Appendix 09.10

Offtakes & PRS Metering Systems

RIIO-2 Spend: XXXX

Investment Decision Pack Overview

This Asset Health Engineering Justification Framework paper outlines the scope, costs and benefits for our proposals. We have prepared an Engineering Justification Paper (EJP) and a Cost-Benefit Analysis (CBA).

Overview

Metering and Calorific Value Determination Device (CVDD) assets form part of the Flow Weighted Average Calorific Value (FWACV) system. The FWACV is critical in correctly determining consumers' gas bills, in measuring the volume and energy conveyed (for transport revenues and system balancing), and in ensuring our continued compliance with regulations including safe dosing of odorant.

A large proportion of our meters are now obsolete and have no redundancy via either a standby meter stream or available spares. This lack of resilience, combined with the asset condition (assets are over 50 years old) is resulting in a higher probability of a metering-system failure, which has an immediate impact on our ability to meter our gas at these offtake sites.

To understand the investment needs of these assets, we have carried out a failure-mode and effects analysis, to identify the sites with the highest probabilities and consequences of failure. This has fed into a CBA process to identify an appropriate level of investment for RIIO-2.

We considered three main options including a baseline of reactive response:

- Reactively replace FWAC system on failure (baseline)
- Proactively replace FWACV system at targeted sites only (based on a risk assessment)
- Proactively replace FWACV system at all sites

To understand the scope and associated costs for the proactive replacement options, we commissioned a concept design study.

Our analysis shows that it is most cost-beneficial to proactively replace FWAC systems at targeted sites (i.e. the 18 sites with the lowest level of resilience). This option delivers better value for money and ensures we can deliver a cost-effective and well-planned upgrade to our meters, rather than spending more money delivering emergency works following a meter failure.

Proactive replacement also provides a number of additional benefits that cannot be accurately reflected in the CBA calculations. For example, this investment will enable us to reduce uncertainty in our FWACV measurement performance[1]. This means we will be more certain of the flow rates and calorific values.

Proactive upgrade of the entire FWACV system on the 18 lowest-resilience sites is the optimum option for RIIO-2. Our proposal is supported by the UNC Performance Assurance Committee (PAC), on the basis of improved system maintenance and accuracy.[2]

Summary of preferred option	£m
RIIO-2 Expenditure	Redacted due to commercial sensitivity
NPV	

Material Changes Since October Submission

We have updated the document into a 18/19 price base.

[1] We currently typically operate at a level of 3% measurement uncertainty under 'grandfather rights' but will be able to deliver improvements to 1%.

[2] link to the minutes from the UNC Performance Assurance Committee, on 12 November 2019:- https://gasgov-mst-files.s3.eu-west-1.amazonaws.com/s3fs-public/ggf/2019-11/Minutes%20PAC%2012Nov19%20v1.0%20final.pdf

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2. Introduction

This document covers our Metering and Calorific Value Determination Device (CVDD) assets that form part of the Flow Weighted Average Calorific Value (FWACV) system. These systems reside predominantly on our 50 FWACV offtake terminals where gas is received from the National Transmission System (NTS) and on the four additional inter-LDZ (Local Distribution Zone) offtake sites, which are part of the Local Transmission System (LTS). This document excludes odourisation, which is covered in 9.11.

The FWACV is critical in correctly determining consumers' gas bills, in measuring the volume and energy conveyed for transport revenues and system balancing, and in ensuring our continued compliance with The Gas (Calculations of Thermal Energy) Regulations as amended 1997. This regulation requires a gas transporter to determine and declare the energy of gas provided to the public by means of measured gas volumes and calorific value (Sections 6 and 7 – provided in Appendix 2).

These FWACV systems also fulfil a critical safety role in ensuring that the amount of stenching agent added to gas via the odourisation system is suitable and proportionate to the gas volume flowing through. Gas Safety (Management) Regulations 1996 mandates the following requirement in Regulation 8 (Section 2): *"The gas shall have been treated with a suitable stenching agent to ensure that it has a distinctive and characteristic odour".*

This odour in gas makes it possible for the public to smell and thereby report any gas escapes from the distribution network. Both over and under odourisation cause the gas to lose this distinctive and characteristic odour.

To understand the investment needs of these assets, we have carried out a failure-mode and effects analysis (FMEA), to identify the sites with the highest probability and consequence of failure. This has fed into a cost-benefit analysis (CBA) process to identify an appropriate level of investment for RIIO-2.

A feature of our offtake metering systems is that a large proportion of our meters are now obsolete (no longer produced) or have no redundancy via either a standby meter stream or available spares.

We have undertaken conceptual design and cost modelling work to inform our December submission.

Our metering systems need to be compliant with several international and British standards including ISO 5167 (for Orifice Plate Meters), ISO 9951 (for Turbine Meters) and ISO 17089 (for Ultrasonic Meters). Moreover, our FWACV system must remain compliant with the requirements of The Independent Gas Transporter Uniform Network Code (iGT UNC) (implemented on 1 May 2007). The UNC is a legally binding contractual document which forms the basis of the arrangements between a Gas Transporter (GT) and the shippers whose gas it transports. The following elements of the UNC are directly or indirectly fulfilled through the FWACV system:

- System security and safety should be assured.
- Pricing should reflect the real costs of the services concerned.
- Robust computer systems are developed and maintained.
- Daily energy balancing should be operated.

Keeping a robust FWACV system is a legal obligation for our 54 'CV-Directed Sites'. A CV-Directed site (as per Section D of the UNC, extract provided in Appendix 2) is a place where the gas transporter is mandated by law (The Gas (Calculation of Thermal Energy) Regulations 1996 – Section 6: a to c) to determine the calorific value of gas that is being conveyed by them to the downstream network and to provide and maintain the required apparatus and equipment necessary for the calorific value (CV) determination. The UNC (Section 4.2.2) further specifies that, for all directed sites, the quantity of gas transported also needs to be measured on all periods within the day, and if there are any errors in measurements, they need to be rectified within eight hours or as soon as reasonably practicable.

These FWACV Offtake sites transport large gas flows. Over the 5-year period between April 2014 and March 2019, these sites have flowed gas at an average of 50,565 cubic meters per hour (i.e. 1,213,560 m^3/day), with an average commercial value of **XXXX** per day per measuring station. This means a flow of **XXXX** worth of gas through our 54 FWACV offtakes every day.

In the RIIO-2 context, this is a flow of gas with an annual value of **XXXX** and a combined 5-year value of **XXXX**. These values highlight the importance of an accurate FWACV measuring system.

Our base case supply-demand scenario for this investment case is our peak 1-in-20-year demand. The variability of demand in future forecasts is small; our demand would have to change significantly to require a step-up or down in the model size of meter system components required. We have therefore only considered one supply-demand scenario.

3. Equipment Summary

Flow weighted average calorific value measuring systems: key components and how they work

A simplistic view of a typical FWACV measuring system is provided in the figure below, within the blue boundary:

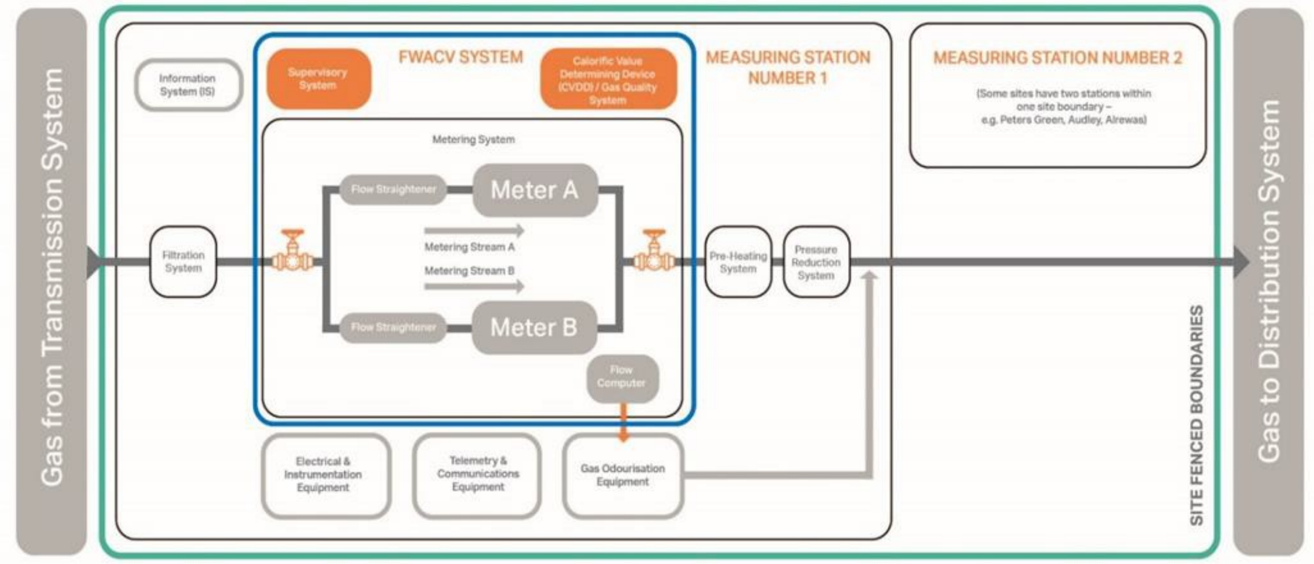

Figure 1: Ideal layout of a measuring station

How a FWACV system works

The green box in Figure 1, above, denotes the physical boundary of an offtake site. Within an Offtake, there may be one or two measuring stations, which contain the various elements that enable the safe reception of high-pressure gas from the NTS or from another LDZ.

The scope of this paper only covers the FWACV system, denoted by the blue box in Figure 1, above.

Within the FWACV System, there are the following sub-systems:

- Metering Systems
- Calorific Value Determining/Gas Quality System
- Supervisory System

FWACV systems determine the quantity of gas conveyed at reference conditions, together with its energy, via suitable application of the CV calculations. This system performs the following critical functions:

- Receives gas from the NTS or another LDZs (either owned by Cadent or another GDN) and measures the volume and CV of that gas.
- Centralised systems receive flow and calorific value data daily from all sites that make up the FWACV solution and calculate the FWACV for each billing zone.
- The flow computer also communicates with the odourisation system to enable correct dosing of odorant (stenching agent) into the gas flow so gas escapes can be detected by members of the public
- The supervisory system then combines the various flow, gas quality, temperature and pressure signals and communicates them to the Distribution National Control Centre (DNCC) where they are monitored and managed to balance network demand with gas supply

Asset Stock: FWACV systems, measuring stations, metering streams and CVDD equipment

The following table sets out the number of sites that contain FWACV systems, the associated number of FWACV measuring stations within these sites, and the associated number of metering streams.

The asset stock for each of our networks, as recorded in the engineering services central records (updated April 2019), is shown in the following table. The table shows the number of NTS-LDZ and LDZ-LDZ offtakes operated and maintained by Cadent, the number of measuring stations on these sites (each station has one metering system with single or multiple metering streams on each system), the number of metering streams and the number of CVDDs:

Network	Number of Sites with FWACV Measuring Stations	Number of FWACV Measuring Stations	Number of Metering Streams	Number of CVDDs
EoE	22	22	32	22
Lon	6	7 [1]	10	6 [2]
NW	10	10	11	10
WM	13	15 [3]	21	14 [4]
Total	**51**	**54**	**74**	**52**

Table 1: Current FWACV sites, measuring stations, metering streams and CVDDs

Notes:

[1] Two Measuring Stations at Peters Green offtake Site
[2] CVDD is shared between the two stations at Peters Green
[3] Alrewas and Audley's sites have two stations each
[4] CVDD is shared at Audley, but each measuring station at Alrewas has its own CVDD

Further details on key components of an FWACV system

The following section provides more detail on the different major components of the FWACV system, and provides photos and equipment counts for:

- Meters
- FWACV panels (which contain the flow computers and supervisory controls)
- CVDDs

Asset Stock: FWACV meters

There are three types of meters in use at Cadent:

Orifice Meter (right) – this consists of an orifice plate carrier with an orifice plate (a circular hole of precisely recorded dimensions in a metal plate) creating a pressure differential. Orifice meters have a simple design and measure the rate of gas flow by measuring the differential pressure (DP) across the orifice plate. These require non-turbulent (laminar) flow conditions and, as such, need long lengths of straight pipework up and downstream, referred to as flow straighteners in Figure 1. Although simple in design, the accuracy of the meter depends on precision engineering of the component parts. The carrier also holds a second plate which is cycled into the pipe when the first plate undergoes its annual calibration. Orifice plates are designed and maintained in accordance with the international standard ISO 5167.

