63	284	0.63
Climbable Tree risk mitigation - HV (Diversions)	3.5	56	0.20	16	0.06	16	0.06
Climbable Tree Risk Mitigation - HV (Reconductoring)	3.5	8	0.03	0	0.00	0	0.00
Climbable Tree Risk Mitigation - HV (Rebuild)	3.5	32	0.11	8	0.03	8	0.03
Climbable Tree risk mitigation - HV (Undergrounding)	10.0	16	0.16	8	0.08	8	0.08
Re-Establish Statutory Clearances - HV (Diversions)	3.5	138	0.48	138	0.48	138	0.48
Re-Establish Statutory Clearances - HV (Reconductoring)	3.5	32	0.11	32	0.11	32	0.11
Re-Establish Statutory Clearances - HV (Rebuild)	3.5	276	0.97	276	0.97	276	0.97

Scheme Name	Assumed UCI (£/unit)	Baseline Scenario Volumes	Baseline Scenario Costs (£m)	Option 1 Volumes	Option 1 Costs (£m)	Option 2 Volumes	Option 2 Costs (£m)
Re-Establish Statutory Clearances - HV (Undergrounding)	10.0	56	0.56	56	0.56	56	0.56
Climbable Tree risk mitigation - EHV (Diversions)	7.7	48	0.37	16	0.12	16	0.12
Climbable Tree Risk Mitigation - EHV (Rebuild)	7.7	32	0.25	8	0.06	8	0.06
Climbable Tree risk mitigation - EHV (Undergrounding)	22.5	16	0.36	8	0.18	8	0.18
Re-Establish Statutory Clearances - EHV (Diversions)	7.7	8	0.06	8	0.06	8	0.06
Re-Establish Statutory Clearances- EHV (Rebuild)	7.7	16	0.12	16	0.12	16	0.12
Total		**12,021**	**27.96**	**17,554**	**39.17**	**11,877**	**27.01**

11.2.2 Scenario Benefits

All scenarios considered in the CBAs achieve the same aim, i.e. the same volumes of climbable tree and clearance issues are eliminated, the alternative options simply consider the approach used to accomplish this. Therefore, the safety benefits in all scenarios are the same, and no calculations were required.

11.3 Results

11.3.1 CBA Results

Table 172 EPN ESQCR Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Option 1	-£2.81	-£3.68	-£4.26	-£4.87
Option 2	£8.21	£10.74	£12.45	£14.25

Table 173 SPN ESQCR Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Option 1	-£8.87	-£11.58	-£13.41	-£15.33
Option 2	£2.05	£2.69	£3.13	£3.59

11.3.2 Discussion

Whilst the baseline scenario was our initial approach for the original business plan submission, the outcome of these CBAs has caused us to reconsider our strategy. Therefore, we propose to undertake less structural mitigation on climbable tree issues where possible. There are occasions where structural mitigation is unavoidable, where landowners do not give us consent to cut down their trees, for example, but overall we believe we can reduce our structural mitigation to 60% for LV issues, 3% for HV, and 3% for 132kV issues.

12 BT21

12.1 Summary

The installation of a fibre-communication network to replace the current teleprotection paths that are currently owned by BT will cost us £43m over RIIO-ED1, and £158m over the assumed 'in-service' period of the network. Five different options were considered by our Asset Management engineers in order to choose the most cost effective approach.

Table 174 CBA Outcome

BT21 Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
BT21CN	7.37		7.34	14.71

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

The CBAs demonstrate that our approach to resolving the BT21 protection communications issue using a mix of own build assets and rented dark fibre circuits optimised against our overhead line interventions offers the best value for money for customers. For more information on our BT21 proposals, please refer to our BT21 Asset Stewardship Reports for EPN and SPN.

12.2 Approach

12.2.1 Options Costs

In order to ensure a reliable teleprotection network, our Asset Management engineers have considered five options that could be employed. These are described below.

- Baseline Scenario: Mix of self-build new network and leased dark fibre aligned with our infrastructure plans – this is our chosen scenario
- Option 1: Self build without alignment, where the infrastructure is partly owned by UK Power Networks and partly leased from a third-party, but installation is aligned with current asset replacement works, so only the incremental costs of the additional cable are attributed to BT21.
- Option 2: Self build with alignment, where the infrastructure is wholly owned by UK Power Networks, but is not aligned with current asset replacement works, so the entire cost of the cable installation is attributed to BT21
- Option 3: Leased dark fibre with alignment, where the infrastructure is wholly owned by a third-party service, but installation is aligned with current asset replacement works, so only the incremental costs of the additional cable is attributed to BT21
- Option 4: Leased dark fibre without alignment, where the infrastructure is wholly owned by a third-party service, and installation is not aligned to when asset replacement works are taking place, so the entire costs of the works are attributed to BT21

The costs for each of these approaches have been estimated by our Asset Management engineers, based on consultations with contractors and equipment suppliers on resourcing and installation rates. For further discussion of the costs, please refer to the BT21 Asset Stewardship Reports.

The costs of each option are summarised below:

Table 175 BT21 Option Costs

Scheme Name	EPN Total ED1 costs	EPN Total Whole life costs	SPN Total ED1 costs	SPN Total Whole life costs
Baseline: Self build and leased dark fibre with alignment	£25.12m	£103.81m	£17.82m	£54.32m
Option 1: Self build without alignment	£52.60m	£132.82m	£74.48m	£39.61m
Option 2: Self build with alignment	£48.07m	£97.22m	£36.30m	£59.16m
Option 3: Leased dark fibre with alignment	£33.89m	£99.40m	£25.54m	£57.14m
Option 4: Leased dark fibre without alignment	£34.53m	£143.56m	£26.06m	£75.03m

12.2.2 Scenario Benefits

Since all of the considered options achieve the same outcome, there were considered to be no difference in benefits between the options. Therefore, this analysis comes down to the least whole-life cost option.

