Cadent
Your Gas Network

Appendix 9.35 Cathodic Protection

RIIO-2 Spend: XXXX

Investment Decision Pack Overview

This Asset Health Engineering Justification Framework outlines the scope, costs and benefits for our proposals. We have prepared an Engineering Justification Paper (EJP) and a Cost Benefit Analysis (CBA) for these assets. A brief overview is provided below.

Overview.

Cathodic protection (CP) is used to prevent the corrosion of a metal pipe (particularly steel) by making it the cathode of an electrochemical cell. In simple terms, this is achieved by connecting the pipeline to a more easily corroded "sacrificial metal" to act as the anode. The sacrificial metal then corrodes instead of the protected metal. For longer and larger pipelines, typically on high and intermediate pressures, where passive cathodic protection is not adequate, an external DC electrical power source is used to provide sufficient current to power the cell. CP schemes in use:

- 1,678 HP/IP CP schemes with 20,415 test posts
- 2,346 MP/LP CP schemes with 12,733 test posts

On average, we will invest XXXX per scheme per year across RIIO-2 to maintain compliance. This investment prolongs the life of the assets and significantly reduces the risk of gas escapes.

We have a legislative obligation under the Pipeline Safety Regulations, 1996 (Regulation 13) to ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair.

Following receiving an improvement notice by the Health and Safety Executive (HSE) in 2015, we have agreed a programme of work to deliver a legislatively compliant CP system. This compromises of; MP/LP and HP/IP interventions, stray current inspections and interventions, and replacement of Remote Monitoring units and battery packs (this document only covers the material investments associated with CP interventions). If we chose not to deliver these programme, the HSE would enforce action.

We have also completed a CBA to illustrate the benefits that CP interventions will bring. For that calculation we have considered three options:

Option
0 - Reactively replace pipeline failures (i.e. the baseline position)
1 - Targeted proactive repair (preferred option)
2 - Sensitivity of Option 1 to interruptions to supply valuation

Our preferred option is to undertake targeted proactive repair, ensuring we are legislatively compliant. We have used switching analysis to test our planned investment. We have employed this method in recognition of the uncertainties in some of the key input data in the cost benefit analysis, as recommended in HM Treasury Green Book

Our CBA switching analysis, has looked at how many reactive failures we would need by the end of RIIO-3, for the proactive option to be the most cost-beneficial. As we have used switching analysis the NPV is set at 0.00

Summary of preferred option:

Summary of preferred option	XXXX
RIIO-2 Expenditure	XXXX
Project NPV (switching analysis)	>0

Material Changes from October

No material changes.

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2. Introduction

This document covers the investment case methodology for interventions on Cadent's High-, Intermediate-, Medium- and Low-Pressure (HP, IP, MP, LP) Cathodic Protection (CP) systems. These systems extend the life of our assets, preventing deterioration through corrosion and ensure compliance with Pipeline Safety Regulations (PSR).

Cadent has a comprehensive rolling programme of inspections, that enables us to make risk-based decisions on critical remediation. Interventions typically take the form of repair or replacement to test posts, electrical components, transformer rectifiers and ground beds. Activity is high volume, low cost. We typically spend around XXXX per annum on average on each scheme.

The table below shows the different investment lines that cover all investments required to manage CP assets. **This document only covers the material investments under Cadent line references 19 and 21 associated with CP interventions, shown below.**

Cadent Line Ref	Description	RIIO-2 Capex	RIIO-2 Opex
Line 19	MP / LP Cathodic Protection interventions		
Line 21	HP / IP Cathodic Protection interventions		
TOTAL for this paper			
Line 22	Cathodic Protection Stray Current Systems inspections	Redacted due to commercial sensitivity	
Line 23	Cathodic Protection Stray Current Systems interventions		
Line 205	Replacement of remote monitoring units		
Line 206	Replacement of monitoring unit battery packs		
TOTAL minor elements			

Table 1: Summary of the key components within the CP investment case

Our investment case for interventions is based on the planned programme of CP inspections, and remediation of the failures identified. Intervention volume for RIIO-2 has been derived from an assessment of the number of interventions resulting from our inspection programmes during RIIO-1.

This approach assures compliance with external codes and company management procedures as well as reflecting good practice. Costs are taken from competitively tendered rates and are efficient, no additional efficiency has been applied. The proposed investments offer value for money and align with regulatory and stakeholder requirements. Cadent are therefore confident that they have identified the right mix of interventions and investment for this asset type.

Background

Cathodic protection (CP) is used to prevent the corrosion of a metal pipe (particularly steel) by making it the cathode of an electrochemical cell. In simple terms, this is via connecting the pipeline to a more easily corroded "sacrificial metal" to act as the anode. The sacrificial metal then corrodes instead of the protected metal. This is known as the Sacrificial Anode (SA) CP system.

For longer and larger pipelines, typically on high and intermediate pressures, where SA cathodic protection is not adequate, an external DC electrical power source (delivered via a Transformer Rectifier connected to a 'ground bed' of multiple anodes) is used to provide sufficient current – this is known as an Impressed Current (IC) system.

The performance of these systems (illustrated in Figure 2) is monitored via Test Posts (TPs) which allow us to measure the current flowing through the cell and therefore enable the effectiveness of the CP system to be monitored. A CP system protects a length of pipeline, the boundaries of the system may be a transition to a different metal, a non-conductive joint or a fitting. The length of steel pipe that is protected by a group of anodes within a closed loop system is called a 'CP scheme'. Each scheme therefore has multiple TPs, each of which is monitored and used to measure current on a time-bound schedule. There are three main categories of inspections: Interim inspection (quarterly inspection), Functional inspections (yearly) and Major inspections (2-yearly for SA systems and 5-yearly for IC system). The inspection frequencies are industry best practice and also recommended as per Cadent's internal CP policy document ECP/1. This policy interprets the requirements of PSR'96 Regulation 13, which mandates a gas operator to: *"ensure that pipelines are maintained in an efficient state, in efficient working order and in good repair".* Table below is an extract from ECP/1, outlining the various inspection frequencies

The frequency of routine monitoring for each type of system is as follows:

	Functional	**Interim**	**Major**	**CIPS**
Sacrificial Anode	-	6 Monthly	2 Yearly	15 Yearly*
Impressed current (single source)	1 Monthly	12 Monthly	5 Yearly	15 Yearly*
Impressed current (multi source)	3 Monthly	12 Monthly	5 Yearly	15 Yearly*

On systems which have good levels of protection and which have more than one source of CP current i.e. two or more T/R's or T/R and bond, remote monitoring can replace the requirement for the site manual checks.

Figure 1: CP scheme inspection frequencies as per ECP/1

If during any of these inspections, the readings at a TP within a scheme are below a specific threshold of voltage, or if the surveyor is not able to take any readings (due to a damaged TP for instance), the scheme is said to have become 'non-compliant' or to have 'failed' the inspection and an intervention request is logged within the central system (called Uptime).

Uptime is a web-based product that uses ESRI GIS technology. It is operated by DNVGL on behalf of Cadent as the repository for the technical asset detail associated with CP schemes, across all pressure tiers. It contains location data for CP assets; the attribute detail associated with each scheme and test facility; the routine maintenance requirements to meet policy; and the maintenance history for Functional, Interim and Major CP inspections. It also links with SAP to issue work to field based technicians via remote field devices.