Figure 2: Orifice plate carrier and orifice plate

Turbine Meter (left) – Turbine gas meters measure gas volume by determining the speed of the gas moving through the meter. The turbine measures the speed of the gas, which is transmitted to a counter. As the volume of gas is calculated by the flow, it is important that flow conditions are non-turbulent (laminar), so they need several lengths of straight pipework upstream and downstream (see Figure 1). Turbine meters are designed and maintained in accordance with the international standard ISO 9951.

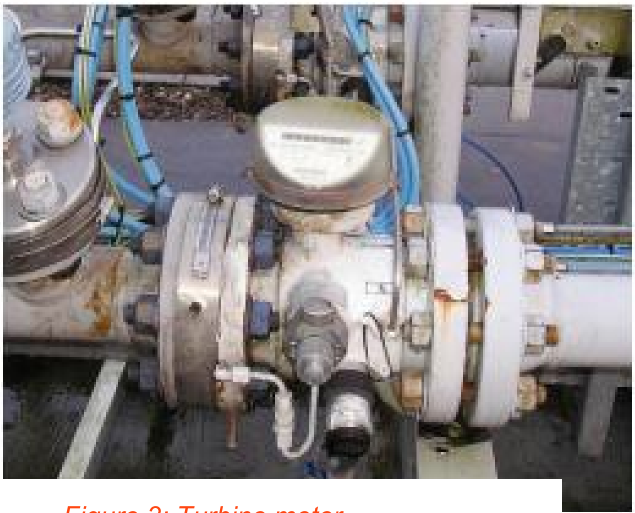

Figure 3: Turbine meter

Ultrasonic Meters (USMs) (right) – Ultrasonic flowmeters use sound waves to determine the velocity of a fluid flowing in a pipe. They work by sending and receiving ultrasonic waves between transducers in both the upstream and downstream directions in the pipe. At no flow conditions, it takes the same time to travel upstream and downstream between the transducers. Under flowing conditions, the upstream wave will travel slower and take more time than the (faster) downstream wave. As the gas moves faster, the difference between the upstream and downstream times increases. The transmitter processes upstream and downstream times to determine the flow rate. These modern units are the industry standard for new installations. They do not impede the flow of gas and are undamaged by any debris in the pipe. However, they still require long lengths of straight pipework up and downstream for accurate measurement. USMs are designed and maintained in accordance with the international standard ISO 17089.

Figure 4: Ultrasonic meter

Metering stream resilience architecture or obsolescence

There is a wide and varied level of resilience and metering configurations across offtake sites. The following table summarises the resilience architecture and our ability to sources meter spares (caused by obsolescence).

Network	% of metering systems with a single metering stream (no resilience)	% of metering systems with multiple metering streams but no standby stream [1]	% of metering systems with no spares commercially available (due to obsolescence)
EoE	55%	86%	14%
Lon	57%	100%	0%
NW	91%	100%	9%
WM	60%	93%	20%
Total	64%	93%	15%

Table 2: Meter redundancy and obsolescence

Note:

[1] There may be multiple streams available however they are all required to operate during winter flows; therefore, no resilience available. Only four sites (3 in EM and 1 in WM) have resilience through standby streams

Asset Stock: FWACV panel

This is the central part of the FWACV system and includes the following components: Flow Computer, Supervisory System, Barriers and Communications Interfaces.

Flow computers combine flow rate signals from the meters, temperature and pressure signals from sensors and calorific value signals from the CVDD to calculate the FWACV. These units are bespoke to the installed metering system and require replacement if the meter is replaced. One of these panels is located at all measuring stations and therefore their population is the same as that of the measuring stations (see Table 1).

Figure 6: Current FWACV panel

Figure 5: Modern FWACV panel

Asset Stock: Calorific Value Determination Devices

Figure 7: Picture of Model 500/2350A CVDD equipment

Information from the CVDD equipment is used in conjunction with flow data from the metering system to determine the FWAC value, and thereby the energy conveyed for transport revenue and system balancing, in line with our obligations under the Gas (Calculations of Thermal Energy) Regulations as amended 1997.

The CVDD equipment is used to measure calorific value (CV) and needs to be approved by Ofgem. This approval stipulates the specific make and model of equipment including software versions and configurations. CVDD is part of the overall FWACV system and therefore errors with CV measurement will directly affect the ability for the system to accurately calculate the FWACV for billing purposes.

Table 1 (above) contains the asset population per network for CVDDs. All directed sites are currently Danalyser Model 500s, pictured in Figure 7 (left). Where trackers were used for the purposes of CV measurement on non-directed sites, these have been changed to Model 700s during RIIO-1.

Both Model 500 and Model 700 are inactive models and are no longer produced by the manufacturer (Emersons). The manufacturer has confirmed that the Model 500 will only be supported until 2021 and Model 700 until 2022; thereafter, the availability of compliant spares and the ability to update software will cease.

4. Problem Statement

Overview of investment drivers

Our customers expect a safe and reliable network. Our FWACV metering systems enable the balancing of supply and demand between the NTS and our gas distribution systems. The outputs are also used to inform revenue payments for gas transported and to ensure gas is suitably odourised to comply with safety legislation.

The following section sets out a summary of the key problems with our existing FWACV metering systems and summarises the investment drivers. These problems are then further expanded and quantified in the probability and consequence sections, later in this document.

Low resilience in the metering system: Based on our engineering review, our current metering systems have very low resilience. Systems are made more resilient through the combination of appropriate levels of redundancy: by providing standby metering streams and having a stock of spares available to ensure any faults or component failures can be quickly resolved. Our systems lack resilience because there are no standby streams on a high proportion of metering systems and an increasing number of metering assets where obsolescence means cost-effective spares are no longer available quickly (lead time of up to 2 years have been quoted).

- **Obsolescence:** Many of our current FWACV meters are now obsolete, with spares no longer being manufactured or available in stock. Our CVDD equipment will also become unsupported from 2021. When an item becomes obsolete, off-the-shelf spares are no longer regularly manufactured by the suppliers. Bespoke spares can sometimes be manufactured as ‘specials’ but are subject to long lead times and significantly higher purchase costs. They also require independent certification to demonstrate compliance with the appropriate design standards (standards for each meter type are stated in Section 3). 15% of our metering systems have meters that are obsolete. Further detail is summarised in Table 2 above.

- **Duty-only metering streams**: As shown in Table 2, across the four distribution networks, a significant percentage of metering systems only have ‘duty’ metering streams. Between 86% and 100% of sites have no redundancy across the four networks. In fact, only four of our stations (3 in EM and 1 in WM) have standby streams available to ensure system redundancy. This driver becomes more significant given the increased likelihood of failure.

This lack of resilience, combined with the asset condition (assets are over 50 years old), is resulting in a higher probability of a metering system failure, which has an immediate impact on our ability to meter our gas at these offtake sites.

If a meter fails, there is no resilience and a repair cannot be made; this, in turn, leads to the potential for a long-term metering outage while an alternative meter is sourced and installed, or a temporary, strap-on meter is used, causing a potential loss in metering accuracy.

Permitted uncertainty levels for offtake metering systems: Annex D-1 of the Ofgem Offtake Arrangements Document (OAD) (provided in Appendix 4) lays out a general obligation for offtakes to have an instantaneous volume flow rate uncertainty level of +/- 1%. However, since the older installations provide a higher uncertainty level than this, individual supplemental agreements for each offtake typically allow for up to 3% uncertainty on specific offtakes (‘grandfather rights’).

The OAD is part the wider Unified Network Code (UNC) document, compliance with which forms part of our contractual obligations as a gas transporter. Cadent’s internal policies (ME/1 and ME/12) interpret our UNC obligation related to measurement certainty and clarify that the legacy 3% uncertainty allowance will not be applicable to sites where a FWACV system replacement or ‘substantial upgrade’ has occurred. This means that for all the sites we’re proposing to invest in during RIIO-2, we will have to comply with a 1% uncertainty performance requirement. This increased performance is possible with modern USM technology, whereas current Orifice Plate and Turbine Meters are not designed to meet this 1% requirement. Through our engagement programme (including a session with the UNC Performance Assurance Committee (PAC) in Nov

2019), shippers have expressed a strong preference for increasing the measurement-certainty, reliability and accuracy of our offtake FWACV systems.

Ageing meters: A significant proportion of our metering asset stock was originally installed in the 1960s as part of the construction of the offtake sites. Although age is not always an accurate reflection of condition or performance, it still needs to be considered that some asset components are 50 to 60 years old. When asset obsolescence is considered, these components indicate an increased risk of failure.

The investment drivers for investment in the FWACV systems are set out below:

- **Safety:** Inaccuracies in flow data and/or a meter failure compromises the dosing levels of odorant. An under-reading of gas flow may lead to under odourisation, compromising the safety of the gas supply as customers may not be able to detect a gas escape.

- **Commercial impact:** DNCCs use data from the metering system to maintain gas flows in line with commercially agreed volumes. Metering and CVDD establish the FWACV of gas transferred. Any undetected metering error, or partial or total loss of metering capability, could lead to a commercial impact as flow balances in the national and local networks will become less certain.

- **Network Reliability:** The absence of effective flow measurement on a site, or a catastrophic failure of meters, may lead to a change to the network configuration by the shut-down of the affected site, which, in turn, removes the balancing potential of the network and in severe cases could cause an interruption to supply. This issue is most significant where a site is a single feed to a population centre and only has a single metering stream, with no standby or (an adequate) bypass. Eight of our 55 NTS or Inter-LDZ Offtakes (15%) are single feeds, and any interruption to supply will result in loss of gas to downstream customers.

- **Legislative duties**: We have a duty to maintain a safe network, underpinned by statutory instruments. Failure of our FWACV systems will result in our failure to meet the Statute Gas (Calculation of Thermal Energy) Regulations (Section 12), licence conditions and Uniform Network Code (UNC). These binding documents require Cadent to provide an FWACV system that is fit for purpose, providing a reliable, accurate, safe and efficient way to measure gas volumes and energy at our offtakes. GSMR Gas Safety (Management) Regulations (1996) states that “gas shall have been treated with a suitable stenching agent to ensure that it has a distinctive and characteristic odour”.

- **Security of supply (flow balancing)**: Our measuring stations provide critical flow-data to National Grid Transmission’s Gas National Control Centre (GNCC) and to Cadent’s Distribution National Control Centre (DNCC). This information is used to dynamically balance supply with demand. Any long-term metering failure or inaccuracy will mean inaccurately regulated flow to meet pressure demands downstream linepack storage levels. USMs support a wider operating envelope (they are accurate over a wider range of flows), which better supports variable demand.

- **Affordability**: In addition, we recognise the importance of investment plans that provide value for money. It is imperative we provide the most efficient and cost-effective long-term solution to manage customer bills. Older, assets in poor condition can cause faults which require numerous site visits in addition to more frequent calibrations for rectification, increasing operating costs.