12.2.3 Sensitivities

A sensitivity has been run on the baseline scenario, to test whether an increase in the estimated whole-life costs has an impact upon the final decision. The sensitivity increases the costs by 10%, which proves to have little impact upon the decision we have made.

12.3 Results

12.3.1 CBA Results

Table 176 EPN BT21 Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Sensitivity on baseline scenario	-£2.17	-£3.12	-£4.07	-£5.40
Option 1	-£15.98	-£16.94	-£24.22	-£27.58
Option 2	-£13.23	-£14.38	-£14.63	-£12.76
Option 3	-£5.58	-£7.98	-£8.43	-£7.37
Option 4	-£5.10	-£5.89	-£14.14	-£19.86

Table 177 SPN BT21 Results

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
Baseline Scenario	N/A	N/A	N/A	N/A
Sensitivity on baseline scenario	-£1.43	-£1.96	-£2.47	-£3.15
Option 1	-£13.67	-£15.29	-£18.83	-£20.71
Option 2	-£11.56	-£13.11	-£13.75	-£13.46
Option 3	-£5.27	-£6.93	-£7.47	-£7.34
Option 4	-£5.11	-£6.04	-£9.75	-£12.40

12.3.2 Discussion

These CBAs show that our proposed approach of using a mix of our own new networks and leased dark fibre to achieve BT21 mitigation provides is more cost effective for dealing with an unavoidable issue than trying to address through a new network that we wholly own or through leasing dark fibre in all instances. This reflects that where dark fibre is readily available it is cheaper to lease than to try to install our own circuits but where there are not large capacity links or where there is no free capacity and especially where we are undertaking other work on the network it is cheaper for UK Power Networks to install its own.

13 Central London Plan

13.1 Summary

We have identified a need for increased expenditure in the Central London area, where resilient supplies are of critical economic priority, to reinforce our network and ensure as little disruption as possible to our customers in this area.

The area itself has a GVA per customer 19 times higher than the UK average.

We propose to spend an additional £11.2m per annum above a 'business as usual' approach on both opex and capex related activities.

Table 178 CBA Outcome

Central London Plan Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
Central London Plan		36.51		36.51

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

We have carried out CBA an assessment showing that the proposed investments offer value for money in terms of quality of supply when considering the relative in GVA for central London compared to the national average (19 times).

13.2 Approach

13.2.1 Options Costs

Please refer to the Central London Network section of our Annex 13a Regional Cost Justification for full details on the increased costs associated with our Central London Plan. We consider that there will be an additional £11.2m per annum of expenditure, composed of £6.9m of operational expenditure, and £4.3m of capital expenditure.

13.2.2 Scenario Benefits

The benefits have been based on the Central London Strategy section of Annex 13a Regional Cost Justification. There are 160,000 customers within the defined area that would benefit, and our predicted benefits are 12,800 customer interruptions per annum, and 1,920,000 customer minutes lost per annum (equivalent to 8 CI per 100 customers and 12CMLs per customer), about 30% of the current performance for this area.

Given the higher criticality of this region, we have increased the value associated with each of these benefits. We have considered two options. The first is that based on the GVA for 2012 of £139,906m for the 162,000 customers which gives £3.94 per minute based on a 10hour working day. On the same basis the national value would be £0.21 per minute. Ofgem have values a minute lost at £0.38 per minute so we have also considered a sensitivity increasing Ofgem's values by the ratio of the GVA (19x) above, as below:

Table 179 CBA Outcome

CBA Model	Ofgem Original Value	New Calculated Value	Alternative value used in sensitivity
CI	£15.44	£160.12	£290.34
CML	£0.38	£3.94	£7.14

13.3 Results

13.3.1 CBA Results

Table 180 Central London

£m CBA Model Output	16 Years	24 Years	32 years	45 Years
No investment	N/A	N/A	N/A	N/A
Central London Strategy values for CI and CML	£11.99	-£0.42	-£8.72	-£17.23
Ofgem's values increased by Central London GVA to national average ratio	£65.73	£53.32	£45.03	£36.51

13.3.2 Discussion

The CBA shows that the economic value of the activity in this area supports the additional expenditure to improve the service levels proposed.

14 Low Carbon Generation

14.1 Summary

The following projects were looked at as potential low carbon generation schemes. Ultimately, the four highlighted projects were selected to progress through to completion after being assessed as the most feasible and beneficial generation schemes. We have therefore proposed to spend approximately £15.35m on additional Low Carbon Generation in RIIO-ED1.

Table 181 Low carbon generation schemes

Scheme Name Low Carbon (Phased Utilisation 2) Whole Life Benefit CBA £m	RAG Status
Trowse Grid 132kV	£47.0
Kings Lynn- Snettisham	£12.7
Kings Lynn- Hempton	£11.6
Kings Lynn South- Downham Market	£7.3
Walsoken- Downham Market	£6.7
Kings Lynn South- Walsoken	£7.0
Snettisham - Hunstanton – Burnham Thorpe	£12.3
Swaffham – Hempton	£12.4
Funtham's Lane – Chatteris tee point	£13.2
Sall – Stody – West Beckham	£12.3
Wroxham – North Walsham No 1	£7.5
Wroxham – Scottow - North Walsham No 2	£7.5
Sall – Sprowston	£12.8
March Grid	£49.1
New Grid Substation between March and Peterborough	£96.2
Peterborough East	£32.8
Total	£348.4
Selected Schemes	£205.5

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

Whilst the CBAs suggested that all schemes should be completed, only four of them were ultimately adopted as projects for completion in RIIO-ED1. This is due to the large uncertainty based around low carbon generation, we felt that it would be prudent to adopt only the most beneficial and viable schemes.