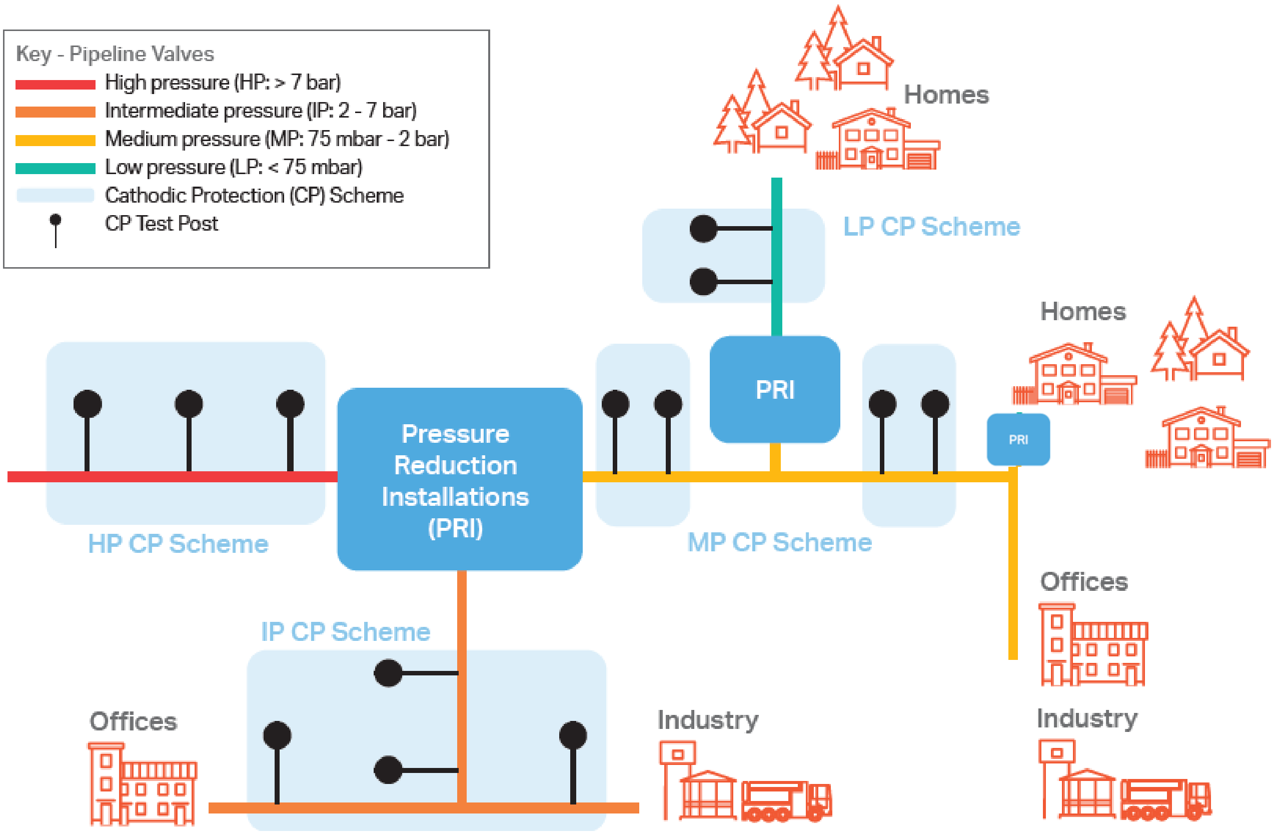

Figure 2: CP schemes included within this investment case

These intervention requests are dealt with during a planned intervention programme each year, generally targeting the oldest non-compliance first, and involve some of the following interventions, depending on the failure mode:

- Replenishing Sacrificial Anode Groups
- Replacing or Refurbishing Transformer Rectifiers (TR)
- Replenishing Ground Beds
- Other Test Facility Interventions e.g. Repairing Cables, Replacing Test Post / Box

3. Equipment Summary

Cadent has the following CP schemes in use:

- 1,678 HP/IP CP schemes with 20,415 test posts
- 2,346 MP/LP CP schemes with 12,733 test posts.

These schemes protect the following lengths of pipelines across Cadent's footprint:

Network	HP (km)	IP (km)	MP (km)	LP (km)
EoE	2,498	1,364	1,066	581
Lon	670	247	386	344
NW	930	416	217	782
WM	883	292	361	847
Total	**4,982**	**2,319**	**2,031**	**2,554**
% of Total Steel Pipeline Length by CP	**100%**	**100%**	**25%**	**4%**

Table 2: Pipeline length & length protected by CP (source: RRP data 2018/19)

Only a small proportion of LP steel mains have cathodic protection. Whilst higher pressure tiers have had centralised policy in place, protection of LP has historically been a decision made at a district level when the assets where installed – as such there is significant geographic variability in application of LP to steel CP.

CP is effective where it operates continuously at the right level, periods of non-compliance during the lifetime of the pipe will have impacted on the pipelines integrity.

The tables below provide a summary of the Scheme asset base per network. The asset base has been derived from Cadent's 'Uptime' Database (September 2019):

Network Schemes	HP	IP	LP	MP
EoE	409	576	197	1276
Lon	146	39	3	264
NW	212	160	79	376
WM	88	48	3	148
Grand Total	**1,678**		**2,346**	

Table 3: Cathodic Protection schemes (uptime data 30/09/2019)

Uptime also shows 48 schemes (with 393 Test Posts within them), listed with no results or test post details; these test posts are included in Table 3, in the column on the far right of the table. These assets constitute around 1% of the total asset base and will still be surveyed as part of our rolling inspection programme.

Network TPs	HP	IP	LP	MP	Cadent Total	Missing Test Posts
EoE	5,699	4,648	881	7,491	18,719	196
Lon	1,842	829	61	1,386	4,118	123
NW	3,707	1,676	305	1,612	7,300	33
WM	1,315	699	20	977	3,011	41
Grand Total	**12,563**	**7,852**	**1,267**	**11,466**	**33,148**	**393**
-	**20,415**		**12,733**		**-**	**-**

Table 4: CP test posts (uptime data 30/09/2019)

Generally, the MP/LP schemes use sacrificial anode (SA) systems, and the HP/IP schemes operate through the impressed current (IC) method.

Through our CP data-improvement project undertaken following the HSE Improvement Notice (Notice Ref No: 306763291, served against National Grid Gas PLC on 11/11/2015), we have identified a proportion of MP/LP CP asset stock that is not within Cadent's 'Uptime' CP records database. Cadent expect this asset stock to be equivalent to 5% of its total cathodic protection schemes and that the assets will be in poorer condition, having received less maintenance. We have informed the HSE of this data omission as part our regular compliance briefings and we are keeping them informed of our progress to rectifying this non-compliance.

Figures below show typical Sacrificial Anode system components and a SA test post mid-installation:

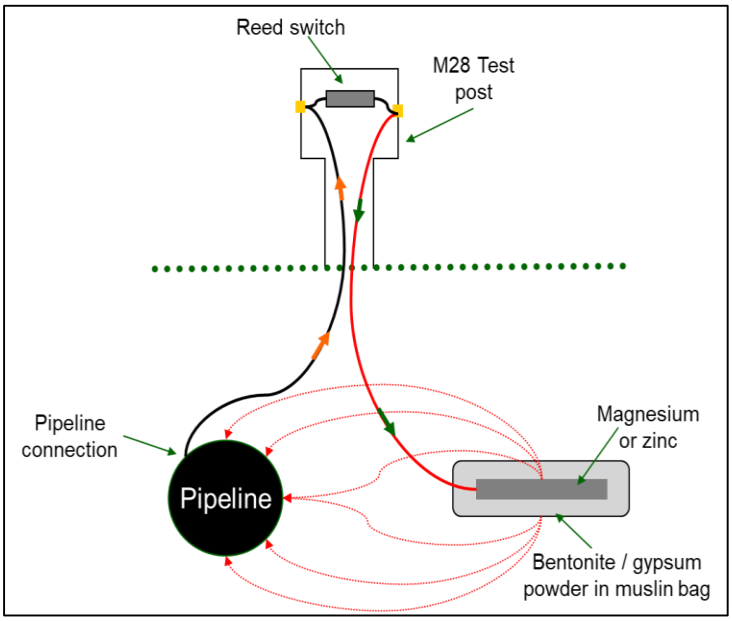

Figure 3: Basic sacrificial anode system

Figures below show typical Impressed Current system components and an IC system mid-installation:

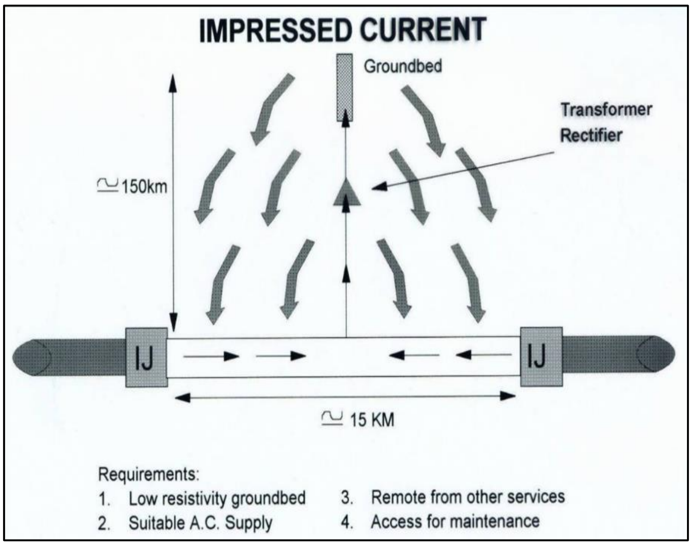

Figure 4: New CP impressed current system installation

4. Problem Statement

The investment driver for cathodic protection is to provide a robust defence to Cadent's steel pipelines from the risk of corrosion and consequent loss of structural integrity.

Cathodic protection is a critical second-line defence to manage the risk from external corrosion to steel pipeline assets, the primary defence being the pipe coating. A deterioration in the performance of cathodic protection assets does not immediately lead to major external corrosion, but corrosion levels will increase, and the pipe coating will degrade, ultimately leading to pipeline integrity failure, and an associated risk of a gas escape and fire or explosion over the following months. Once metal is lost to corrosion it can never be recovered.

Cadent Gas has a legislative obligation under the Pipeline Safety Regulations, 1996 (Regulation 13) to inspect and maintain its pressurised pipes and to keep them in good repair. The regulation states: *"The operator shall ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair"*.

In 2015, the HSE issued an Improvement Notice to Cadent Gas (Notice Ref No: 306763291, served against National Grid Gas PLC on 11/11/2015) in respect of deficiencies in the approach to inspections and interventions on MP/LP pressure systems[1]. Cadent has thereafter increased its efforts to improve the condition and performance of its cathodic protection systems, to mitigate the risk of steel-pipeline failure. The HSE letter stated;

"Taking into account all results reviewed it is clear that whilst readings of the MP & LP CP schemes are being taken, assessment of these readings with respect to the impact on pipeline integrity is noticeably absent. There is minimal commitment to addressing problems on these systems such that it is foreseeable that corrosion leakage is likely to occur. Regulation 13 of the Pipelines Safety Regulations 1996 requires the operator to ensure that a pipeline is maintained in an efficient state, in efficient working order and in good repair. Given the shortcomings in respect of identifying and carrying out remedial work on the cathodic protection systems installed on low pressure and medium pressure systems it is foreseeable that this can lead to corrosion failure of steel pipelines that will subsequently lead to uncontrolled escapes of gas. There is therefore non-compliance with PSR, Regulation 13".

The HSE investigation and the subsequent notice was specific to the MP/LP CP schemes, however, the obligations under PSR 1996, Regulation 13 apply equally to the HP/IP pressure tiers as well.

CP health and performance is measured in terms of non-Compliance (when CP voltage reading is below the acceptable threshold) and exceptions (when taking a reading has not been possible). CP scheme performance is reported to the HSE annually, and the reported long-term trend is shown in Figure 6, below:

[1] Notice 306763291: http://www.hse.gov.uk/notices/notices/notice_details.asp?SF=CN&SV=306763291

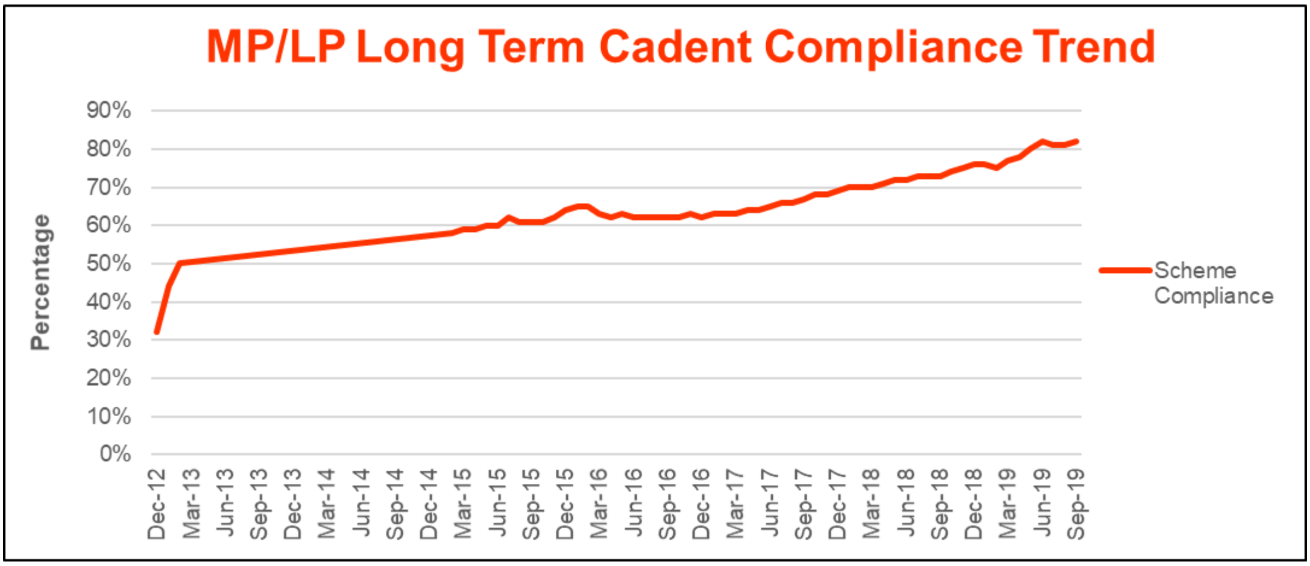

Figure 5: MP / LP CP compliance trend (2011 to 2018)

Following the Improvement Notice, Cadent has fast-tracked surveys and interventions to rapidly improve CP compliance to 90%, with an ambition to maintain compliance above this percentage, on its MP/LP and HP/IP CP asset stock. We are aiming to achieve an overall compliance in excess of 90% by the end of RIIO-1. However, we expect there to be a known volume of non-compliances identified during the last years of RIIO-1, which will need to be remediated within the early years of RIIO-2.