The obsolescence of the meters and the CVDD, combined with the lack of redundancy provides Cadent with an opportunity to cost-effectively and holistically build; a reliable, and resilient FWACV system at currently high-risk sites. The improved system further mitigates risk by the addition of duty and standby metering streams, commercially available spares, pipework layouts that improve accuracy and a component sequence that allows effective condition-based monitoring.

In summary, we now understand that many of the critical components within our metering systems are obsolete (meters and CVDD) and cannot be quickly and cost-effectively repaired. When this obsolescence is combined with the lack of redundancy due to the lack of standby metering streams or critical spares, our current FWACV system configuration shows an unacceptably high probability of a meter failure, leading to a long metering outage. Without investment, we expect to see many of our FWACV systems suffer a long-term outage, and therefore we propose this FWACV system replacement programme.

Required outcomes

In summary, the required outcomes for this investment are:

- Provide a safe, reliable and cost-effective FWACV systems at our offtake sites.
- Ensure continued compliance with legislative requirements.
- Enable effective flow balancing between gas distribution and transmission through the provision of accurate measurements of transported energy.
- Providing appropriate resilience within our metering systems, to quickly and cost-effectively mitigate risks posed by single meter failures in the future.

These outcomes will be supported by achieving the following outputs:

- Providing additional monitoring and analytics to further reduce the risk of FWACV-system failures.
- Providing modern-day equivalent flow meters that will increase the meter reading certainty to + or - 1% (rather than the current 3% on some sites).
- Managing and remediating asset deterioration to ensure that we minimise safety risk and improve the security of supply to our customers.

Supply-Demand Scenario Sensitivities

We have analysed the demand forecasts of all our offtakes to check if demand fluctuations over RIIO-2 would cause us to design our metering-system remediations for either an increased or decreased gas-flow. This investment case is not sensitive to the range of demand forecasts modelled. The graph below shows the trend per offtake of demand through to 2026:

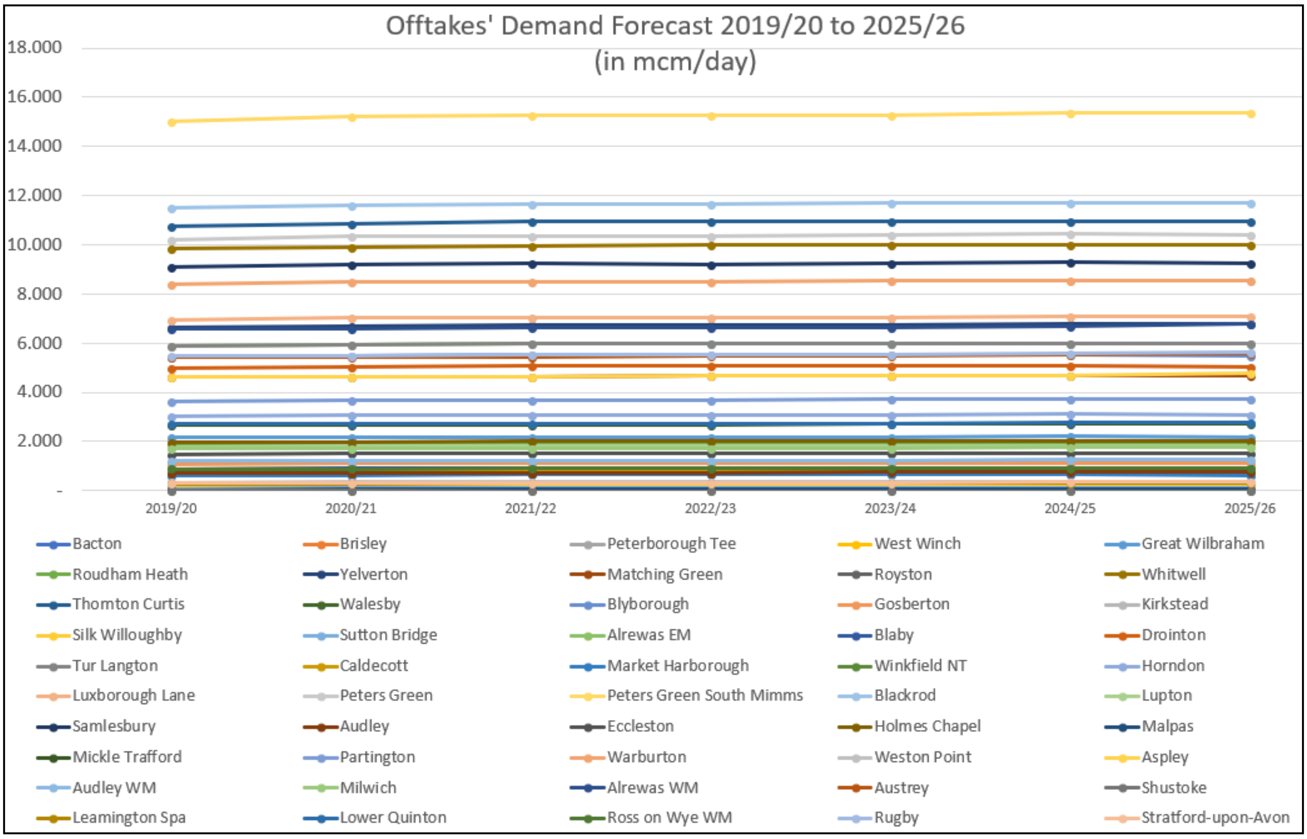

Figure 8: Demand Forecast for Offtakes 2019/20 to 2025/26

As such this investment case is based on the requiring all replacement assets to be able to meet the current peak demand stated in the Supplemental Agreements under the Unified Network Code.

4.1. Narrative Real-Life Example of Problem

Turbine meter failure case study: Cadent Silk Willoughby Offtake

The metering system consisted of two 4” diameter, long-bodied turbine metering streams (both streams are required to supply in winter conditions i.e. no standby) with pressure and temperature measurement. These streams were in line with the pressure reduction streams, as is the case with all turbine meters.

One of these meters failed in Autumn 2012. An independent study was subsequently carried out by DNV-GL which investigated the failure mode and provided recommendations to prevent similar failures happening again. Modern ultrasonic meters (USMs) were subsequently installed at this offtake as per the recommendations of this study. The safety, interruption and commercial impacts of this failure were low as the site had resilience outside of winter demand due to its twin stream metering system and commercially available spares. However, such an incident at any sites where this resilience is not present, a higher impact would have been encountered.

The study concluded that the meter failure was a result of the seizure of the turbine blades caused by fractured and non-rounded bearings and misalignment of the turbine shaft. This misalignment also caused the turbine blades to come into contact with the internal wall of the metering unit, contributing to the failure.

Figure 9: Pictures of the components (ball bearings, turbine shaft and internal wall) that failed at Silk Willoughby

Turbine meters are inherently susceptible to wear and fatigue because they have moving mechanical parts. The cause of the failure remained inconclusive however, according to the study, the overloading damage on the bearing could have been caused by a breakdown of lubrication due to high pressures between the balls and the race surface. Any lack of lubrication creates increased friction and adhesion and is likely to result in fractured bearings.

Due to the proximity of the meter to the preheating and pressure regulating equipment, a like for like replacement was not possible, as turbine meters are not designed to meet the performance requirements of modern metering performance standards, especially in absence of long lengths of straight pipework and flow straightening equipment upstream. Therefore, modern ultrasonic meters were installed. These are now being trialled successfully during RIIO-1. USMs do not have any moving parts or any parts that obstruct gas flow, so similar failure modes are not applicable to them.

4.2. Spend Boundaries

The assets within the scope of this investment case cover the following aspects of the FWACV system:

- CVDD
- Metering system
- Flow computer and FWACV rack
- Any immediately associated electrical, instrumentation, civil structure or pipework assets

5. Probability of Failure

Over the last ten years, two reported meter failures have required us to replace the metering system. Our routine meter calibrations provide some early warnings of possible meter failures, and this calibration process often identifies and enables us to rectify signs of wear and tear on orifice plates before they fail. This is possible where spares have been available. Any mismeasurement or damage between calibrations can go undetected in the absence of a dynamic condition-based monitoring system.

We have been fortunate that the meter failures have occurred on sites where there was resilience from standby meter-streams or second orifice calibration plates. While we have experienced few failures to date, with the metering stock ageing, as the next section will explain, the likelihood of a future meter failure is large and increasing with time.

While we have used the NOMs methodology to understand the risks of our metering-system assets, we have recognised through our engineering review that these models do not accurately reflect the asset obsolescence and redundancy risk. We have therefore developed a risk-based framework to consistently assess the risk of any metering system component failure that would lead to an immediate loss of metering capability due to low system resilience (as discussed in Section 4).

Our risk-based framework allowed us to consistently review each metering system on every offtake site and identify a range of different risk categories related to the redundancy architecture, unavailability of spares due to obsolescence, and the complexity of any remediation arising from the pipework configuration and component sequencing on these sites. A table summarising the likelihood of failure by risk category with the assumed probability of failure and duration of outage in the event of a failure is summarised in the consequence section.

For completeness, the 'failure effects' that our NOMS model considers are set out below:

- **Meter over-reading** – where metering systems reads higher than the actual flow, an incorrect reading is recorded. This can affect the level of odorant injected into the gas system (over-injection) and will cause a breach of regulatory obligations since an over-odorised gas loses its characteristic and distinct smell.

- **Meter under-reading/No reading** – where metering systems reads lower than the actual flow, an incorrect reading is recorded as well. This can affect the level of odorant injected into the gas system (under-odourisation) and will cause a breach of regulatory obligations as low/no smell will cause gas escapes to go undetected by members of the public.

- **Release of gas** – relating to the failure of a meter carriage, seal or another pressure containing component on site leading to an unconstrained release of gas within, and possibly off, the site.

- **General failure** – relating to other failures not leading to either a safety, environmental or gas-supply related consequence.

For our engineering approach, we have only considered a single-failure effect of 'meter under-reading/no reading'**.** Our rationale for this approach is because much of the current meter stock is between 50 and 60 years old and, with the lack of spares and on-site redundancy on many of our offtake sites, this factor alone causes sufficient risk to drive investment.

5.1. Probability of Failure Data Assurance

In the absence of failure data, we have developed a risk based analytical framework for these assets. We use the following data to develop this framework:

- Meter type

- Meter make and model
- Stream redundancy
- Declared Offtake Max Volume Flow Rate Rating (from Omni config) (scm/hr)
- Average Flow Rates per Measuring Station (mcm/gas day)
- Whether single feed or not

The source for this data is the Network Strategy's central FWACV database. Based on these data we have developed estimates of:

- failure rates, i.e. the risk that the meter will fail each year and need to be reactively replaced.
- duration impacts i.e. the time it will take to replace the meter once failed or provide alternative metering capability.

These estimates are consistently applied to our metering asset stock. These are based on engineering judgement and validated and tested through our CBA sensitivity testing.

We have also compared the outputs from this framework with the NOMS through running several comparative scenarios using the NOMS approach.

6. Consequences of Failures

The consequence of a meter failure depends first on whether there is a standby stream available to flow the gas and second, on how quickly a repair can be made. In the absence of resilience (provided by standby streams or the ability of the downstream distribution network to allow for the site to go offline), the impact is immediate.

These FWACV Offtake sites transport large gas flows. Over the 5-year period between April 2014 and March 2019, these sites have flown gas at an average of 50,565 cubic meters per hour (i.e. 1,213,560 m3/day), with an average commercial value of **XXXX** per day per measuring station. This means a **flow of XXXX worth of gas through our 54 FWACV offtakes every day**; this value provides the context towards the importance of accurate FWACV measuring system. Various consequences of metering failure are discussed below.

On 64% of our sites, the failure of a single meter will lead to an immediate lack of metering capability due to lack of system redundancy. On some orifice plate systems, the second cycled orifice plate provides some redundancy while the first plate is replaced/repaired, checked for reliability and recalibrated.