14.2 Approach

14.2.1 Options Costs

Our Asset Management engineers estimated the following costs for each site, based on their experience and knowledge of similar projects. The options were simply whether to reinforce the network using low carbon generation, or whether to reinforce through more traditional means.

Table 182 Low carbon generation schemes

Scheme Name	Estimated Cost (£m)
Trowse Grid 132kV	£0.35
Kings Lynn- Snettisham	£1.50
Kings Lynn- Hempton	£2.50
Kings Lynn South- Dowham Market	£1.00
Walsoken- Downham Market	£1.50
Kings Lynn South- Walsoken	£1.20
Snettisham - Hunstanton – Burnham Thorpe	£1.80
Swaffham – Hempton	£1.70
Funtham's Lane – Chatteris tee point	£1.00
Sall – Stody – West Beckham	£1.80
Wroxham – North Walsham No 1	£0.80
Wroxham – Scottow - North Walsham No 2	£0.80
Sall – Sprowston	£1.40
March Grid	£4.00
New Grid Substation between March and Peterborough	£10.00
Peterborough East	£14.00

14.2.2 Scenario Benefits

The key benefits considered were the reduction in emissions gained from low carbon generation, which is measured by the amount, in MWh, of generation a scheme would produce each year. This was calculated by translating the MVA provided by the additional generation into the corresponding MW values. Essentially, this was done by multiplying by a load factor of 0.4, and a power factor of 1. This MW value is then turned into the annual MWh, by multiplying by the number of hours in a year. This produces the following values for input into the CBA model.

Table 183 Low carbon generation schemes

Scheme Name	Additional MVA provided (Winter)	Equivalent MW	Annual Low Carbon MWh
Trowse Grid 132kV	40	16	140160
Kings Lynn- Snettisham	12	4.8	42048
Kings Lynn- Hempton	12	4.8	42048
Kings Lynn South- Dowham Market	7	2.8	24528
Walsoken- Downham Market	7	2.8	24528

Scheme Name	Additional MVA provided (Winter)	Equivalent MW	Annual Low Carbon MWh
Kings Lynn South- Walsoken	7	2.8	24528
Snettisham - Hunstanton – Burnham Thorpe	12	4.8	42048
Swaffham – Hempton	12	4.8	42048
Funtham's Lane – Chatteris tee point	12	4.8	42048
Sall – Stody – West Beckham	12	4.8	42048
Wroxham – North Walsham No 1	7	2.8	24528
Wroxham – Scottow - North Walsham No 2	7	2.8	24528
Sall – Sprowston	12	4.8	42048
March Grid	45	18	157680
New Grid Substation between March and Peterborough	90	36	315360
Peterborough East	40	16	140160

14.2.3 Sensitivities

Due to the uncertain and untested nature of low carbon generation, we have applied a number of sensitivities to ensure we propose only the most robust schemes with a clear case for doing so.

Since the capacity is not guaranteed to be taken up in one year. We carried out a number of sensitivities looking at different take up rates.

Phased Utilisation 1

Phased Utilisation of Capacity as follows:

Year 1	Year 2	Year 3	Year 4	Year 5
50.00%	80.00%	100.00%	100.00%	100.00%

Phased Utilisation 2

Phased Utilisation of Capacity as follows:

Year 1	Year 2	Year 3	Year 4	Year 5
10.00%	50.00%	90.00%	100.00%	100.00%

Phased Utilisation 3

Phased Utilisation of Capacity as follows:

Year 1	Year 2	Year 3	Year 4	Year 5
10.00%	20.00%	40.00%	60.00%	100.00%

Additionally we tested the potential outcome should not all the capacity be low carbon generation. We have run scenarios where only 75% of proposed capacity is low carbon and another with only 50%.

14.3 Results

14.3.1 CBA Results

Table 184 Low Carbon Generation Reinforcement – Immediate Utilisation

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Trowse Grid 132kV	£20.75	£36.19	£45.34	£47.78
Kings Lynn- Snettisham	£5.18	£9.64	£12.26	£12.88
Kings Lynn- Hempton	£4.43	£8.76	£11.30	£11.83
Kings Lynn South- Dowham Market	£2.93	£5.51	£7.03	£7.38
Walsoken- Downham Market	£2.56	£5.07	£6.55	£6.86
Kings Lynn South- Walsoken	£2.78	£5.34	£6.84	£7.17
Snettisham - Hunstanton – Burnham Thorpe	£4.96	£9.37	£11.98	£12.56
Swaffham – Hempton	£5.03	£9.46	£12.07	£12.67
Funtham's Lane – Chatteris tee point	£5.56	£10.07	£12.74	£13.40
Sall – Stody – West Beckham	£4.96	£9.37	£11.98	£12.56
Wroxham – North Walsham No 1	£3.08	£5.69	£7.23	£7.59
Wroxham – Scottow - North Walsham No 2	£3.08	£5.69	£7.23	£7.59
Sall – Sprowston	£5.26	£9.72	£12.36	£12.98
March Grid	£20.64	£37.55	£47.55	£49.99
New Grid Substation between March and Peterborough	£39.79	£73.36	£93.17	£97.89
Peterborough East	£10.54	£24.24	£32.24	£33.52