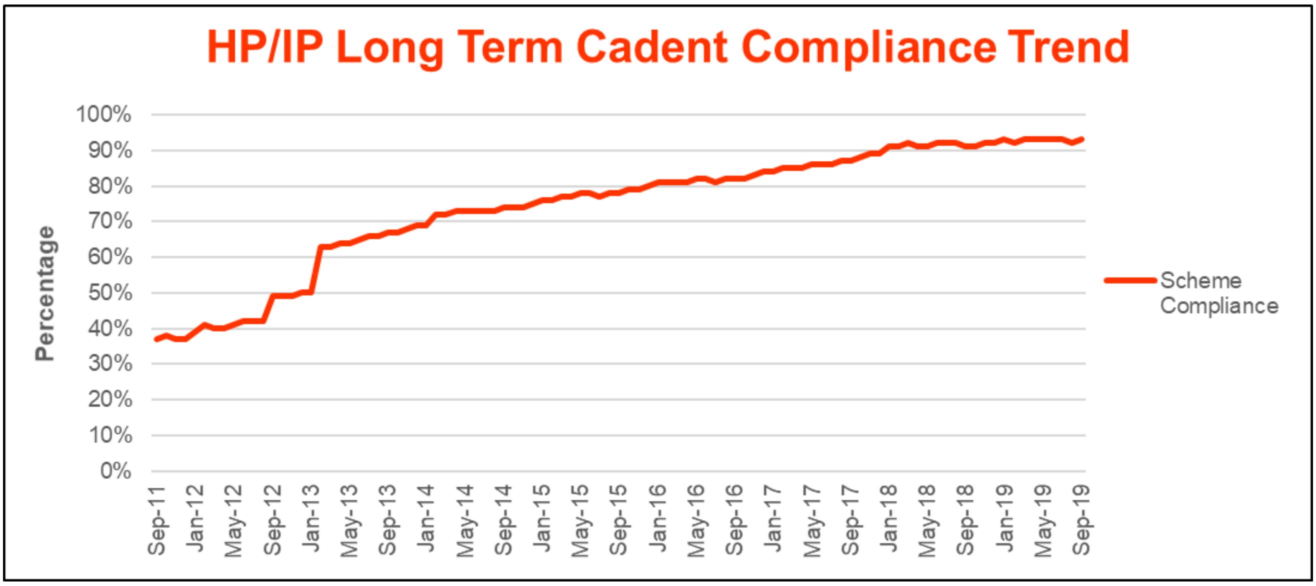

Figure 6: HP / IP CP compliance trend (2012 to Aug 2018)

This graph shows an improving trend over the last eight years, with over 90% compliance being maintained during 18/19. We recognise that continuing high levels of compliance will minimise pipeline deterioration in the long term.

We have been reporting our compliance recovery and performance to HSE bi-annually up to 2018 with a specific MP/LP compliance briefing but since February 2018, HSE have indicated their satisfaction with our progress by allowing us to reduce the frequency of engagement down to once a year, and to make CP one of the agenda items within a wider compliance reporting pack (rather than the previous CP specific briefing). They have verbally stated within these meetings that if our compliance performance trend deteriorates, falling below the 90% threshold, they will look into their options of prosecuting Cadent under PSR '96, Regulation 13.

Key outcomes

Investment in cathodic protection will provide a critical defence to manage the risk from external corrosion to steel pipeline assets. This will ensure compliance with PSR '96 and will satisfy the requirements of the improvement notice issued by HSE.

Understanding project success

To achieve and maintain a compliance rate in excess of 90% in each our networks during RIIO-2.

4.1. Narrative Real-Life Example of Problem

A CP fault report was raised following a major survey of 'Spondon Borrowash' MP SA CP scheme and related to the Test Post at Borrowash Road, Derby, on 8 October 2018 (as per ESRI location screenshot below). The TP is on the CP scheme protecting 1,605m of the primarily 8-inch Medium Pressure steel pipe (blue pipe in figure below), which at this location is the inlet to the MP to LP District Governor (with a size of 150mm at this location) feeding the neighbouring residential area of Derby.

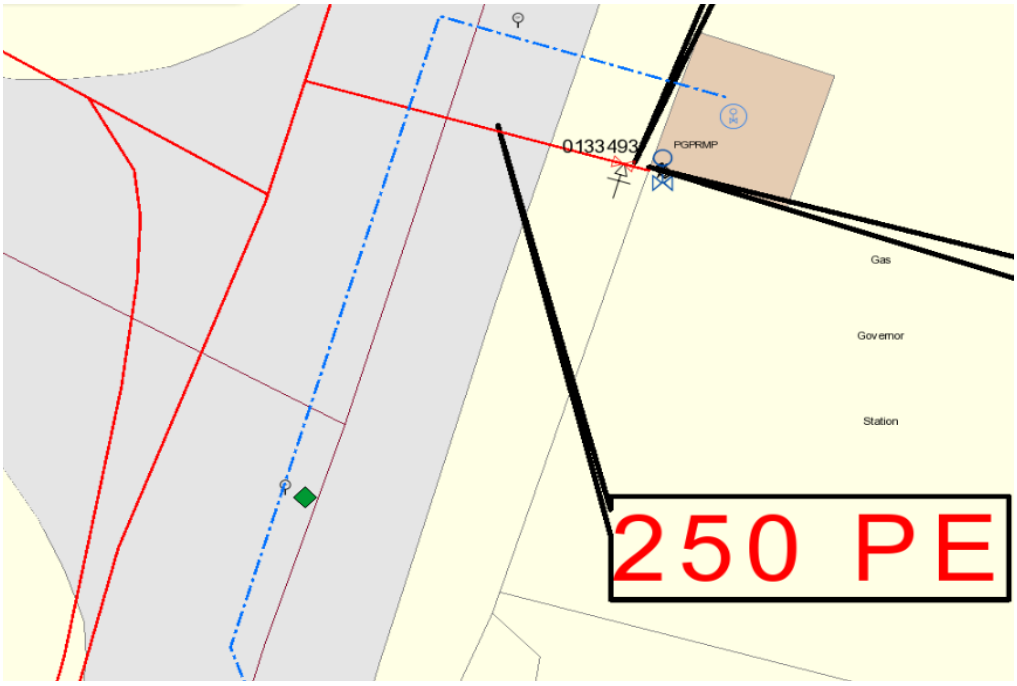

Figure 7: ESRI screenshot of location of CP Intervention

The scheme has 15 test posts along the 1,605m of its length (of which 14 were highlighted as faulty). This particular TP was not located in the optimal position to ensure accurate readings, had lost its face plate and its wiring had become detached. Such a failure is recorded within Cadent as an 'exception' which means readings cannot be accurately taken to verify the effectiveness of the CP. Our contractors installed a new test post and new anodes to ensure that the post was fit for future compliance readings to be taken. This job was completed on the 21st of August 2019 at a cost of XXXX, which consisted of the contract framework rate plus tarmac reinstatement and traffic management costs.

Figure 8: Test post installation before, during and after

(from left – installation excavation, transformer rectifier and vertical CP ground bed installation)

The restoration of the TP allowed scheme compliance to be confirmed, thereby ensuring that the pipeline was adequately protected, and the risk of pipeline failure managed.

4.2. Spend boundaries

Electrical and Instrumental (E&I) equipment associated with CP is covered within the spend boundaries of this case and any overlap has been removed from the E&I investment. The assets which overlapped across to E&I are transformer rectifiers and any associated cabling and these have been taken out from the E&I case and included within CP.

The costs do not include CP on shared pipelines with National Grid Metering (NGM), due to low materiality. This should not, however, affect any work on this category that may be deemed necessary in the future.

CP for pipeline sleeves is also excluded from this investment case and included separately in the pipeline sleeves investment case.

Furthermore, the costs do not include extension of CP networks triggered by construction of new steel pipelines (Diversions or Reinforcements).

5. Probability of Failure

Cadent's CP scheme inspection frequencies are described previously in Section 2 (Figure 1). Among the various inspection regimes, the Major Inspections are most holistic and during these inspections all the identified non-compliances are recorded in Uptime for subsequent planned interventions.