A large proportion of these offtake sites has a low level of network resilience (some sites being single feeds to the downstream network).

On many of the sites, a meter failure would require a meter replacement due to obsolescence. If a modern-day meter needs to be installed, we may need to **rebuild the metering system** as the pipework may also be inadequate to achieving the meter-reading uncertainty of 1% or below, as stipulated in the Offtakes Arrangement Document (OAD), which is part of the Unified Network Code (UNC). This would result in long metering-system outages. The overall scale of the impact would be increased considerably due to the long duration of an outage. In some cases, where pipework configurations allow, a strap-on ultrasonic meter could be used as a temporary mitigation, but the measuring accuracy will be reduced.

The loss of a meter and use of inaccurate temporary metering will also **affect the ability to accurately dose the stenching agent**. A short-term mitigation for this risk is to dose an appropriate amount of odorant manually based on flow estimations. Manual dosing can only be employed as a short-term approach and will require specialist rhinologist operatives to continually smell the gas to ensure the odorant amount remains suitable. While this will temporarily reduce the safety risk from unodourised gas, potential under- or over-dosing will consequently make us non-compliant with our GS(M)R obligations under Regulation 8 (Section 2), which states that we need to ensure that downstream gas: “has a distinctive and characteristic odour”. Both over- and under-odourisation will result in the gas losing its distinctive and characteristic odour.

The loss of a meter, or a continued lower meter reading accuracy, may also have a significant **impact on flow balancing** in the NTS and on revenue calculations.

In the event of a meter reading error or fault, Cadent will need to employ independent specialists – as per the Meter Error Reconciliation (MER) process – to investigate and study the failure. The cost for using the MER process on a large-scale, long-duration metering error is significant. **Error investigation costs of between XXXX to XXXX** for each suspected metering failure, depending on the severity and duration of the error.

For completeness, we have included the consequences of failure considered within the NOMs model below:

- **Pre-odour release** – an increase in public reported escapes (PREs) in the vicinity of the offtake due to odour release
- **Release of gas** – a loss of gas arising from the Metering asset itself
- **Undetected escapes downstream** – undetected gas escapes downstream
- **Pre-high odour** – an increase in public reported escapes downstream of the network due to over-odourisation
- **Ignitions or explosion** – either within the metering station or in the downstream network

Based on this assessment, we have identified seven different risk categories using the variables of metering redundancy, network resilience and meter reliability. For each of these, we have then assessed, using our risk-based framework, a reasonable probability of metering-system failure, and a likely duration of outage. The size of impact is derived from the actual average gas flow-rates per site over the 5-year period of between 01/04/14 and 31/03/19. The duration of metering outage is impacted by the length of time to source a compliant meter replacement and/or proactively upgrading of the site using a modern-day equivalent meter. In many cases, the lead times for an ISO and British Standard compliant replacement could range from six months to two years. For our assessment, we have assumed that a temporary mitigation could be put in place in less time, albeit at a reduced level of accuracy and an increased risk of inaccurate odourisation.

Risk Category	Description of Category Rationale for Probability & Duration of Outage.	Meter types within category	Probability	Metering accuracy impacted for
Category 1	**Metering systems with no redundancy and long lead times to replace/repair meters:** Single meter failure leads to medium-term outage. Estimated 1-2 years to modify the metering system. Accuracy restored within 90 days via temporary arrangements. Short body restricts temporary options.	Daniels DVS Orifice Plate Meters and Short Bodied Turbine Meters	1 in 5 yrs.	90 days
Category 2	**Metering systems with no redundancy but shorter lead times to replace/repair meters:** Single meter failure leads to medium-term outage. Estimated 6-12 months outage of metering system to modify it. Accuracy restored within 30 days via temporary arrangements.	Long Bodied Turbine Meters	1 in 5 yrs.	30 days
Category 3	**Metering systems where site-specific features are increasing the risk of single or multiple meter failures** (flooding, insufficient bypass dimensions, other asset failures or safety risks)	Specific Sites (with Non-DVS Orifice Plate Meters)	1 in 5 yrs.	30 days
Category 4	**Sites are large single-feed offtakes (no network resilience), having single-stream metering systems where a calibration spare is available** Single meter failure would remove critical metering-redundancy (currently provided by a cycled 2nd orifice plate). Only multiple meter failure would have an impact, but having no network resilience means that loss of a meter has a larger impact on network control and a large impact on the supply-demand balance	Non-DVS Orifice Plate Meters	1 in 20 yrs.	30 days
Category 5	**Metering systems with duty/standby; meters obsolete and no spares:** Single meter failure would remove critical metering-redundancy. Multiple meter failure would cause metering-system outage, therefore a lower probability of failure. Estimated 1-2 years, to modify the metering system.	1st Generation USMs	1 in 200 yrs.	30 days
Category 6	**Single stream systems as per Category 4, but gas flows are lower and or network resilience is available (not single feed).** A single meter failure would remove critical metering redundancy (currently provided by a cycled plate). Only multiple meter failure would have an impact. However, with network resilience, some risk from loss of metering can be mitigated.	Non-DVS Orifice Plate	1 in 200 yrs.	15 days
Category 7	**Metering redundancy present; spares commercially available, no major site-reconfiguration.** Only multiple metering failure would cause this, with short-duration works to upgrade the meter systems as a result of a failure.	Various Turbines & Orifice Plates	1 in 200 yrs.	5 days
Out of Scope Metering Stations	**Already upgraded to modern ultrasonic meters or upgrade planned.** 2 out of scope sites: the first metering station where an upgrade to USMs is already completed and the second station where the upgrade is planned to be completed in RIIO-1.			

Table 3: Risk Categorisation of all meter-systems based on probability of 'meter failure' and duration of outage.

To further support the analysis, we have carried out suitable sensitivity testing, which is discussed in Section 8.2.

Based on our view of risk, we have used CBA to help us understand the optimum investment plan for RIIO-2. This is discussed later, in Section 8. In this section, we have included a diagram that shows this distribution of risk by network – supporting data is provided in Appendix 4.

In Section 7 (Options Considered), we have discussed how we have used this view of risk to select the optimum programme for RIIO-2 and RIIO-3. The graph below shows all the FWACV sites ranked by measurement-inaccuracy risk. The y-axis has been set to a logarithmic scale to better demonstrate the comparative risk differences rather than absolute differences:

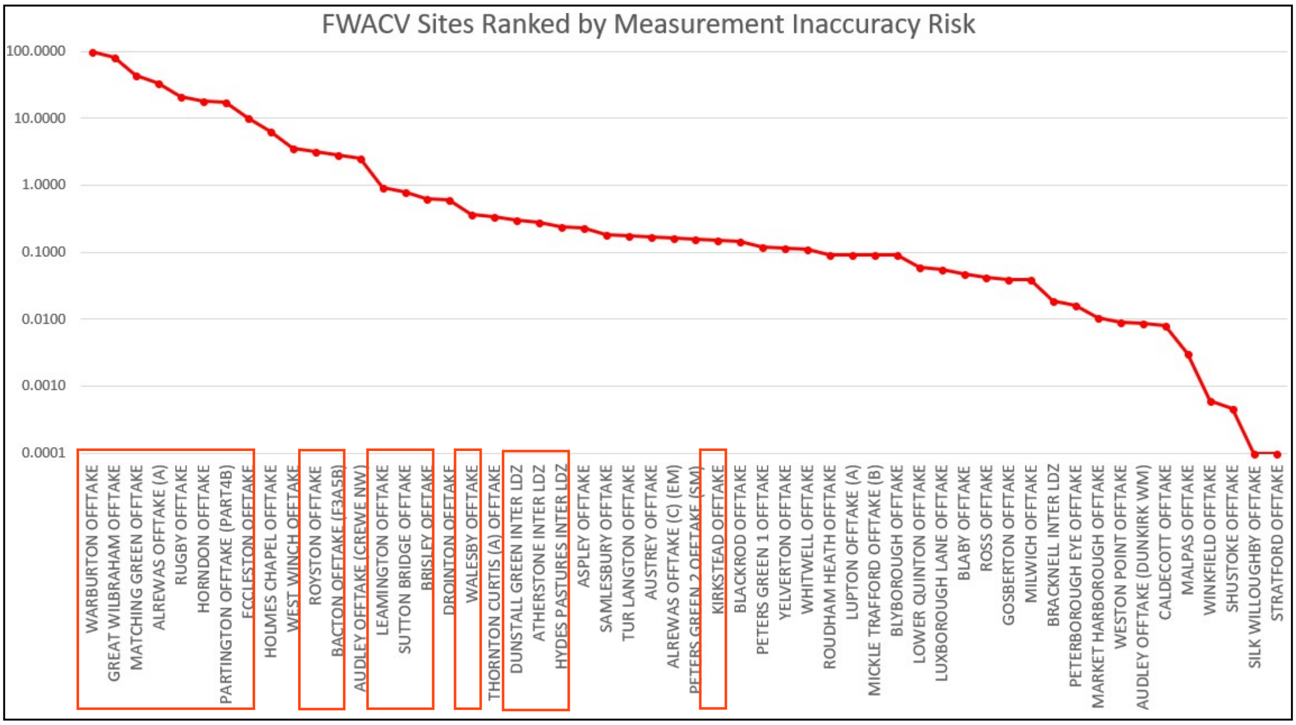

Figure 10: Sites ranked by 'Sites marked with the red boxes have been selected for RIIO-2 interventions

7. Options Considered

As explained previously, we have identified a significant risk to the resilience of our metering systems posed by the current lack of redundancy (either from the site-specific redundancy architecture or due to the lack of available spares, caused by obsolescence).

This lack of redundancy and obsolescence in both the meter and CVDD asset stock, together with an ageing asset fleet, inadequate pipework configuration and a higher metering uncertainty compared to modern standards, gives Cadent an opportunity to improve its FWACV systems to provide resilient, reliable, modern-day-equivalent installations.

During RIIO-1, other IDNs have upgraded many of their legacy meters to modern USMs. Cadent has observed that while this has not always been entirely straightforward, as different configurations of meters have been iteratively explored, the success of these explorations has now better informed the industry, matured the USM technology, increased the availability of skilled labour to deal with USMs and reduced implementation costs such that Cadent now consider the technology suitable for long-term investment and RIIO-2 to be the appropriate period for this programme.

We have assessed the following options, which are discussed below:

- Baseline: Reactively replace FWACV systems: improving metering system redundancy
- Option 1: Proactively replace FWACV systems: improving metering system redundancy (ensuring standby streams are installed where currently unavailable)
- Option 2: Reactively repair or replace FWACV system components on failure

We have engaged an independent specialist consultant to carry out an engineering assessment and to establish cost estimates for the required upgrades for our Baseline & Option 1.

We also carried out a sensitivity test on Option 1, to assess the impact of maintaining the current metering-system redundancy at all sites; therefore, some sites would remain with a duty-only meter, thereby losing the opportunity to improve system resilience, this is discussed as part of Option 1.

Additional scenarios considered in NOMs were explored. These are discussed further in Appendix 5.

7.1 Baseline Option: Reactively repair or replace FWACV systems on failure: improving metering system redundancy

This option looks at reactively replacing the entire FWACV system on failure. This option has been considered as our do-minimum option in our baseline CBA.

This option differs from Option 1 in that it looks at delivering this FWACV replacement reactively after the failure of an obsolete meter across all sites. Cadent would need to mitigate the loss of metering capability at the same time as mobilising a contract to design and build the FWACV system.