Table 185 Low Carbon Generation Reinforcement – Phased Utilisation 1

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Trowse Grid 132kV	£20.39	£35.83	£44.99	£47.43
Kings Lynn- Snettisham	£5.08	£9.53	£12.16	£12.77
Kings Lynn- Hempton	£4.33	£8.65	£11.20	£11.73
Kings Lynn South- Dowham Market	£2.87	£5.45	£6.97	£7.32
Walsoken- Downham Market	£2.49	£5.01	£6.49	£6.80
Kings Lynn South- Walsoken	£2.72	£5.27	£6.78	£7.11
Snettisham - Hunstanton – Burnham Thorpe	£4.85	£9.27	£11.87	£12.46
Swaffham – Hempton	£4.93	£9.35	£11.97	£12.56
Funtham's Lane – Chatteris tee point	£5.45	£9.97	£12.64	£13.29
Sall – Stody – West Beckham	£4.85	£9.27	£11.87	£12.46
Wroxham – North Walsham No 1	£3.02	£5.62	£7.16	£7.53
Wroxham – Scottow - North Walsham No 2	£3.02	£5.62	£7.16	£7.53
Sall – Sprowston	£5.15	£9.62	£12.25	£12.88

March Grid	£20.25	£37.16	£47.15	£49.59
New Grid Substation between March and Peterborough	£39.00	£72.56	£92.38	£97.09
Peterborough East	£10.19	£23.89	£31.89	£33.17

Table 186 Low Carbon Generation Reinforcement – Phased Utilisation 2

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Trowse Grid 132kV	£19.99	£35.43	£44.58	£47.03
Kings Lynn- Snettisham	£4.95	£9.41	£12.04	£12.65
Kings Lynn- Hempton	£4.21	£8.53	£11.08	£11.61
Kings Lynn South- Dowham Market	£2.80	£5.38	£6.90	£7.25
Walsoken- Downham Market	£2.42	£4.94	£6.42	£6.73
Kings Lynn South- Walsoken	£2.65	£5.20	£6.71	£7.04
Snettisham - Hunstanton – Burnham Thorpe	£4.73	£9.15	£11.75	£12.34
Swaffham – Hempton	£4.80	£9.23	£11.84	£12.44
Funtham's Lane – Chatteris tee point	£5.33	£9.85	£12.52	£13.17
Sall – Stody – West Beckham	£4.73	£9.15	£11.75	£12.34
Wroxham – North Walsham No 1	£2.95	£5.55	£7.09	£7.46
Wroxham – Scottow - North Walsham No 2	£2.95	£5.55	£7.09	£7.46
Sall – Sprowston	£5.03	£9.50	£12.13	£12.76
March Grid	£19.79	£36.70	£46.70	£49.14
New Grid Substation between March and Peterborough	£38.09	£71.66	£91.47	£96.19
Peterborough East	£9.79	£23.48	£31.48	£32.76

Table 187 Low Carbon Generation Reinforcement – Phased Utilisation 3

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Trowse Grid 132kV	£19.39	£34.83	£43.98	£46.43
Kings Lynn- Snettisham	£4.77	£9.23	£11.86	£12.47
Kings Lynn- Hempton	£4.03	£8.35	£10.90	£11.43
Kings Lynn South- Dowham Market	£2.69	£5.27	£6.80	£7.14
Walsoken- Downham Market	£2.32	£4.84	£6.32	£6.62
Kings Lynn South- Walsoken	£2.54	£5.10	£6.60	£6.93
Snettisham - Hunstanton – Burnham Thorpe	£4.55	£8.96	£11.57	£12.16
Swaffham – Hempton	£4.62	£9.05	£11.66	£12.26
Funtham's Lane – Chatteris tee point	£5.15	£9.67	£12.34	£12.99
Sall – Stody – West Beckham	£4.55	£8.96	£11.57	£12.16
Wroxham – North Walsham No 1	£2.84	£5.45	£6.99	£7.35
Wroxham – Scottow - North Walsham No 2	£2.84	£5.45	£6.99	£7.35

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Sall – Sprowston	£4.85	£9.32	£11.95	£12.57
March Grid	£19.12	£36.03	£46.02	£48.46
New Grid Substation between March and Peterborough	£36.74	£70.30	£90.12	£94.83
Peterborough East	£9.18	£22.88	£30.88	£32.16

Table 188 Low Carbon Generation Reinforcement No Phasing – 75% Low Carbon

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Trowse Grid 132kV	£15.49	£27.06	£33.92	£35.75
Kings Lynn- Snettisham	£3.61	£6.90	£8.84	£9.27
Kings Lynn- Hempton	£2.86	£6.02	£7.88	£8.22
Kings Lynn South- Dowham Market	£2.01	£3.91	£5.04	£5.27
Walsoken- Downham Market	£1.64	£3.48	£4.56	£4.75
Kings Lynn South- Walsoken	£1.86	£3.74	£4.84	£5.07
Snettisham - Hunstanton – Burnham Thorpe	£3.38	£6.64	£8.55	£8.95
Swaffham – Hempton	£3.46	£6.72	£8.65	£9.06
Funtham's Lane – Chatteris tee point	£3.98	£7.34	£9.32	£9.79
Sall – Stody – West Beckham	£3.38	£6.64	£8.55	£8.95
Wroxham – North Walsham No 1	£2.16	£4.09	£5.23	£5.48
Wroxham – Scottow - North Walsham No 2	£2.16	£4.09	£5.23	£5.48
Sall – Sprowston	£3.68	£6.99	£8.93	£9.37
March Grid	£14.74	£27.29	£34.70	£36.45
New Grid Substation between March and Peterborough	£27.98	£52.83	£67.48	£70.80
Peterborough East	£5.29	£15.12	£20.82	£21.48

Table 189 Low Carbon Generation Reinforcement No Phasing – 50% Low Carbon

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Trowse Grid 132kV	£10.24	£17.94	£22.50	£23.71
Kings Lynn- Snettisham	£2.03	£4.16	£5.41	£5.66
Kings Lynn- Hempton	£1.28	£3.29	£4.45	£4.61
Kings Lynn South- Dowham Market	£1.09	£2.32	£3.04	£3.17
Walsoken- Downham Market	£0.72	£1.88	£2.56	£2.65
Kings Lynn South- Walsoken	£0.94	£2.14	£2.84	£2.96
Snettisham - Hunstanton – Burnham Thorpe	£1.81	£3.90	£5.12	£5.34
Swaffham – Hempton	£1.88	£3.99	£5.22	£5.45