We have a good understanding of our CP failure rates, compared to the volume of CP major inspections. We have used the most up to date failure rates from the major inspections completed during 2018/19 (1st April 2018 to 31st March 2019) to forecast the average intervention rates required for RIIO-2.

The following table shows failure rates used for RIIO-2 workload forecasting, based on failure rates seen during CP major inspections (for MP/LP and HP/IP schemes) for 2018/19:

Network	Failure Rates on MP/LP Schemes Used for RIIO-2 Forecasting	Failure Rates on HP/IP Schemes Used for RIIO-2 Forecasting
EoE*	15%	21%
Lon	11%	15%
NW	15%	18%
WM	17%	15%

Table 5: 2018/19 Failure Rates: HP/IP and MP/LP CP systems

* EoE percentages are the weighted average of our East Anglia and East Midland regions (which together make up the East of England network)

As mentioned in the equipment summary (Section 3) some of our MP/LP asset stock has not been surveyed or maintained since 2010 (approximately 5% of the asset stock) and is likely to have a higher failure rate on inspection. We have only recently started to survey these CP assets and therefore do not have sufficient data to inform a precise intervention volume. We have used initial survey results and expert judgement to predict a 50% intervention rate per test post survey on this small volume of assets.

We estimate that the lifeline of our pipelines without investment is at best 10 years. Therefore, without any investment we would quickly start to see pipelines failing over RIIO-2 and RIIO-3.

This uncertainty has resulted in the switching analysis approach to CBA.

Failure modes

There are two types of failure:

1 – Failure of the CP system: These failures include a sacrificial anode or ground-bed depleting and thereby reaching the end of its serviceable life and no longer being able to provide protection to the pipe.

2 – Failure of the monitoring system: Failures associated with the test post and cabling which mean that readings cannot be taken.

The former failure mode means that the system is not working correctly, and the pipeline is degrading. The later mean that we are unable to determine whether the system is operating correctly or not.

Both failure types constitute non-compliance with Pipelines Safety Regulations 1996, Regulation 13.

5.1. Probability of Failure Data Assurance

We have calculated an intervention volume based on our most recent complete year of survey data. This failure rate has been derived from 12 months of survey data during a period of around 90% compliance. The data is held within an Uptime extract, taken on the 18th April 2019.

6. Consequence of Failure

The consequence of failure for these CP assets are corrosion to Cadent's HP/IP and MP/LP pipelines, ultimately leading to the risk of a pipeline failure or gas-escape, which would have the following impacts:

- Risk to the security of supply as a result of a gas-escape, while the pipeline is isolated to affect a repair
- Costs to reactively fix a gas-escape
- Environmental impact due to the gas-escape
- Risk of fire and explosion due to a gas-escape, causing a health and safety risk to the public and to Cadent employees
- Non-compliance to the Health and Safety Act 1974
- Non-compliance to the Pipelines Safety Regulations 1996.

For the purposes of calculating a CBA we have applied monetary values to these consequences as outlined in Appendix 1.

However, **failure to maintain our CP system is a breach of Pipeline Safety Legislation**. As demonstrated by the HSE enforcement in 2015. As such the driver of investment is legislative compliance rather than economic analysis.

7. Options Considered

Having been given an improvement notice by the HSE in 2015 we have agreed a programme of work to deliver a legislatively compliant CP system. The HSE challenged Cadent to recover compliances as quickly as reasonably practicable. In response we tendered the programme of work and three CP specialist contractors responded. We have entered into an arrangement with each of these organisations and deployed all of the qualified engineers they have available. The resultant run rate was agreed with the HSE and forms the basis of our planned work programme. We have rejected an option to try to further accelerate the programme of work, this would not be reasonably practicable given that we have already materially increased our delivery rate and fully deployed the available resources. As such there is only a single option for this programme of work.

Within each instance of CP "failure" we do however consider a range of solution-interventions, from repair or replacement. Depending on site requirements, we carry out a repair; replacement or a more whole-sale remediation is carried out, where key components are at the end-of-life asset life and/or obsolete, resulting in no spares being commercially available. We also consider whether the CP system need to be reduced (if metallic pipes have been replaced) or if extra protection is needed due to interference from other electrical systems.

Notwithstanding the legal mandate we have for CP remediation, we have completed a CBA to illustrate the benefits that this programme of work will bring. For that calculation we have considered:

- **Baseline: Reactively replace, after pipeline failure**: We have added the costs of reacting to a failure into the proactive options below as avoided costs.
- **Option 1: Proactive repair Cathodic Protection equipment**, prior to pipeline failure.

We have tested the sensitivity of our CBA analysis to the inclusion of the societal benefits (willingness to pay) for preventing supply interruptions. This has been inserted in our CBA data tables as Option 2.

7.1. Baseline Option: allow CP to deteriorate, respond to pipeline failures

This option consists of not spending any money on CP inspections or interventions and responding to pipeline failures only. This option would be a breach of our obligations under the PSR and would fail to meet our legal mandate under our recent HSE enforcement notice.

This option is our baseline case but has not been developed into a real-option due to the high levels of uncertainty around deterioration rates and spend. In this scenario, we have set the baseline as zero and, in the option below, the ***changes*** in costs are considered. For this investment case, we have included the costs of reacting to a HP / IP pipeline failure as avoided costs in option 1, rather than as absolute levels of anticipated costs in the baseline.

7.2. Option 1: Proactively inspect and repair any CP failures, to prevent pipeline deterioration

For this option, an average percentage of RIIO-1 interventions per test-post inspection has been used to forecast the volume of repairs/replacements required. Furthermore, an average intervention cost per test post has been used to forecast repair and replacement costs [2].

[2] Where possible, we have sought to consider the do-nothing position and options in absolute terms, allowing a comparison of the options to the baseline and each other. There are some instances where the forecast baseline cannot be assessed, such as for this case. In these circumstances, the baseline is set at zero and in the options the changes in costs are considered, i.e., we include the costs of reacting to a failure occurring as avoided costs in each option, rather than as absolute levels of anticipated costs in the baseline. This means that the template (non-baseline options) is populated with the proposed proactive investment, and the avoided private costs and avoided societal costs of the investment. This allows us to consider whether the proposed investment in RIIO-2 is value for money given the resultant expected change in performance and avoided costs over time. **From a pure CBA point of view the two approaches are equivalent – as CBA is all about comparing differences between options.**

Our intervention volumes have been derived from:

- Interventions on CP asset stock that has been subject to ongoing inspection (Tables 5 and 6 refer to the intervention rates per CP inspection) (41.5% of total interventions)
- Interventions on CP asset stock that have not been surveyed since 2010 and thus have a higher intervention rate (MP/LP CP systems only) (12% of total interventions)
- A volume of work caused by a forecast-volumes of CP interventions identified in the last years of RIIO-1 (46.5% of total interventions)

Applying this approach to forecast inspections has allowed Cadent to generate the following intervention programme for cathodic protection for RIIO-2 (Tables 7 and 8):

Network	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	478	423	298	262	356	**1,816**
Lon	87	21	21	25	51	**206**
NW	270	190	221	158	193	**1,033**
WM	49	77	48	72	44	**291**
Grand Total	**801**	**1,015**	**206**	**1,033**	**291**	**3,345**

Table 6: RIIO-2 HP/IP CP intervention volumes (Cadent line 21)

Network	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE	1,145	1,088	1,142	1,104	1,160	**5,638**
Lon	325	316	322	177	83	**1,224**
NW	768	387	263	170	273	**1,861**
WM	213	212	216	211	213	**1,064**
Grand Total	**801**	**1,015**	**206**	**1,033**	**291**	**9,787**

Table 7: RIIO-2 MP/LP CP intervention volumes (Cadent line 19)