The business would look to install some form of temporary strap-on ultrasonic meter, with poorer levels of accuracy, as a temporary mitigation to the failure. We would, however, expect the business to suffer the following impacts as a result:

- Higher costs to design and build the new FWACV system, because of the urgent, reactive nature of the project. The ability to commercially negotiate is weakened due to time pressures. Reactive replacement is significantly more expensive than planned work, increasing the cost that our customers would have to pay.
- Inability to manage the works to coincide with low-demand periods, thus putting greater pressure on the supply-demand balance. For single-feed sites, this will result in downstream supply disconnections (in case of a catastrophic failure) or flowing of unmetered gas.
- NTS Network control is affected due to lower accuracy metering and the reduced ability to accurately flow-balance.

- Additional costs are incurred by employing independent consultants to verify the metering failure

Cadent's Contracts and Procurement (C&P) specialists have analysed our RIIO-1 experience of the typical difference of reactive and proactive project costs. We have concluded that it is typical to have the costs associated with labour go up to 50% more during a reactive mobilisation and material costs to go up by 30%. This expert judgement on increased costs in reactive mobilisation is based on the following characteristics of reactive work:

- premium labour costs due to prescriptive and tight deadlines for reactive delivery
- reduced commercial leverage (buying power) due to the reactive nature of work
- urgent manufacturing and delivery request

Based on factors above, our conservative judgement suggests that the cost of a reactive upgrade would be at least 120% of the proactive costs. We have therefore added this uplift to all the proactive upgrade costs derived from the engineering study, to inform this option.

The option costs are built up from the probability of failure on a site by site basis, as set out in Appendix 4, multiplied by the reactive costs of failure.

As a result, the capex cost profile for this option is as follows:

Network	21/22	22/23	23/24	24/25	25/26	Total Capex
EoE						
Lon						
NW			Redacted due to commercial sensitivity			
WM						
Total Capex						

Table 4: Baseline: Reactive capex cost profile

7.2. Option 1: Proactively replace entire FWACV system on 18 metering stations: improving metering system redundancy

This option looks at proactively replacing the entire FWACV system before failure. As shown in figure 11 below, this option considers the replacement of all components within the FWACV boundary, highlighted in blue. This option increases the metering redundancy on sites that currently lack it because the chosen solution assumes that a duty/standby metering stream is required to be provided on all sites. On many sites, the current metering systems only have a single duty meter, with an unmetered bypass stream available (which is not always suitably sized for peak demand).

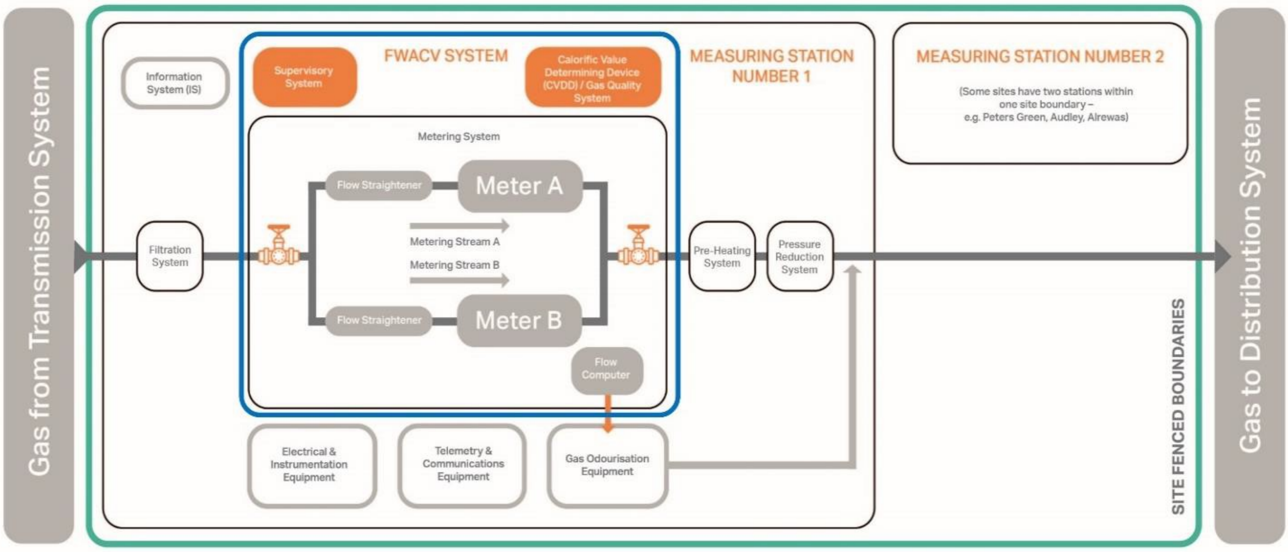

Figure 11: FWACV system boundary

Based on our site surveys, knowledge of assets, and our risk-based framework for assessing metering risk, we have identified the highest risk sites for delivery in RIIO-2 and RIIO-3, by tackling the systems without redundancy with the greatest risk to metering accuracy, in early RIIO-2 (See Section 6, Figure 10 and Appendix 4). Our metering programme in RIIO-3 would then look to address the medium-risk sites. This option looks to proactively upgrade 18 measuring stations in RIIO-2, with the remaining 34 stations being upgraded in RIIO-3. We have tested this option using CBA.

Figure 7 in Section 6 shows all sites ranked by 'volume of gas impacted due to metering failure'.

This option recommends that we replace the metering systems at the following offtake sites in the following years:

Network	21/22	22/23	23/24	24/25	25/26	Total Sites
EoE	Pre-Construction Surveying and Design	Great Wilbraham Matching Green Sutton Bridge	Royston Walesby	Bacton Kirkstead	Brisley	**8**
Lon			Horndon	Dunstall Green Inter-LDZ		**2**
NW		Warburton	Partington	Eccleston		**3**
WM		Alrewas (A) Leamington	Hydes Pastures Inter-LDZ	Atherstone Inter-LDZ	Rugby	**5**
Total Sites Completed	**0**	**6**	**5**	**5**	**2**	**18**

Table 5: Proposed delivery programme for Option 1

The costs for the metering upgrades for each site is contained in Section 7.5. Options Cost Summary Table. A total installed cost per site (excluding contingency) has been derived by a specialist independent consultant and we have added the 2.5% programme level contingency on those costs.

The resulting proactive capex cost profile for this option is summarised below:

Network	21/22	22/23	23/24	24/25	25/26	Total Capex
EoE						
Lon						
NW			Redacted due to commercial sensitivity			
WM						
Total Capex						

Table 6: Proposed spend profile for Option 1 (post efficiency)

As a sensitivity check, our consultants also looked at how these FWACV-system replacement costs would change if we retained like-for-like redundancy. Therefore, if the site has a single meter and a bypass, the future solution would provide the same configuration instead of the ideal duty-standby metering stream configuration. In this option, overall capex for RIIO-2 for the same 18 sites only reduces by circa **XXXX**.

A replacement of the entire FWACV system has many benefits, these include:

- The ability to provide appropriate levels of resilience through the provision of meter-stream redundancy (for sites with duty-only meter streams)
- To upgrade the obsolete CVDD, meters and flow-computers at the same time, improving cost efficiency and ensuring inter-compatibility of new assets
- To improve the metering certainty and in the process resolve cramped and unsuitable pipework arrangements on site
- To standardise our asset-components, thereby simplifying and improving maintenance and to provide an opportunity for Cadent to look at a strategic spares programme to further improve resilience

This option is identical to the baseline and only differs because this option looks to proactively replace the meters before any metering-system failure. A proactive replacement programme enables Cadent to:

- Negotiate appropriate commercial contracts to design and deliver the metering programme in a cost-effective and planned way. To fit in with network outages and to avoid peak-demand periods.
- Manage the supply-demand balance in a more planned way.
- Reduce or mitigate the NTS flow-balancing risk.

The costs have been derived from an engineering study and associated cost modelling exercise undertaken by Prem-Tech Ltd. We have then applied a 2.5% contingency figure on top of this estimate.

This proactive upgrade of the entire metering system was discussed with the UNC Performance Assurance Committee (PAC) (12 Nov 2019). PAC was generally supportive of the approach proposed by Cadent to ensure maintenance and **better accuracy.** Only this whole-sale metering system replacement enables us to consistently achieve this better metering accuracy.

7.3 Option 2: Repair or replace FWACV system-components on failure

This option describes the feasibility of repairing or replacing individual components of the FWACV system as and when they fail. These components could comprise individual meters, flow computers and CVDD equipment. This option would typically be considered the "do-minimum" option i.e. we repair or replace following a failure, but due to the various technical issues identified (discussed below), this do-minimum option is not viable. For this reason, an alternative baseline option was selected.

As already discussed, a high proportion of the critical components within our FWACV systems are ageing and are either obsolete or are becoming obsolete during RIIO-1 or early years of RIIO-2. This affects a significant number of our meters, flow computers and CVDD related equipment.

Consideration has been given over many years to the feasibility of sourcing more strategic spares. However, there are several different meter sizes, makes and models in use across the four networks that stockpiling of spares over the years has not been feasible or cost-effective. Some meters (orifice plate meters) still have a functional spare (calibration 2nd orifice plate), which is used currently when the first plate needs to be removed and calibrated periodically. Once the duty, and any spare plate, fail, a quick repair may not be feasible, due to obsolescence and/or the bespoke nature of the asset.

We have considered the possibility of replacing and repairing any failed components with a like-for-like replacement. It is possible to get bespoke, specialist spares manufactured for the non-obsolete assets, but several important compliance, sourcing and performance considerations result in long lead times to source these spares. The whole process of sourcing spares can, therefore, take more than 6 to 12 months because:

- Specialist suppliers are required to build these bespoke spares or assets; not all suppliers will be willing or able to undertake this service. Even such specialist suppliers would consider this one-off work as a lower priority and charge a high price. There is also very limited choice in suppliers for this specialist work.
- Following manufacture, these bespoke assets or components then need to be independently tested to ensure they comply with the required ISO standards described previously. Recent experience has indicated that the supplied components may fail these quality assurance tests and getting further replacements may add more time to the project.

Additionally,

- In the longer-term, we will still have assets that require bespoke spares, which still poses a significant long-term risk to resilience.
- The metering systems are still reliant on old technology with a higher metering uncertainty of 3%, rather than 1%.

We have also considered a repair which replaces the failed asset with a different make, model or type of asset – one that is not obsolete**.** This was considered in detail for the meters, and several significant technical difficulties were identified:

- Pipework on site would need to be modified to enable a different meter type to be installed (this may be complex - pipework on several offtakes is poorly configured and cramped). There is often insufficient straight-pipework upstream and downstream to achieve appropriate metering certainty and accuracy. Meter body-length is often very different between meter types.
- A different meter would then require the associated flow computer to be replaced, for technical compatibility, which may have an impact on electrical and ICA panels.
- Sites with only a single metering stream may need to be shut-down temporarily to undertake the modifications. This might not be possible, especially for single feed sites, and there would be a need to rebuild the metering system and then connecting back onto the live network.
- There is a lack of space on several sites and it is highly likely that the neighbouring land cannot be purchased, and if it is available for purchase it will be at a high premium.

One of the major disadvantages with merely replacing key components is the lost opportunity to improve the FWACV or metering system as a whole, to modern-day standards with condition-based dynamic monitoring capabilities. The following list sets out the main disadvantages of Option 2:

- **The resilience of the metering systems is not improved** through the creation of standby meter streams (on currently single stream systems or where two streams are available, but both are duty-streams).
- **The metering uncertainty is not improved** from 3% to 1%. We have therefore lost the opportunity to further improve network control and the accuracy of revenue calculations

- **We would not achieve the preferred aim of our Shippers.** Through our engagement programme, our Shippers have expressed a preference for improving accuracy and measurement certainty levels.

We have discounted this reactive component-level replacement option as non-viable.