£m CBA Model Output Scheme Name	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Funtham's Lane – Chatteris tee point	£2.40	£4.60	£5.89	£6.18
Sall – Stody – West Beckham	£1.81	£3.90	£5.12	£5.34
Wroxham – North Walsham No 1	£1.24	£2.49	£3.23	£3.38
Wroxham – Scottow - North Walsham No 2	£1.24	£2.49	£3.23	£3.38
Sall – Sprowston	£2.10	£4.25	£5.51	£5.76
March Grid	£8.83	£17.03	£21.85	£22.90
New Grid Substation between March and Peterborough	£16.16	£32.30	£41.79	£43.72
Peterborough East	£0.04	£5.99	£9.40	£9.45

14.3.2 Discussion

All the scenarios produced positive costs benefit assessments. As we do not expect all generation projects to progress we have used the benefit to cost ratio to select the projects included in our proposals. Projects above the upper quartile benefit/cost ratio have been included in our proposals. The four schemes represent 56% of potential identified capacity, and 34% of identified potential expenditure.

15 Losses Strategy

15.1 Summary

Our Losses Strategy Document details the various opportunistic measures we are planning to employ in order to minimise losses on our network, from Demand Side Response to Optimised Transformer Specifications. Because these measures are opportunistic, any additional investment required is minimal. For the purposes of the CBA, we note that these additional costs are only £250k above what is built into our existing load and non-load expenditure plans.

In addition, a new possible EU directive may lead to new, tougher standards for electrical losses in our distribution transformers. A CBA assessment has been carried out and sensitivities were run to establish a threshold for the price of a new low loss transformer that would produce a positive CBA result. This is essentially a 'tipping point' price, where if these new transformers are below a certain price, installation of them can be considered justifiable, whereas if they turn out to be more expensive, it will not. The outcome of this CBA does not determine a 'correct' approach to take, but will assist in the decision making process when required.

Table 190 CBA Outcome

Losses Strategy Whole Life Benefit CBA Model 3m	RAG Status
UKPN Losses Strategy	£293.6

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

15.2 Approach

15.2.1 Options Costs

As our Losses strategy is very much an 'opportunistic' approach, where reduced losses investment is often in conjunction with other investment drivers, only the incremental costs of these initiatives are taken into account in the options. Therefore, the baseline scenario is a 'business as usual' approach, assuming these other investment drivers are undertaken anyway, without the added costs of the loss reduction measures.

The alternative option is to employ these loss reduction processes, and predicts an additional cost of £250,000 over and above what is already built in to our capital expenditure proposals to adopt these measures.

15.2.2 Scenario Benefits

The CBA model has been used to calculate a benefit for all the loss reduction initiatives we have identified for RIIO-ED1. For all of the measures set out in the Losses Strategy (Annex 7), an overall 'reduced losses' amount was calculated for each year of RIIO-ED1, and then flat-lined beyond this. These calculations can be seen in the CBA model, using predicted peak demand growth to calculate the losses saved.

When calculating the benefits of moving to the low EU losses standard, the baseline scenario is where more traditional, higher loss transformers continue to be installed. The multiple options are modelled around various ratings and types of low loss transformers (315kVA transformer, 500kVA transformer, 800kVA transformer, 1000kVA transformer, 25kVA Pole Mounted Transformer (PMT), 50kVA PMT and 100kVA PMT), looking at the additional cost of a low loss transformer, against the benefits of reduced losses. Standard losses ratings for our current transformers were compared against the losses ratings for the new, proposed transformers. An annual MWh was then calculated for each, and the two compared to get a 'reduction in losses' benefit.

15.3 Results

15.3.1 CBA Results

Table 191 Loss Reduction Strategy

Loss Reduction	8 years	16 years	24 years	32 years	45 years
Baseline: Employ no loss reduction measures					
Documented losses strategy	£46.87	£129.2	£196.9	£244.6	£293.6

15.3.2 Discussion

Our proposed loss reduction measures are forecast to bring benefits of over £45m during the RIIO-ED1 period.

The CBA testing the effects of the new EU directive, requiring new standards for losses in distribution transformers, found that, for 1000kVA transformers to be considered a justifiable expenditure, they need to be within 25% (based on 100kVA transformer) of the current cost of a new transformer. Our current 500kVA transformer specification already provides for low losses until the more stringent EU standards are available at reasonable costs.

16 Smart Grid Solutions

16.1 Summary

A number of Smart technologies have been tested through Ofgem's CBA model, looking at whether the use of these technologies to defer conventional investment, provides sufficient justification for their utilisation. The technologies that were considered were:

- Demand Side Response
- Partial Discharge Testing (switchgear)
- OHL Ratings
- Real Time Transformer Ratings

Please refer to our Innovation Strategy for detailed information of what each of these technologies involve.

Table 192 CBA Outcome

Smart Grid Strategy Whole Life Benefit CBA £m	EPN	LPN	SPN	Total
Smart Grid Strategy	0.28	0.01	0.05	0.33

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

Our smart grid CBAs show a positive benefit for our chosen policies. Together our smart grid benefits come to £141m for RIIO-ED1.

16.2 Approach

16.2.1 Option costs

For all Smart Grid solution schemes except Partial Discharge Monitoring, the baseline scenario is set as network reinforcement during RIIO-ED1, with the options examining the effects of employing these Smart Grid Solutions in order to defer investment by a number of years, depending on the technology. The deferral lengths are shown below.