Network	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon		[redacted]				
NW		Redacted due to commercial sensitivity				
WM						
Grand Total						

Table 8: RIIO-2 HP/IP CP intervention costs (line 21)

The above forecast of intervention volumes generated the following cost profile for CP interventions for RIIO-RIIO-2 (Tables 9 and 10):

Network	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon						
NW			Redacted due to commercial sensitivity			
WM						
Grand Total						

Table 9: RIIO-2 MP/LP CP intervention costs (line 19)

7.3. Options Technical Summary Table

	Baseline	Option 1
Option title	Allow CP to deteriorate, respond to pipeline failures	Proactively remediate CP, upon a non-compliant CP reading.
First year of spend	This has been discounted, because this will fail to meet our obligations under our HSE enforcement notice and lead to prosecution.	2021/22
Final year of spend		2026/27
Volume of interventions		3,345 HP / IP CP interventions 9,787 MP / LP CP interventions
Equipment or investment design life		Various, depending on CP component being remediated.
Total installed cost (Total spend request)		Redacted due to commercial sensitivity

Table 10: Technical Summary Table: CP interventions

Scenario 2: Sensitivity of Option 1 to interruptions to supply valuation

In the CBA data tables, an “Option 2” has been inserted. This scenario is identical to Option 1, but with the benefits of interruptions removed.

7.4. Options Cost Summary Table

Only one programme-level option has been developed for this investment case, based on proactively investing in CP remediation following a non-compliant CP reading, following CP inspections. This is the minimum level of investment required to comply with our HSE enforcement notice.

The cost summary for this option is shown in Table 8 and Table 9 above.

Unit cost derivation

For our preferred option we have used the following unit costs set out below.

There is a wide range of CP interventions that are required because of CP inspection failures (new anodes, new test posts, new wiring, new ground-beds, replacement of TR kiosks etc.). These interventions are low cost high volume activity. The exact blend of interventions required in RIIO-2 is unknown. We have chosen to calculate a blended-average cost per intervention, based on RIIO-1 out-turn costs, to inform future CP interventions costs. It is reasonable to assume that the work mix will remain the same between both periods.

Table 11, below, sets out the blended-average unit costs used for the CP interventions for Cadent line references 19 and 21:

Distribution Network	Costs per HP / IP CP intervention (line 21)	Costs per MP / LP CP intervention (line 19)
EoE*	[redacted]	[redacted]
Lon		
NW		
WM		

Table 11: Average CP interventions costs per region and pressure-tier. (Delivery costs per intervention)

* Weighted average of EA and EM LDZs, which form the EoE network

We have also added the following additional staffing costs to cover direct Cadent costs in managing the CP programme. These costs cover network supervision, programme management and support from the data management-team to manage the CP survey and performance data and plan future inspections.

These additional annual costs are as follows (Table 15):

Distribution Network	HP / IP annual Cadent Direct Costs	MP / LP annual Cadent Direct Costs
EoE	[redacted]	[redacted]
Lon		
NW		
WM		

Table 12: RIIO-2 Cadent Direct Costs for managing CP intervention programme

Cost Confidence

For Cathodic Protection our confidence is defined as being within Construction stage with a range of +/-5%.

Our RIIO-2 forecasts, as well as adjusting for workload and work mix factors, also include ongoing efficiencies flowing from our transformation activities including from updating and renewing our contracting strategies. Our initiatives are outlined in Appendix 09.20 Resolving our benchmark performance gap. For Capex activities this seeks a 2.9% efficiency improvement by 2025/26 on the end of RIIO-1 cost efficiency level. We have not applied specific efficiency to this element of investment.

8. Business Case Outline Discussion

We must manage our cathodic protection risks proactively to ensure we comply with our HSE enforcement notice. We have used CBA, for illustrative purposes, which shows that, even without this legal mandate, a proactive approach is the optimum approach. The results of our CBA have been included in Appendix 1.

8.1. Key Business Case Drivers Description

Our objective is to build a plan which best reflects customer and stakeholder expectations and meets the required outcomes for this investment.

For CP assets there is a clear expectation form our key stakeholder, the HSE, that we maintain performance to comply with Pipeline Safety Legislation.

From our CBA calculations, without the legal mandate, the key investment driver would be:

- Safety: avoiding fatalities from pipeline failures is the key societal benefit of our proposed investment
- Reliability: avoiding interruptions associated with failures is part of the benefits
- Other: more minor benefits relate to avoiding property damage and preventing emissions

8.2. Business Case Summary

We have considered two options for this investment case as summarised below:

<table>
<tr><th></th><th>Baseline</th><th>Option 1 (chosen)</th></tr>
<tr><td>Option title</td><td>Allow CP to deteriorate, respond to pipeline failures</td><td>Proactively remediate CP, upon a non-compliant CP reading.</td></tr>
<tr><td>First year of spend</td><td rowspan="5">This has been discounted, because this will fail to meet our obligations under our HSE enforcement notice and lead to prosecution.</td><td>2021/22</td></tr>
<tr><td>Final year of spend</td><td>2026/27</td></tr>
<tr><td>Volume of interventions</td><td>3,345 HP / IP CP interventions
9,787 MP / LP CP interventions</td></tr>
<tr><td>Equipment or investment design life</td><td>Various, depending on CP component being remediated.</td></tr>
<tr><td>Total installed cost (Total spend request)</td><td>Redacted due to commercial sensitivity</td></tr>
</table>

Table 13: Business Case Summary

We have chosen a RIIO-2 programme (Option 1), which ensures we intervene on our cathodic protection assets, in a timely way when we identify a non-compliant CP reading. This proactive approach ensures we comply with our legal mandate.

Our current preferred option is to proactively invest to rectify 13,132 non-compliant CP readings during RIIO-2.

We have used CBA for illustrative purposes only to demonstrate that a proactive approach to managing cathodic protection failures is optimum.

We have taken an alternative approach to modelling the CBA for our baseline case. This baseline-option cannot be forecast in absolute-terms, due to the high levels of uncertainty. In this scenario, we have set the baseline as zero and, in option 1, the ***changes*** in costs are considered. A specific example of this is where we have included the costs of reacting to a failure as avoided costs in each option, rather than as absolute levels of anticipated costs in the baseline.

Our CBA switching analysis, has looked at how many reactive failures we would need by the end of RIIO-3, for the proactive option to be the most cost-beneficial. The table below summarises this CBA analysis.

	EoE	Lon	NW	WM	Company Level
Breakeven Failures by the end of RIIO-3	37	2	10	4	**53** **(from a total of 13,132)**

Table 14: Breakeven RIIO-3 Failure levels for the Preferred Option

This **baseline option of reacting upon failure**, assumes that we don't invest in maintaining any of these CP assets in the remaining years of RIIO-1 and all of RIIO-2 & RIIO-3. The results of this switching analysis tell us that we would only need 0.41% of these 13,132 poor condition or non-compliant CP assets, to deteriorate to such a level within a 12-year period, to cause a pipeline integrity failure, for the proactive option to be cost beneficial.

We estimate that the life of our pipelines without suitable protection is, at best, 10 years – and therefore without the proposed investment we would quickly start to see pipelines failing, and over RIIO-2 and RIIO-3 we would expect to observe hundreds of our pipelines affected by the lack of protection. **We can therefore be highly confident the investment is cost beneficial and value for money**.

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

Cadent's preferred option for the CP RIIO-2 investment programme is Option 1.

9.2. Asset Health Spend Profile

Distribution Network	2021/22	2022/23	2023/24	2024/25	2025/26	Total
EoE						
Lon		[redacted] Redacted due to commercial sensitivity				
NW						
WM						
Total						

Table 15: RIIO-2 CP spend profile

9.3. Investment Risk Discussion

We have not identified any material delivery risks.