Options Technical Summary Table

	Baseline	Option 1	Option 2
Description	Reactively replace entire FWACV system: improved metering stream redundancy	Proactively replace entire FWACV system: improved metering stream redundancy	Reactively replace components upon failure
Volumes	18 + No. sites	18 No. sites	N/A: Discounted on technical grounds
Redundancy	FWACV standard solution with duty-standby streams	FWACV standard solution with duty-standby streams	N/A
Design life	10 – 20 yrs. dependent on component	10 – 20 yrs. dependent on component	N/A
Total installed cost (RIIO-2)	**XXXX**	**XXXX**	**XXXX**

Table 7: Options Technical Summary Table

7.5. Options Cost Summary Table

The following section summarises the unit costs per site for each option (in 18/19 price base), but pre-efficiency. We have also explained our view of cost confidence and the levels of efficiency we are applying to this investment case. In Section 7.2 above, the preferred phasing of this workload has been discussed and thereafter the post-efficiency yearly spend profile in the 18/19 price base has been presented.

Costs vary due to whether the work is done proactively versus reactively.

The following table summarises the total installed costs by site, used for each of the above options. [3]

Network	Measuring Stations	Option 1: Total installed cost (pre-efficiency) *Proactive upgrade: solution with improved metering redundancy*	Baseline: Total installed cost (pre-efficiency) *Reactive upgrade: solution with improved metering redundancy*
EoE	MATCHING GREEN OFFTAKE		
EoE	ROYSTON OFFTAKE		
EoE	BACTON OFFTAKE (F3A5B)		
EoE	BRISLEY OFFTAKE		
EoE	GREAT WILBRAHAM OFFTAKE		
EoE	KIRKSTEAD OFFTAKE		
EoE	SUTTON BRIDGE OFFTAKE		
EoE	WALESBY OFFTAKE		
	Total East of England		
Lon	HORNDON OFFTAKE		
Lon	DUNSTALL GREEN INTER LDZ		
	Total North London		
NW	WARBURTON OFFTAKE		
NW	PARTINGTON OFFTAKE		
NW	ECCLESTON OFFTAKE		
	Total North West		
WM	HYDES PASTURES INTER LDZ		
WM	ALREWAS OFFTAKE (A)		
WM	ATHERSTONE INTER LDZ		
WM	RUGBY OFFTAKE		
WM	LEAMINGTON OFFTAKE		
	Total West Midlands		
Total Across All Sites			

Redacted due to commercial sensitivity

Table 8: Options cost summary tables – pre-efficiency [3]

The total installed costs quoted above have been calculated by taking the cost breakdown provided by our engineering consultant and applying a 2.5% contingency as a small programme-level risk and uncertainty allowance (no risk has been built into individual projects).

To retain like-for-like redundancy on the above 18 sites, the proactive upgrade (Option 1) would be circa **XXXX** less. This is 5% additional capex investment to achieve a more resilient FWACV system, which is aligned with the view of the UNC Performance Assurance Committee.

Offtakes & PRS FWACV Systems have various estimates of cost confidence. Some sites have had further design progressed than others. 11 of the 18 proposed sites have had a detailed site survey and cost modelling exercise based on equipment sizing, site specific constraints and flow requirements. Remaining 7 locations have undergone a desktop study. Taking these various project maturity stages into account provides us with a weighted position within the Conceptual Design stage with a range of +/-19%.

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 applied an average efficiency to this investment area of 0.90% over 5 years. Commencing at 0.3% in the first year rising to 1.50% in the fifth year. All costs in this document are post efficiency (apart from those provided in Table 8 above).

[3] To simplify presentation, i.e. to avoid the impact of efficiency phasing, the costs in this table are comparable to each other but will not match the final post investment position. Efficiency for this investment case increases from 0.3% to 1.5% from year 1 to 5 in RIIO-2, and as such the delivery-year will impact on the delivery cost for each site.

8. Business Case Outline and Discussion

This section sets out the results of the CBA. The CBA approach and basis of calculation have been included in Appendix 5.

Due to the restrictions in the CBA data table around CBA option-naming and numbering, we have inserted a table (below) to explain the naming and numbering convention between the options as discussed in this document, versus the options within the CBA data tables.

Options within this document	Options within CBA data tables
Baseline: Reactive replacement of metering systems upon failure	This is the **Baseline** option within the CBA template.
Option 1: Proactive replacement of metering systems at targeted sites	We have run two scenarios, called Option 1 and Option 2 within the CBA template. **CBA Option 1:** The targeted proactive replacement of 18 No. sites. **CBA Option 2:** The proactive replacement of all 52 sites across RIIO-1 & 2.
Option 2: Reactive replacement of metering system components upon failure	This option has been technically discounted; therefore, no CBA has been produced for this option.

Table 9: Options naming and numbering convention between document and CBA data tables

8.1. Key Business Case Drivers Description

A key driver for investment is value for money and ensuring we can deliver a cost-effective, well-planned proactive upgrade to our FWACV system, rather than spending more money delivering emergency works to our measuring stations following a system failure. We have estimated, based on historical projects, that reactive or emergency works could cost 20% more to deliver.

While we have estimated commercial value from meter mismeasurement, this does not drive investment but rather illustrates the importance of the assets in the national energy system

We are also aware that there are other impacts of metering failure that have not been monetised within our CBA calculations. As discussed earlier, the non-monetised impacts of reactive replacing meters following metering failure are:

- Further reactive costs to employ independent experts to investigate and verify the metering failure or error.
- Loss of confidence from shippers due to low certainty, low resilience meters.
- Potential impacts on flow balancing within the NTS due to meter mismeasurement.
- Impact on gas odourisation: increased opex costs to implement temporary mitigations due to failure of the permanent meters, to ensure appropriate levels of stenching agent are added to the gas

8.2. Business Case Summary

We assessed three options for this investment case, these are summarised below:

	Baseline	Option 1	Option 2
Description	Reactively replace entire FWACV system: improved metering stream redundancy	Proactively replace entire FWACV system: improved metering stream redundancy	Reactively replace components upon failure
Volumes	18 + No. sites	18 No. sites	N/A: Discounted on technical grounds
Redundancy	FWACV standard solution with duty-standby streams	FWACV standard solution with duty-standby streams	N/A
Design life	10 – 20 yrs. dependent on component	10 – 20 yrs. dependent on component	N/A
Total installed cost (RIIO-2)			
Ratio NPV to RIIO-2 spend		Redacted due to commercial sensitivity	
Total NPV			
NPV relative to Baseline			
Advantages / Disadvantage	Unable to plan; will be completing the work under-duress. Less efficient Unable to plan site outages effectively	Achieves greater metering accuracy / certainty Improves metering system resilience Efficient method to replace multiple end-of life or obsolete assets in a proactive programme	Technically not viable due to component obsolescence and lack of commercially available spares.

Table 10: Business Case summary

The results of the Metering CBA are shown in more detail in the tables below.

CBA Option No.	Option Name	PV Expenditure & Costs (£m)	PV Revenue (£m)	Total NPV (£m)	NPV (relative to baseline) (£m)	Cost beneficial	Payback Year	Ratio NPV to RIIO-2 spend
Baseline	Reactive replacement							
1 (1.1)	**Proactive Targeted Replacement (18 sites)**			Redacted due to commercial sensitivity				
2 (1.2)	Proactive Complete Replacement (all sites)							

Table 11: Results of CBA for Metering (£m)

The approach to assessing CBA:

- For each option, we estimate the Total NPV. This is the discounted sum of costs over time relative to our do-nothing position (known as the baseline position).
- All costs are discounted in line with Ofgem's recommended approach
- A positive NPV means an option reduces the profile of costs relative to the do nothing (baseline) position and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial option.
- Payback shows the year when the sum of costs associated with an option is lower than the baseline i.e. this is the point at which the option can be considered cost beneficial. This is driven by the profile of the costs and the capitalisation rate.
- The table shows the RIIO-2 proactive expenditure; the ratio of NPV to RIIO-2 spend shows how much NPV per £ spent in RIIO-2 the options generate. A positive figure means the investment is cost beneficial. The higher the figure the most cost beneficial the option is.

The table clearly shows that the Option to undertake targeted proactive replacement is cost beneficial, with an NPV relative to the baseline of **XXXX** and **XXXX** payback.

It is not cost-beneficial to undertake proactive replacement of all meters as shown in CBA Option 2 (1.2), with an NPV relative to the baseline of **XXXX**.

Overall it is clear from the analysis that Option 1, the targeted proactive replacement of meters is cost-beneficial.

This targeted proactive replacement of the entire FWACV programme will provide Cadent with several key additional benefits that cannot be accurately reflected in the above CBA calculations. We have however included this additional justification within this section for completeness. These benefits include:

- The ability to provide appropriate levels of resilience through the provision of meter-stream redundancy (for sites with duty-only meter streams).
- Upgrading the obsolete CVDD, meters and flow-computers at the same time will improve cost efficiency and ensure inter-compatibility of new assets.
- To improve the metering certainty (1% meter uncertainty) and in the process resolve cramped and unsuitable pipework arrangements on site.
- To standardise our asset-components, thereby simplifying and improving maintenance and to provide an opportunity for Cadent to look at a strategic spares programme to further improve resilience.

We are therefore confident that a proactive upgrade of our entire FWACV systems on the 18 highest risk sites, is the optimum option for RIIO-2.

CBA Sensitivity Analysis:

We have tested the sensitivity of the CBA results by removing the benefits of 'avoiding revenue misreading'. This is shown in Option 3 in Table 12 below, which clearly shows that the chosen FWACV upgrade programme remains cost-beneficial even in the absence of these benefits:

CBA Option No.	Option Name	PV Expenditure & Costs (£m)	PV Revenue (£m)	Total NPV (£m)	NPV (relative to baseline) (£m)	Cost beneficial	Payback Year	Ratio NPV to RIIO-2 spend
Baseline	Reactive replacement							
1	Proactive targeted FWACV system replacement on 18 sites							
2	Replacement of FWACV systems on all sites							
3	Option 1 (without misread revenue)							

Redacted due to commercial sensitivity

Table 12: Results of CBA for Metering (£m)

We have also tested the sensitivity of the positive cost-benefit results to lower rates of probability of failure for our highest priority obsolete meters targeted under option 1.

- Testing a 15% failure rate gives a positive NPV relative to the baseline of **XXXX**and
- Testing a 10% failure rate gives a positive NPV relative to the baseline of **XXXX**.

It should also be noted that we have used a short, 15 years, asset life for the CBA calculation. Extending this life increases the NPV of Option 1 relative to the Baseline to **XXXX**.

We have also tested the sensitivity of the positive cost-benefit results to the reactive uplift. Uplifting the reactive costs to only 5% as compared to the evidenced assumption of 20% does not affect the results that the targeted replacement option is cost beneficial. It reduces the NPV relative to the baseline by **XXXX** to **XXXX**.

We can therefore conclude that the positive results of the cost-benefit analysis are robust to rates of failure that are lower than our central estimates.

9.4. Regulatory Treatment

This investment will be tracked through the NARMs methodology, the benefits are recorded in our submitted NARMs tables.

This investment is accounted for in the Business Plan Data Table 3.01 LTS, Storage & Entry, within the PRS Sub-table under Other Tanks.

9. Preferred Option Scope and Project Plan

9.1. Preferred Option

Option 1: Proactively replace the entire FWACV system on 18 sites is our preferred investment option for RIIO-2. The CBA for this option is Option 1 in the CBA template.