Table 193 CBA Deferral Lengths

Smart Grid Solution	Deferral Length
Demand Side Response- EPN & SPN	3 years/6 years, depending on sensitivity
Demand Side Response- LPN	4 years
33kV OHL Ratings	3 years
132kV OHL Ratings	2/4/6 years, depending on sensitivity
Real Time Transformer Rating	3 years

For Partial Discharge Monitoring, as installation of this equipment does not guarantee the ability to defer reinforcement, the baseline scenario has been set as 35% of sites equipped with monitoring devices are able to defer further investment by 5 years, with sensitivities run around this of 20%, 50% and 60%.

The costs used for most CBAs are based around estimations of what a traditional reinforcement scheme would cost, since the CBAs are mainly looking at the effects of deferral of these costs. Employment of these technologies has a small cost, detailed below:

Smart Grid Solution	Deferral Length
Demand Side Response- EPN & SPN	DSR Payment costs of £30k per annum
Demand Side Response- LPN	DSR Payment costs of £86k per annum
33kV OHL Ratings	One off dynamic rating Costs of £35k
132kV OHL Ratings	One off dynamic rating Costs of £86k
Real Time Transformer Rating	RTTR on two transformers at £70k per transformer
Partial Discharge Monitoring	£300k for initial equipment, £3k per annum opex costs

16.3 Results

Table 194 EPN and SPN Demand Side Response

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Baseline Scenario-£3m reinforcement	£0.00	£0.00	£0.00	£0.00
2MVA of DSR allow deferment of £3m reinforcement for 3 years.	£0.30	£0.26	£0.24	£0.18
2MVA of DSR allow deferment of £1m reinforcement for 3 years.	£0.04	£0.02	£0.00	-£0.02
2MVA of DSR allow deferment of £0.5m reinforcement for 6 years.	-£0.03	-£0.07	-£0.10	-£0.14

Table 195 LPN Demand Side Response

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Baseline Scenario-£5m reinforcement	£0.00	£0.00	£0.00	£0.00
5MVA of DSR allow deferment of £5m reinforcement for 4 years.	£0.47	£0.38	£0.31	£0.22
5MVA of DSR allow deferment of £13.1 reinforcement for 4 years.	£1.90	£1.73	£1.60	£1.30

Table 196 Smart Solutions Partial Discharge Testing

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Baseline Scenario-30 sites equipped defers investment of 35% of sites (11 sites / £11m) by 5 years £11m cost split equally between the last 5 years of the ED1 period OPEX Incurred up to the last replacement (beyond ED1)	£0.70	£0.22	-£0.12	-£0.50
30 sites equipped defers investment of 50% of sites (15 sites / £18m) by 5 years £15m cost split equally between the last 5 years of the ED1 period OPEX Incurred up to the last replacement (beyond ED1)	£1.52	£1.02	£0.67	£0.25

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
30 sites equipped defers investment of 60% of sites (18 sites / £18m) by 5 years £18m cost split equally between the last 5 years of the ED1 period OPEX Incurred up to the last replacement (beyond ED1)	£2.09	£1.55	£1.17	£0.71

Table 197 Smart Solutions 132kV Overhead Line Ratings

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Baseline Scenario- £6.36m Reinforcement	£0.00	£0.00	£0.00	£0.00
Defer reinforcement for 8 years	£1.32	£1.08	£0.89	£0.68
Defer reinforcement for 4 years	£0.37	£0.19	£0.06	-£0.08
Defer reinforcement for 2 years	-£0.14	-£0.29	-£0.39	-£0.50

Table 198 Smart Solutions 33kV Overhead Line Ratings

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Baseline Scenario- £2.7m Reinforcement	£0.00	£0.00	£0.00	£0.00
Defer reinforcement for 3 years	£0.26	£0.24	£0.23	£0.21

Table 199 Smart Solutions Real Time Transformer Ratings

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
Baseline Scenario- £1.5m Reinforcement	£0.00	£0.00	£0.00	£0.00
RTTR on two transformers at £70k per transformer allow £1.5m deferment for 3 years	£0.08	£0.05	£0.04	£0.00

16.3.1 Discussion

In EPN & SPN, demand side response can be seen to be beneficial 2MVA of DSR defers more than £1 million of reinforcement investment for 3 or more years. In LPN our DSR assessment has considered that a larger amount of DSR would have to be procured to defer investment, but that this would defer a higher value of investment. This indicated that 5MVA of DSR deferring £5m for 4 years would provide a positive cost benefit.

Partial Discharge: The analysis shows that the additional installation and opex costs are outweighed by the benefits of deferring the replacement of switchgear.

OHL Ratings: The scenarios assessed indicate that providing deferral is greater than 3 years, the employment of OHL rating equipment is justified.

RTTR: Installing equipment to allow real time transformer ratings is beneficial if reinforcement can be deferred for 3 years.

17 Quality of Supply

17.1 Summary

Whilst we are no longer asking for any funding for Quality of Supply improvements within RIIO-ED1, we have constructed a CBA to demonstrate that employing these measures represent a beneficial saving.

The QoS schemes that were considered are:

- Algorithmic Automation
- ASL Programme
- Auto Recloser Programme
- Switchgear Change Programme
- Improved Operational Response

A detailed discussion of the benefits is included in the Quality of Supply Strategy.

Table 200 CBA Outcome

Quality of Supply Whole Life Benefit CBA (£m)	RAG Status
EPN Quality of Supply	£22.48
LPN Quality of Supply	£2.17
SPN Quality of Supply	£14.20

These values are for the full 45 year CBA period and are converted to an 8 year straight line equivalent for the executive summary and stakeholder facing documents.

17.2 Approach

17.2.1 Option Costs

The baseline scenario is simply not employing any Quality of Supply Improvement initiatives, and hence no additional costs are input into the model. The alternative option looks at the costs and benefits of employing these benefits, which have been taken from our initial submission costs, from CV106 in Ofgem's data tables.