- RIIO-2 will involve a stable delivery profile with achievable workload targets.
- The predicted workload is broadly aligned with the current delivery and will not require a material change in headcount. Therefore, there are no material delivery risks.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.35 - 001	Supply & Demand deliverability risk of Resource availability within the Gas industry	Potential cost increases in labour / commodity markets as demand is greater than supply	Med	Intelligent procurement and market testing. Apprenticeship and Training programmes to fill skills gaps
09.35 - 002	Stretching efficiency targets may not be deliverable (unit costs increase)	Outturn costs are not met increasing overall programme costs.	Low	Established market place - ability to manage the known commodity market
09.35 - 003	Unforeseen outages and failures restrict access for planned work	Programme and delivery slippage due to delay of planned outages and or site access	Low	Proactive asset management with ongoing condition surveys and response plans to prevent failures

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.35 - 004	Unseasonal weather in 'shoulder months', Autumn and Spring reduce site access/outage windows	Increased demands affecting access to sites and planned outages delay and cost increases	Low	Controlled forecasting and maintenance of flexibility to react to unforeseen events. Detailed design solutions to minimise outages and reduce exposure.
09.35 - 005	Unexpected / uncommunicated obsolescence during RIIO-2 period of equipment components	Inability to maintain equipment at full capacity with risk of impact upon supply	Low	Maintain a close relationship with equipment supply chain and manage a proactive early warning system where spares / replacements become at risk.
09.35 - 006	Legislative change - There is a risk that legislative change will impact the delivery of our work.	Potential increase in the amount of consultation and information exchange required and require us to align our plans with the safety management processes operated by 3rd Party landowner / asset owners. The potential impact is more engagement and slower delivery	Med	We have established management teams to address these issues. We have also identified UMs for key areas.
09.35 - 007	Volume estimates are under required works	Increased costs and programme impact	Low	Ongoing work to identify specific schemes and manage impacts

Table 16: Risk Register

9.4. Regulatory Treatment

This investment will not be processed through the NARMs reporting tool.

Cost variance for low materiality projects such as this will be managed through the Totex Incentive Mechanism (TIM).

This investment is accounted for in the Business Plan Data Table 2.04 within Non-Routine Maintenance Sub Table under the Other Non-Routine Maintenance section of the table under the Cathodic Protection line. This table also includes investment line 23.

Other investment elements described in section 2 are accounted for in:

- Table 3.05 Other Capex within Other Capex: Projects <X Aggregated Sub-Table under the Other line.
- Opex elements are contained within Table 2.04 Maintenance within Routine Maintenance Sub-Table under the Other Routine Maintenance Section under the Cathodic Protection line

Appendix 1. Basis of calculation for CBA

The following section sets out our approach to CBA, the assumptions made in deriving the benefits for each technical option, and the results of the CBA shown in the data tables.

Approach to CBA

Switching analysis has been used to ensure value for money in this area.

Switching analysis, as set out the in Her Majesty Treasury Green Book, is a form of sensitivity analysis that identifies the input values required to change the cost-benefit analysis results.

> *'A switching value refers to the value a key input variable would need to take for a proposed intervention to switch from a recommended option to another option or for a proposal to not receive funding. (HM Treasury Green Book, p33)*

As set out in The Green Book, this approach is particularly useful where there are significant future uncertainties, making specification of accurate risk scenarios problematic. It is the most appropriate approach to Cost-Benefit Analysis in this area as although we are able to model the consequences of cathodic protection failure, the probability of a pipeline failure is very uncertain.

The switching analysis approach allows us to identify the probability of failure that would make the programme breakeven – the switching point. Expert judgement is then used to review this switching point to assess whether it is a reasonable minimum description of the uncertain probability of failure. If so, then it is reasonable to consider the investment cost beneficial. Taking an extreme case as an example, a breakeven probability or failure rate for the identified stretch of pipe of 1 in 2 years would not be reasonable whereas 1 in 500 years clearly would.

We have undertaken the following options in our CBA analysis.

Option	Modelled Costs	Modelled Benefits
Option 0: Reactively replace pipeline failures	N/A Costs of reacting to failure are included as benefits (i.e. costs avoided) in relevant Options below	N/A No activity is being undertaken
Option 1: Targeted Proactive repair	RIIO-2 costs as submitted.	Private and societal costs avoided by the option: • Reactive Costs • Interruptions to supply • Transport disruption • Property Damage • Emissions • Health & Safety These are set at the breakeven failure rate level.
Option 2: Sensitivity of Option 1 to interruptions to supply valuation	RIIO-2 costs as submitted.	As above without Interruptions to Supply

Table A1: CBA options / scenarios analysed

As noted in the above table, we have taken an alternative approach to modelling the CBA for our baseline case. This baseline-option cannot be forecast in absolute-terms, due to the high levels of uncertainty. In this scenario, we have set the baseline as zero and, in option 1, the ***changes*** in costs are considered. A specific example of this is where we have included the costs of reacting to a failure as avoided costs in each option, rather than as absolute levels of anticipated costs in the baseline. This approach has also enabled us to test the sensitivity of the levels of avoided reactive costs more easily.

For this scenario, we have used a switching analysis, to look at what the cost and the impact of failure would need to be to result in the proactive approach being more cost-beneficial than a reactive one.

The costs from avoiding such impacts of HP/IP pipeline failure have been added into Option 1 (below) as avoided costs.

Calculating the Benefits

The consequences of a pipeline failure have been derived from the values used with in the LTS AIM model (more detail can be found in Appendix 09.00 Overview: how we have developed our investment plan).

We have calculated the benefits of Option 1 as follows:

CBA Benefit	CBA basis of calculation
Annual Avoided Reactive Costs	(Annual rate of reactive repair) * (Cost of reactive repair) The cost of reactive repair of CP systems is assumed, conservatively, to be the 1.2 times that of proactive repair. This is because evidence shows that emergency reactive costs are substantially above planned proactive costs (in the region of 40 to 60% higher). Further our experience of reactive pipeline repair that may occur as a result of CP failure is that it is in the region of XXXX per incident (for higher pressure tiers) which is substantially above the reactive repair of CP equipment. The annual rate of reactive CP repair is the failure rate, the breakeven value of which is assessed via Switching analysis. These avoided reactive costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business. The calculation at the company level is: Failure rate * XXXX The figure would be higher if the costs of pipeline repair where added to the costs of CP repair, reducing the point at which investment would be cost beneficial.