Network	21/22	22/23	23/24	24/25	25/26	Total Sites
EoE	Pre-Construction Surveying and Design	Great Wilbraham Matching Green Sutton Bridge	Royston Walesby	Bacton Kirkstead	Brisley	**8**
Lon			Horndon	Dunstall Green Inter-LDZ		**2**
NW		Warburton	Partington	Eccleston		**3**
WM		Alrewas (A) Leamington	Hydes Pastures Inter-LDZ	Atherstone Inter-LDZ	Rugby	**5**
Total Sites Completed	**0**	**6**	**5**	**5**	**2**	**18**

Table 13: Workload for Preferred Option 1

9.2. Asset Spend Profile

The proposed RIIO-2 programme of costs for our preferred **option 1**, is:

Network	2021	2022	2023	2024	2025	Total
EoE						
Lon						
NW						
WM						
Total						

Redacted due to commercial sensitivity

Table 14: Cost profile of Preferred Option 1

9.3. Investment Risk Discussion

There are two key delivery risks for this investment case:

- We intend to create a new, dedicated delivery team within Cadent to effectively manage this programme of work. Any delay in this internal reorganisation may impact on the delivery timescales of this programme.
- This programme involves a large volume of proactive metering-system upgrades. We have not yet secured a delivery partner to work with us on this project.

Reference	Risk Description	Impact	Likelihood	Mitigation /Control
09.10 - 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	Low	Intelligent procurement and market testing. Apprenticeship and Training programmes to fill skills gaps
09.10 - 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
09.10 - 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
09.10 - 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.
09.10 - 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.
09.10 - 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	Med	We have established management teams to address these issues. We have also identified UMs for key areas.

		landowner / asset owners. The potential impact is more engagement and slower delivery		
09.10 - 007	Failure on specific units which affect multiple sites	Impact upon gas flow monitoring and delivery programme and cost	Low	Ongoing survey programme and identifying risks through inspections for proactive interventions

Table 15: Risk Register

Appendix 1. Meter Types

This table summarises the different meter manufacturers and models of equipment installed across the 54 offtake sites.

Meter Type	Number of metering systems in use across all offtake sites.	Obsolete
Orifice Plate (OP) - Daniels with Double Vulcanised Bonded Seals (DVS)	7	High likelihood in the near future
Orifice Plate (Non-DVS)	33	No
Turbine (Short Bodied < 8" Q75)	5	Yes
Turbine (Other)	6	No
1st Gen Ultrasonic	2	Yes
2nd Gen Ultrasonic	1	No
Total	**54**	

Table 16: Meter manufacturers and models

Appendix 2. The Gas Regulations 1996 - Regulation 6 and 7

The Gas (Calculation of Thermal Energy) Regulations 1996 – Regulation 6 (Regarding CVDD)

Determinations of calorific values

6. A public gas transporter shall—

(a) make determinations of calorific values of the gas conveyed by him to premises, or to pipe-line systems operated by other public gas transporters, on the basis of samples of gas taken at such places or premises, at such times and in such manner as the Director may direct;

(b) make such determinations at such places or premises, at such times and in such manner as the Director may direct;

(c) provide and maintain such premises, apparatus and equipment for the purpose of making such determinations as the Director may direct;

(d) make available for inspection free of charge during normal office hours by any person the results of such determinations made by the transporter during the preceding twelve months at—

(i) an office reasonably accessible to the public; and

(ii) the place or premises at which any such determinations were made;

(e) carry out tests of apparatus and equipment provided and maintained by virtue of paragraph (c) above for conformity with the requirements of directions given under that paragraph at intervals not exceeding 35 days;

(f) notify the results of such tests to the Director within seven days of the end of the calendar month in which the tests were completed; and

(g) make available for inspection free of charge during normal office hours by any person the results of such tests carried out within the preceding 12 months at—

(i) an office reasonably accessible to the public; and

(ii) the place or premises at which any such tests were carried out.

The Gas (Calculation of Thermal Energy) Regulations 1996 – Regulation 7 (Regarding Calculation of Thermal Energy Using Metered Gas Volume)

Calculation of thermal energy

7.—(1) Where a public gas transporter makes a declaration of calorific value or adopts a declaration of calorific value made by another public gas transporter in accordance with regulation 8(1) below in respect of any area within an authorised area of the transporter, the number of therms or kilowatt hours conveyed by the transporter to any take off point situated in the area to which the declaration relates during the relevant period shall be calculated in accordance with the following formulae—

$$\text{number of therms so conveyed} = \frac{A \times B}{105.5}$$

$$\text{number of kilowatt hours so conveyed} = \frac{A \times B}{3.6}$$

Where:

A is the number of cubic metres in the converted volume of gas conveyed to the take off point during the period and B is the declared calorific value of the gas.

UNIFORM NETWORK CODE – OFFTAKE ARRANGEMENTS DOCUMENT - SECTION D - MEASUREMENTS

A 'CV-Directed' Offtake is an NTS/LDZ Offtake or LDZ/LDZ Offtake which is a place in relation to which the Authority has given directions pursuant to regulations 6(a) and (b) of the Gas (Calculation of Thermal Energy) Regulations; and

The quantity of gas flowing on (or in any period within) a Day at an Offtake shall be determined: (a) where the Offtake is a CV-Directed Offtake, on the basis of the measurements at that Offtake under this Section D, for the purposes of determining the daily CV for the LDZ served by that Offtake as described in Section F.

Appendix 3. UNC Offtake Arrangement Document – Annex D-1

Uniform Network Code - Offtake Arrangements Document

Annex D-1

Measured Data and Permitted Ranges
(Paragraphs 1.3.2, 1.4 and 2.1.1(a))

Part 1 – NTS/LDZ Offtakes

Property	Unit	Specified Range	Permitted Uncertainty Level
Instantaneous Volume Flow Rate (Note 1)	MCM/day	Per relevant Supplemental Agreement	± 1.0%
CV (for CV-Directed NTS/LDZ Offtakes)	MJ/m^3	35 – 44	± 0.1 MJ/m^3
CV (other NTS/LDZ Offtakes)	MJ/m^3	35 – 44	± 0.3 MJ/m^3
Instantaneous Energy Flow Rate (Note 1)	TJ/day	Per relevant Supplemental Agreement	± 1.1%
Pressure	barg	0 – 85	± 0.5 barg
Temperature	°C	0 – 40	± 1.0 °C
Carbon Dioxide (where applicable – Note 2)	Mole %	0 – 5	± 0.01 mole %.
Nitrogen (where applicable – Note 2)	Mole %	0 – 10	± 0.01 mole %.
Relative Density (where applicable – Note 2)		0.5 – 0.8	± 0.001
Wobbe Number (where applicable – Note 2)	MJ/m^3	45 – 55	± 0.1 MJ/m^3

Note 1: Measurement Equipment must also be capable of integrating Instantaneous Volume Flow Rate and Instantaneous Energy Flow Rate to give volume and energy flows over any period.

Note 2: These properties are applicable where they are required in relation to a CV-Directed Offtake pursuant to the arrangements made (in relation to that Offtake) for the purposes of regulation 4A of the Gas (Calculation of Thermal Energy) Regulations 1996, as amended.

Appendix 4. Site by Site Risk Assessment

The following table summarises all offtakes sites by region, assigned risk category and gas flow-rate, which has been used to calculate the value of the commercial loss from loss of the metering-system.

Network Maintainer	Name	Risk Category	(A) Average Flow Rates per Measuring Station (scm/hour) Past 5-year average of daily averages	(B) Average Flow (scm/hr) Multiple Feed Sites = 20% Flow Rates (A*0.2)	(C) Metering Volume Mismeasured (scm/hr) - 5% of Average Flow (B*0.05)	(D) Probability of Failure (e.g. 1 in 10 years = 0.1)	(E) Duration of Metering Accuracy Impacted for (years)	Ranking of meter-accuracy risk (probability x duration x mis-measurement) (C*D*E)
NW	WARBURTON OFFTAKE	1	200,077	40,015	2001	0.2	0.25	98.67
EA	GREAT WILBRAHAM OFFTAKE	1	33,814	33,814	1691	0.2	0.25	83.38
EA	MATCHING GREEN OFFTAKE	1	88,505	17,701	885	0.2	0.25	43.65
WM	ALREWAS OFFTAKE (A)	1	67,295	13,459	673	0.2	0.25	33.19
WM	RUGBY OFFTAKE	3	128,208	25,642	1282	0.2	0.08	21.08
Lon	HORNDON OFFTAKE	1	37,171	7,434	372	0.2	0.25	18.33
NW	PARTINGTON OFFTAKE (PART4B)	1	36,064	7,213	361	0.2	0.25	17.78
NW	ECCLESTON OFFTAKE	1	20,949	4,190	209	0.2	0.25	10.33
NW	HOLMES CHAPEL OFFTAKE	4	31,582	31,582	1579	0.05	0.08	6.49
EA	WEST WINCH OFFTAKE	4	17,615	17,615	881	0.05	0.08	3.62
EA	ROYSTON OFFTAKE	2	3,855	3,855	193	0.2	0.08	3.17
EA	BACTON OFFTAKE (F3A5B)	2	3,437	3,437	172	0.2	0.08	2.82
WM	AUDLEY OFFTAKE (CREWE NW)	4	12,525	12,525	626	0.05	0.08	2.57
WM	LEAMINGTON OFFTAKE	1	1,922	384	19	0.2	0.25	0.95
EM	SUTTON BRIDGE OFFTAKE	1	1,590	318	16	0.2	0.25	0.78
EA	BRISLEY OFFTAKE	2	3,823	765	38	0.2	0.08	0.63
EM	DROINTON OFFTAKE	5	146,441	29,288	1464	0.005	0.08	0.60

EM	WALESBY OFFTAKE	1	760	152	8	0.2	0.25	0.37
EM	THORNTON CURTIS (A) OFFTAKE	6	167,757	33,551	1678	0.005	0.04	0.34
Lon	DUNSTALL GREEN INTER LDZ	2	1,851	370	19	0.2	0.08	0.30
WM	ATHERSTONE INTER LDZ	2	1,712	342	17	0.2	0.08	0.28
WM	HYDES PASTURES INTER LDZ	3	1,490	298	15	0.2	0.08	0.24
WM	ASPLEY OFFTAKE	6	111,409	22,282	1114	0.005	0.04	0.23
NW	SAMLESBURY OFFTAKE	6	90,723	18,145	907	0.005	0.04	0.19
EM	TUR LANGTON OFFTAKE	6	87,420	17,484	874	0.005	0.04	0.18
WM	AUSTREY OFFTAKE	6	81,484	16,297	815	0.005	0.04	0.17
WM	ALREWAS OFFTAKE (C) (EM)	6	79,515	15,903	795	0.005	0.04	0.16
Lon	PETERS GREEN 2 OFFTAKE (SM)	7	232,676	46,535	2327	0.005	0.01	0.16
EM	KIRKSTEAD OFFTAKE	2	905	181	9	0.2	0.08	0.15
NW	BLACKROD OFFTAKE	7	211,192	42,238	2112	0.005	0.01	0.14
Lon	PETERS GREEN 1 OFFTAKE	7	176,763	35,353	1768	0.005	0.01	0.12
EA	YELVERTON OFFTAKE	6	57,251	11,450	573	0.005	0.04	0.12
EA	WHITWELL OFFTAKE	7	160,927	32,185	1609	0.005	0.01	0.11
EA	ROUDHAM HEATH OFFTAKE	6	44,722	8,944	447	0.005	0.04	0.09
NW	LUPTON OFFTAKE (A)	6	44,459	8,892	445	0.005	0.04	0.09
NW	MICKLE TRAFFORD OFFTAKE (B)	6	44,228	8,846	442	0.005	0.04	0.09
EM	BLYBOROUGH OFFTAKE	6	44,145	8,829	441	0.005	0.04	0.09
WM	LOWER QUINTON OFFTAKE	5	14,615	2,923	146	0.005	0.08	0.06
Lon	LUXBOROUGH LANE OFFTAKE	7	81,947	16,389	819	0.005	0.01	0.06
EM	BLABY OFFTAKE	6	22,993	4,599	230	0.005	0.04	0.05