Table 201 CBA Option Costs

CBA Model	Qos Costs
EPN	£17.44m
LPN	£6.43m
SPN	£8.07m

17.2.2 Option Benefits

Similar to above, the CI and CML improvements achieved through these schemes are taken from the CV106 table in Ofgem's data tables. Since these benefits are stated per 100 customers, a total saving in customer interruptions and customer minutes lost are calculated by multiplying these numbers by 1/100th of the total customers in each DNO licence area. This produces the following CI and CML benefits per annum:

Table 202 Quality of Supply CI/CML Benefits

Option/Sensitivity	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23
EPN CI Benefits	35,563	45,730	55,898	66,065	76,233	86,400	96,568	106,735
EPN CML Benefits	711,256	1,584,697	2,458,137	3,331,578	4,205,019	5,078,459	5,951,900	6,825,341
LPN CI Benefits	18,232	19,871	21,509	23,147	24,786	26,424	28,063	29,701
LPN CML Benefits	227,905	326,206	424,507	522,808	621,109	719,410	817,711	916,012
SPN CI Benefits	33,870	38,162	42,454	46,746	51,039	55,331	59,623	63,916
SPN CML Benefits	1,128,984	1,362,006	1,595,029	1,828,051	2,205,067	2,530,537	2,856,007	3,181,477

17.3 Results

Table 203 Quality of Supply

£m CBA Model Output	CBA NPV £m (16 Yrs)	CBA NPV £m (24 Yrs)	CBA NPV £m (32 Yrs)	CBA NPV £m (45 Yrs)
EPN Improvement Schemes	£28.16	£25.75	£24.14	£22.48
LPN Improvement Schemes	£4.26	£3.37	£2.78	£2.17
SPN Improvement Schemes	£16.81	£15.70	£14.96	£14.20

18 Conclusions

Overall, we are confident that the cost benefit assessments we have conducted demonstrate that our current investment plans provide value for money to our customers.

18.1 Asset Replacement

Our CBAs support over 60% of our proposed asset replacement expenditure. In carrying out assessments of the actual projects that our asset replacement intervention strategies have identified, we have demonstrated that our intervention strategies produce robust investment plans and that our asset management plans provide good value compared to the industry average and WPD's Fast Tracked plans.

Most CBAs show that our plans offer benefits above our current level of spend and where we must increase expenditure above the DPCR5 levels our plans represent the most value of the alternative options.

18.2 Load Related Expenditure

Our CBAs have covered a sample of proposed reinforcement schemes in the CBA form showing that our plans represent value for money in addition to the scheme papers we have submitted. We have shown that the plan to move to 132kV from 66kV in north London represents the right long term solution.

18.3 High Value Projects

We have demonstrated all reinforcement and replacement High Value Projects represent good value for customers, achieving the stated intention at least possible cost.

We have demonstrated that the replacement of gas filled cables between Sydenham and Eltham in south east London should be carried out in RIIO-ED1 rather than being deferred until RIIO-ED2.

18.4 Flooding

Our flood mitigation schemes effectively eliminate the risk of interruption to customer supplies at the least cost. Whilst a reactive response approach is lower cost, and enclosing all sites in a flood wall completely eliminates any risk of flooding, our approach strikes an effective balance between the two.

18.5 ESQCR

Our predicted mix of structural mitigation is the least-cost approach, eliminating all climbable tree issues through tree cutting where possible. When structural mitigation is unavoidable, the individual case goes through a hierarchal decision tree to eliminate the risk at the least possible cost.

18.6 BT21CN

Our engineers have analysed and costed a range of possible options for dealing with BT21; we have selected an approach that achieves a reliable network at the most efficient cost.

18.7 Central London

Through CBA, we have proved that the additional costs of investment required in central London, for more frequent inspections, additional labour requirements etc. are more than offset by the savings in CIs and CMLs that are gained in this critical region.

18.8 Low Carbon Generation

We have used CBA to justify investment in EPN of £15.4m which will increase network capacity by 187MVA, as well as reducing carbon emissions enormously.

18.9 Losses

We have used CBA to value the impact of our loss reduction initiative, showing that for very minimal additional costs, we can reduce losses on our network greatly. We have also identified the tipping point for investing in low loss transformers ahead of any limits being imposed by EU directives.

18.10 Smart Grid Solutions

We have used CBA to test the parameters we have used to assess the impact smart technologies will have on our investment plans. These support using

- Demand side response to defer investment. Separate parameters have been defined around 2MVA in deferring reinforcement for at least 3 years in EPN and SPN and 5MVA of DSR deferring reinforcement for 4 years in LPN.
- Partial Discharge testing provides benefits in deferring switchgear replacement
- Smart adaptation of overhead line ratings will allow reinforcement to be managed more effectively
- Equipment to allow real time transformer rating provides benefits in allowing capacity increases to be deferred.

These technologies will allow our investment plans to be better optimised and uncertainties better managed.

18.11 Summary

The tables below summarises the results where CBA assessment has been used to justify specific investment. The show that in aggregate our investment proposals for RIIO-ED1 show positive benefits against our DPCR5 plans and that in EPN and SPN we are not increasing volumes on aggregate. For asset replacement and reinforcement they demonstrate that on balance the volumes in our RIIO-ED1 plan offer better value than in DPCR5 with positive overall CBA results. In LPN the overall result is negative against the DPCR5 baseline due to a number of specific projects and increase transformer replacement as a result of our DPCR5 plan having addressed many transformers able to be refurbished.