<table>
<tr><th>CBA Benefit</th><th>CBA basis of calculation</th></tr>
<tr><td>Annual value of Interruptions to Supply</td><td>
(Annual rate of interruption to supply) * (Number of properties affected) * (WTP to avoid interruption) * (Volume of interventions)
The annual rate of interruption to supply is the failure rate, the breakeven value of which is assessed via Switching analysis.
The number of properties affected is forecast via the AIM model and the WTP to avoid an interruption of the likely length of 24 hours to 1 week is XXXX. As the AIM model is for LTS and CP relate to a wider range of pipelines, the failure of which may affect a lower number of properties than the LTS pipelines, we have taken only 10% of the properties affected in the AIM model as conservative estimate of properties affected.
Our current preferred option is to proactively invest to rectify 13,132 non-compliant CP readings during RIIO-2. That is intervene at 13,132 locations.
<table>
<tr><th>Region</th><th>Number of Properties affected by any failure in LTS AIM model</th></tr>
<tr><td>EoE</td><td>732</td></tr>
<tr><td>Lon</td><td>1,198</td></tr>
<tr><td>NW</td><td>918</td></tr>
<tr><td>WM</td><td>772</td></tr>
<tr><td>All</td><td>838</td></tr>
</table>
The calculation at the company level is:
Failure rate * XXXX
These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.
</td></tr>
<tr><td>Annual value for transport disruption</td><td>
(Annual rate of disruptions to transport network) * (Number of days affected) * (Social cost of transport disruption) * (Volume of interventions)
The annual rate of interruption is the failure rate, the breakeven value of which is assessed via Switching analysis.
The number of days affected is forecast by the AIM model and set out in the table below.
<table>
<tr><th>Region</th><th>National railway (critical)</th><th>National Railway (other)</th><th>Motorway</th><th>A Road</th><th>Minor Road</th></tr>
<tr><td>EoE</td><td>0.0040</td><td>0.0000</td><td>0.0004</td><td>0.0029</td><td>0.0173</td></tr>
<tr><td>Lon</td><td>0.0065</td><td>0.0000</td><td>0.0018</td><td>0.0094</td><td>0.0184</td></tr>
<tr><td>NW</td><td>0.0080</td><td>0.0000</td><td>0.0033</td><td>0.0091</td><td>0.0184</td></tr>
<tr><td>WM</td><td>0.0058</td><td>0.0000</td><td>0.0023</td><td>0.0055</td><td>0.0212</td></tr>
<tr><td>All</td><td>0.0054</td><td>0.0000</td><td>0.0015</td><td>0.0055</td><td>0.0183</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>CBA Benefit</th><th>CBA basis of calculation</th></tr>
<tr><td></td><td>
The average social cost of disrupting transport networks is set out below.
<table>
<tr><td>Severity</td><td rowspan="6">Redacted due to commercial sensitivity</td></tr>
<tr><td>Transport disruption: Minor road</td></tr>
<tr><td>Transport disruption: A road (modelled - average A roads)</td></tr>
<tr><td>Transport disruption: Motorway</td></tr>
<tr><td>Transport disruption: National rail (critical routes)</td></tr>
<tr><td>Transport disruption: National rail (other routes)</td></tr>
</table>
These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business
The social cost of rail disruption is based on a conservative analysis of Department of Transport data and a conservative assumption for a single day of disruption.
</td></tr>
<tr><td>Annual Value for Property Damage</td><td>
(Annual rate of property damage) * (number of properties affected) * (Social cost of property damage) * (Volume of interventions)
The annual rate of property damage is the failure rate, the breakeven value of which is assessed via Switching analysis.
The number of properties affected is forecast by the AIM model and set out in the table below.
<table>
<tr><th>Region</th><th>Number of Properties Damaged per failure</th><th>Value per property</th></tr>
<tr><td>EoE</td><td>0.03</td><td rowspan="5">Redacted due to commercial sensitivity</td></tr>
<tr><td>Lon</td><td>0.26</td></tr>
<tr><td>NW</td><td>0.13</td></tr>
<tr><td>WM</td><td>0.08</td></tr>
<tr><td>All</td><td>0.09</td></tr>
</table>
These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.
</td></tr>
<tr><td>Annual Probability of Fatality/Injury</td><td>
(Annual rate of injury) * (Number of injuries) * (Volume of interventions)
The input to the template in this area is the annual probability and the annual value is calculated within the template.
The annual rate of injury is the failure rate, the breakeven value of which is assessed via Switching analysis.
The number of injuries is forecast via the AIM model as shown in the table below.
</td></tr>
</table>

<table>
<tr><th>CBA Benefit</th><th>CBA basis of calculation</th></tr>
<tr><td></td><td>
<table>
<tr><th>Region</th><th>Number of Fatalities & Injuries</th></tr>
<tr><td>EoE</td><td>0.005</td></tr>
<tr><td>Lon</td><td>0.024</td></tr>
<tr><td>NW</td><td>0.013</td></tr>
<tr><td>WM</td><td>0.012</td></tr>
<tr><td>All</td><td>0.010</td></tr>
</table>
These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.
</td></tr>
<tr><td>Annual Level of Emissions</td><td>
(Annual rate of emissions) * (Amount of emissions per failure) * (Volume of interventions)

The input to the template in this area is the annual expected amount of emissions and the annual value is calculated within the template.

The annual rate of emissions is the failure rate, the breakeven value of which is assessed via Switching analysis.

The level of emissions is forecast via the AIM model as shown in the table below.
<table>
<tr><th>Region</th><th>Level of emissions (kg/m3)</th></tr>
<tr><td>EoE</td><td>821.36</td></tr>
<tr><td>Lon</td><td>1177.26</td></tr>
<tr><td>NW</td><td>762.69</td></tr>
<tr><td>WM</td><td>1539.58</td></tr>
<tr><td>All</td><td>986.61</td></tr>
</table>
These avoided social costs are assumed to begin in 2027 at the end of RIIO-2 and to last for 23 years in line with average asset lives across the business.
</td></tr>
</table>

Table A2: Basis of calculations used for CBA

CBA Results

The following sets out the results obtained from the CBA modelling / switching analysis completed:

Option Name	PV Expenditure & Costs	PV Environment	PV Safety	PV Other	Total PV	NPV*
Baseline	[redacted]					
Preferred Option						
Preferred Option Without WTP						

* Switching analyses set to estimate the failure rates that would result in a zero NPV

Table A3: Results of Preliminary Cost Benefit Analysis (£m)

The annual benefits associated with the breakeven failure rate are set out in Table 14 below:

Benefit	Breakeven Level
Avoided Cost	[redacted]
or	
Interruptions to Supply	
or	
Transport Disruption	
or	
Property Damage	
or	
Probability of a fatality	
or	
Probability of a minor injury	
or	
Emissions	

Table A4: Company breakeven Level of Annual Benefits (with WTP scenario)

Our current preferred option is to proactively invest in 13,132 non-compliant CP test posts during RIIO-2.

We have used CBA for illustrative purposes only to demonstrate that a proactive approach to managing cathodic protection failures is optimum. We recognize that we have a legal mandate following our enforcement notice from the HSE to proactively manage our CP asset stock.

Our CBA switching analysis has looked at how many reactive failures we would need by the end of RIIO-3, for the proactive option to be the most cost-beneficial. The table below summarises this CBA analysis.

	EoE	Lon	NW	WM	Company Level
Breakeven Failures by the end of RIIO-3 **(pipeline failures as a result of CP failure)**	37	2	10	4	**53**

Table A5: Breakeven RIIO-3 Failure levels for the Preferred Option

This **baseline option of reacting upon failure**, assumes that we don't invest in maintaining any of these CP assets in the remaining years of RIIO-1 and all of RIIO-2 & RIIO-3. The results of this switching analysis tell us that we would only need 0.41% of these 13,132 poor condition or non-compliant CP assets, to deteriorate to such a level within a 12-year period, to cause a pipeline integrity failure, for the proactive option to be cost beneficial.

We estimate that the life of our pipelines without suitable protection is, at-best, 10 years – and therefore without the proposed investment we would quickly start to see pipelines failing, and over RIIO-2 and RIIO-3 we would expect to observe hundreds of our pipelines affected by the lack of protection.

Because of its large size EoE has the highest number of expected interventions (57% of the company level) and half of the cost, but generally lower value consequences per failure. As such it has a higher breakeven failure rate. Lon has higher value consequences and therefore a lower breakeven failure rate.

We have undertaken a sensitivity test on the conservative avoided reactive costs used in this analysis to test the implications on the results of using the higher value of XXXX pipeline repair as experienced at King's Lynn. This reduces the breakeven failure by 82%. Meaning that if the reactive costs of fixing a pipeline failure were all as large as in the King's Lynn case then it would only require 10 failures over RIIO-3 rather than the 53 set out in Table A5.

Therefore, the cost-benefit analysis demonstrates that our proposed proactive programme of work is the optimum approach.