Table 204 Summary CBA results against DPCR5 baseline

CBA RIIO ED1 Total Benefit £m	kV	EPN	LPN	SPN
Fluid Filled Cable Intervention	132	-0.31	-2.69	-0.56
	66		0.07	
	33	2.58	2.88	0.84
EHV Transformer Intervention	132	-2.78	-1.68	2.21
	66		-0.26	
	33	-0.16	-2.37	-0.69
Switchgear Intervention	132	1.46	-0.75	1.61
	66		-0.30	
	33	0.21	0.58	0.74
	11	-5.51	-1.07	-2.64
Link Boxes		0.37	2.22	1.09
Distribution Switchgear		15.32	-4.10	-0.23
Steel Towers		0.00		0.00
Asset Replacement and Reinforcement		**11.16**	**-7.46**	**2.36**

Load Related Expenditure		10.92	4.64	2.56
High Value Projects		2.01	12.59	3.15
Flood Mitigation		8.11	3.16	4.28
ESQCR		2.53		0.64
BT21CN		1.31		1.31
Central London Plan			6.49	
Low Carbon generation		2.73	0.00	0.00
Losses		17.40	17.40	17.40
Smart Grid Strategy		0.05	0.00	0.01
QoS		4.02	0.40	2.54
Total		**60.24**	**37.22**	**34.24**

Against our RIIO-ED1 scenarios representing industry average equivalent condition based replacement our CBA assessments indicate that our plan volumes are well justified as indicated by the size of the positive benefits shown below.

Table 205 Summary CBA results - Industry Average Equivalent Condition Based Volumes

CBA RIIO ED1 Total Benefit CBA £m	kV	EPN	LPN	SPN
Fluid Filled Cable Intervention	132	2.7	5.1	10.1
	66		10.6	
	33	0.7	1.0	3.1
EHV Transformer Intervention	132	5.9	-0.05	2.2
	66		3.9	
	33	25.5	45.5	8.3
Switchgear Intervention	132	0.8	2.1	1.9
	66		0.1	
	33	4.3	3.3	5.0
	11	12.7	7.3	5.8
Link Boxes		0.1	2.2	0.3
Distribution Switchgear		29.7	4.7	11.0
Steel Towers		0.0		0.0
Asset Replacement and Reinforcement		82.3	85.7	47.8

Load Related Expenditure		10.9	4.6	2.6
High Value Projects		2.0	12.6	3.2
Flood Mitigation		8.1	3.2	4.3
ESQCR		2.5		0.6
BT21CN		1.3		1.3
Central London Plan			6.5	
Low Carbon generation		2.7	0.0	0.0

Losses		17.4	17.4	17.4
Smart Grid Strategy		0.0	0.0	0.0
QoS		4.0	0.4	2.5
Total		131.4	130.3	79.6

Our CBA assessments of our RIIO-ED1 plans against the scenarios representing WPD equivalent condition based replacement and refurbishment also show that our overall plan volumes are well justified.

Table 206 Summary CBA results - WPD equivalent Condition Based Volumes

CBA RIIO ED1 Total Benefit £m	kV	EPN	LPN	SPN
EHV Transformer Intervention	132	4.61	1.19	3.84
	66		-0.19	
	33	8.40	8.97	3.06
Switchgear Intervention	132	-2.69	0.32	0.86
	66		-2.05	
	33	0.89	0.91	2.13
	11	1.27	1.96	1.40
Asset Replacement and Reinforcement		**256.58**	**195.06**	**201.44**

18.11.1 Summary of asset replacement and refurbishment against Industry and WPD equivalent condition based volumes

The industry average equivalent condition based scenarios and the WPD equivalent condition based scenarios were developed to help Ofgem better compare our proposed programme with the proposals from the other DNOs.

Table 207 and Table 208 show the results for the industry benchmark and WPD benchmark. In aggregate for non-load UK Power Networks is £216m more efficient on volumes than the industry benchmark (£329m when scaled assuming the results are representative of all expenditure) and £35m more efficient on volumes than the WPD benchmark (£112m if scaled). This represents a significant benefit to customers from our asset management approach that was not taken into account in the Fast Track assessment.

Table 207 CBA Results against equivalent industry condition based replacement

£m RIIO ED1 Total Benefit	KV	UKPN	EPN	LPN	SPN
FFC	132	17.9	2.7	5.1	10.1
	66	10.6	0.0	10.6	0.0
	33	4.8	0.7	1.0	3.1
Transformers	132	8.1	5.9	0.0	2.2
	66	3.9	0.0	3.9	0.0
	33	79.3	25.5	45.5	8.3
Switchgear	132	4.8	0.8	2.1	1.9
	66	0.1	0.0	0.1	0.0
	33	12.6	4.3	3.3	5.0
	11	25.8	12.7	7.3	5.8
Link boxes		2.5	0.1	2.2	0.3
Distribution switchgear		45.4	29.7	4.7	11.0
Steel towers		0.0	0.0	0.0	0.0

£m RIIO ED1 Total Benefit	KV	UKPN	EPN	LPN	SPN
Total		**215.7**	**82.3**	**85.7**	**47.8**
scaling		65%	65%	65%	67%
Scaled total		**329.0**	**137.1**	**120.6**	**71.3**

Table 208 CBA Results against equivalent WPD condition based replacement

£m RIIO ED1 Total Benefit	KV	UKPN	EPN	LPN	SPN
Transformers	132	9.6	4.6	1.2	3.8
	66	-0.2	0.0	-0.2	0.0
	33	20.4	8.4	9.0	3.1
Switchgear	132	-1.5	-2.7	0.3	0.9
	66	-2.0	0.0	-2.0	0.0
	33	3.9	0.9	0.9	2.1
	11	4.6	1.3	2.0	1.4
Total		**34.9**	**12.5**	**11.1**	**11.3**
scaling		32%	32%	32%	27%
Scaled total		**112.1**	**34.6**	**36.3**	**41.3**