WM	**ROSS OFFTAKE**	**6**	**20,352**	**4,070**	**204**	**0.005**	**0.04**	**0.04**
EM	GOSBERTON OFFTAKE	6	19,229	3,846	192	0.005	0.04	0.04
WM	MILWICH OFFTAKE	6	19,186	3,837	192	0.005	0.04	0.04
Lon	BRACKNELL INTER LDZ	6	9,026	1,805	90	0.005	0.04	0.02
EA	PETERBOROUGH EYE OFFTAKE	7	23,466	4,693	235	0.005	0.01	0.02
EM	MARKET HARBOROUGH OFFTAKE	6	5,087	1,017	51	0.005	0.04	0.01
NW	WESTON POINT OFFTAKE	6	4,383	877	44	0.005	0.04	0.01
WM	AUDLEY OFFTAKE (DUNKIRK WM)	7	12,521	2,504	125	0.005	0.01	0.01
EM	CALDECOTT OFFTAKE	7	11,696	2,339	117	0.005	0.01	0.01
NW	MALPAS OFFTAKE	7	878	878	44	0.005	0.01	0.00
Lon	WINKFIELD OFFTAKE	6	289	58	3	0.005	0.04	0.00
WM	SHUSTOKE OFFTAKE	6	228	46	2	0.005	0.04	0.00
EM	SILK WILLOUGHBY OFFTAKE	Out of Scope	Already upgraded to USMs in RIIO-1					
WM	STRATFORD OFFTAKE	Out of Scope	Will be upgraded to USMs by the end of RIIO-1					

Table 17: Site by Site Risk Assessment

Appendix 5. Cost-Benefit Analysis: Basis and approach

A full CBA has been undertaken to ensure value for money. Our approach is compliant with HM Treasury's Green Book and the relevant Ofgem guidance. We have followed the Ofgem approach, spreadsheet and societal-benefit values and calculations.

The table below sets out the options that have been assessed using CBA, and what costs and benefits have been used in the CBA calculations. We have also used the NOMs model to validate the results of our targeted proactive investment options (Option 1 below).

Option in document	Option in CBA template	Costs used	Benefits used
Baseline: Reactively replace FWAC system on failure	Baseline	Costs of reacting to expected failures	None
Option 1: Proactively replace FWACV system	**CBA Scenario 1 (1.1):** Proactive Replacement of targeted sites This is the first CBA scenario testing the number of sites that should be proactively invested in.	RIIO-2 proactive intervention costs as submitted Costs of reacting to failures across the remaining 34 in-scope (non-targeted) sites.	Avoided misread revenue from targeted sites.
N/A	**CBA Scenario 2 (1.2)**: Proactive replacement of all sites This is the second CBA scenario testing the number of sites that should be proactively invested in.	RIIO-2 proactive intervention costs as submitted Plus Costs of replacing meters scheduled for replacement in RIIO-3	Avoided misread revenue from all sites.
Option 2: repair or replace FWACV components on failure	N/A Option discounted prior to CBA as set out above.		

Table 18: Basis of Calculations in CBA Template

The Baseline (reactively replace meter systems upon failure) sets out the costs of a reactive strategy of replacing upon failure. The alternative options are then assessed in relation to this reactive baseline.

To test the sensitivity of the results to the cost of reactive repair we have also modelled the options against an alternative baseline scenario with lower reactive costs.

All costs and benefits are assumed to last 15 years in line with GD NOMS reporting which states that across the industry after 15 years meters start to show accelerated failure deterioration and at 15 years meters are effectively at condition grade 5. This means that to be cost-beneficial any intervention must payback within 15 years. This is a short period given that our existing meter stock has lasted over 40 years. If a longer period was used NPV would increase as costs would be depreciated over a longer period and replacement costs would be deferred. As such 15 years is a very conservative position.

Reactive Cost Calculations:

The detailed calculations of the costs included in the template are set out below for the various CBA scenarios (options).

The annual cost of reacting to expected failures (reactive cost) in RIIO-2 is the sum of the annual probability of failure of each site multiplied by the cost of replacement on failure, for all 52 in-scope sites. The probability of failure for our 18 highest risk sites is the most material element of this calculation.

Our assumption (as set out previously in section 7.1) is that the cost of reactive replacement is 120% of the cost of proactively replacing FWACV system. For the purposes of cost-benefit modelling, we have assumed the cost of reactive replacement is 120% multiplied by the average pre-efficiency cost of **XXXX** per site. This gives us a reactive replacement average cost of **XXXX** per site.

The average annual reactive cost associated with the 18 highest priority sites which have been targeted for RIIO-2 is **XXXX**, as set out in Table 2.

To test the sensitivity of the results to the reactive costs, we have also undertaken the analysis for a 5% uplift on the pro active costs rather than 20%. This more conservative option is a useful check.

Network	Site	Probability of failure (A)	Cost of Proactive Replacement (B) (Pre-efficiency)	Expected Annual Reactive Cost (20% uplift) (i.e. A * B * 1.2)	Expected Annual Reactive Cost (5% uplift) (i.e. A * B * 1.05)
EoE	MATCHING GREEN OFFTAKE	0.2			
EoE	ROYSTON OFFTAKE	0.2			
EoE	BACTON OFFTAKE	0.2			
EoE	BRISLEY OFFTAKE	0.2			
EoE	GREAT WILBRAHAM OFFTAKE	0.2			
EoE	KIRKSTEAD OFFTAKE	0.2			
EoE	SUTTON BRIDGE OFFTAKE	0.2			
EoE	WALESBY OFFTAKE	0.2			
	Total East of England			Redacted due to commercial sensitivity	
Lon	HORNDON OFFTAKE	0.2			
Lon	DUNSTALL GREEN INTER LDZ	0.2			
	Total North London				
NW	WARBURTON OFFTAKE	0.2			
NW	PARTINGTON OFFTAKE	0.2			
NW	ECCLESTON OFFTAKE	0.2			
	Total North West				
WM	HYDES PASTURES INTER LDZ	0.2			
WM	ALREWAS OFFTAKE (A)	0.2			
WM	ATHERSTONE INTER LDZ	0.2			
WM	RUGBY OFFTAKE	0.2			
WM	LEAMINGTON OFFTAKE	0.2			
	Total West Midlands				
Total Across All Sites					
Per Site Average (Total Across All Sites / 18)					

Table 19: Reactive Cost of Highest Priority 18 Sites (RIIO-2 Sites)

The annual reactive costs of the 34 remaining in-scope sites are significantly lower as the probability of failure of these sites is substantially lower than the 18 targeted for RIIO-2. Using the same approach as for the first 18 sites, the results set out in the table below are generated:

Intervention Scheduled	Number of Sites in scope	Reactive Cost of failure (120%) (£m pa)	Reactive Cost of failure (105%) (£m pa)
RIIO-2 (as per Table 6)	18	Redacted due to commercial sensitivity	
2027 onwards	34		
Total	**52**		

Table 20: Total Reactive Cost (£m)

After RIIO-2 the annual costs of reacting to expected failures is lower. As the first 18 sites have a probability of failure of **XXXX** per annum, these will have been replaced over RIIO-2. Therefore, the annual reactive costs from 2027 relates to the remaining 34 sites only. This is calculated in the same way as set out in Table 6 for the 18 prioritised sites and gives an annual reactive cost of **XXXX**. We have currently undertaken the analysis up to 2040 in line with an average FWACV system life of 15 years as discussed above.

For the baseline CBA scenario, we are reactively replacing all meters, CVDDs and FWACV panel (the FWACV system) upon failure. For the targeted proactive replacement option 1 (1.1, CBA option 1), we have a reactive cost of **XXXX** throughout. For the proactive replacement of all sites, no reactive costs are included.

The following table summarises the reactive costs used in the CBA calculation for all CBA scenarios.

Year	Reactive replacement Option 2 CBA Baseline	Targeted Proactive replacement Option 1 CBA Scenario 1	Proactive replacement of all sites CBA Scenario 2
2022 – 2026		Redacted due to commercial sensitivity	
2027 - 2040			

Table 21: Reactive Cost included in the CBA calculations for each option(£m)

Benefit Calculations:

When FWACV system fails there is a consequence in terms of accurate flow recording and charging leading to loss of accuracy. Proactive replacement avoids this consequence of failure. This is a monetizable benefit which we have incorporated into the analysis.

We have taken a conservative estimate of the level of flow that may be subject to mis-recording and hence losses in accuracy.

For sites that have no network resilience (i.e. single feed sites) we have assumed that the full flow through the site will be subject to meter mis-recording.

For sites, where there is network resilience, i.e. the network can be reconfigured to mitigate the loss of the site, we have assumed that 20% of average flow would be exposed to mis-recording.

We have assumed that on most sites a temporary strap-on meter would be installed at a lower level of accuracy, resulting in a miss-recording of flows by plus or minus 5%.

For each FWACV system, the potential lost commercial value is therefore:

Flow at risk * 5% mis-recording * duration of impact in days * price

Price is **XXXX** per m^3 in line with values across the business plan.

Using an extract from Table 17, earlier in the report:

Network Maintainer	Name	Risk Category	(A) Average Flow Rates per Measuring Station (scm/hour) Past 5-year average of daily averages	(B) Average Flow (scm/hr) Multiple Feed Sites = 20% Flow Rates (A*0.2)	(C) Metering Volume Mismeasured (scm/hr) - 5% of Average Flow (B*0.05)	(D) Probability of Failure (e.g. 1 in 10 years = 0.1)	(E) Duration of Metering Accuracy Impacted for (years)	Ranking of meter-accuracy risk (probability x duration x mis-measurement) (C*D*E)
NW	WARBURTON OFFTAKE	1	200,077	40,015	2001	0.2	0.25	98.67
EA	GREAT WILBRAHAM	1	33,814	33,814	1691	0.2	0.25	83.38
EA	MATCHING GREEN OFFTAKE	1	88,505	17,701	885	0.2	0.25	43.65

We have calculated the commercial impact of meter mis-recording for Matching Green, as follows:

The flow of gas mis-measured (mcm/hr)	Probability of metering failure	Duration of 'failure' in hours	Price of gas (£ per mcm)	Total commercial impact (Flow Mis-measured x Probability x Duration x Price)
0.000885054	0.2	24* 90	**XXXX**	**XXXX**

Table 22: Commercial loss calculation for Matching Green meters

Once all the targeted meters have been replaced in RIIO-2, the following table shows the annual avoided potential cost misallocation due to meter-mismeasurement.

Region	Targeted proactive replacement CBA Option 1 (£m) 1.1	Complete proactive replacement CBA Option 2 (£m) – 1.2
East of England		
North London		
North West	Redacted due to commercial sensitivity	
West Midlands		
Total		

Table 23: Annual Avoided Misread Revenue after completion of RIIO-2 Options (£m)

CBA Results

The results of the Metering CBA are shown in the tables below.

CBA Option No.	Option Name	PV Expenditure & Costs (£m)	PV Revenue (£m)	Total NPV (£m)	NPV (relative to baseline) (£m)	Cost beneficial	Payback Year	Ratio NPV to RIIO-2 spend
Baseline	Reactive replacement							
1	Proactive Targeted Replacement				Redacted due to commercial sensitivity			
2	Complete Replacement							

Table 24: Results of CBA for Metering (£m)

The approach to assessing CBA:

- For each option, we estimate the Total NPV. This is the discounted sum of costs over time relative to our do-nothing position (known as the baseline position).
- All costs are discounted in line with Ofgem's recommended approach.
- A positive NPV means an option reduces the profile of costs relative to the do nothing (baseline) position and is therefore cost beneficial. The option with the highest positive NPV is the most cost beneficial option.
- Payback shows the year when the sum of costs associated with an option is lower than the baseline i.e. this is the point at which the option can be considered cost beneficial. This is driven by the profile of the costs and the capitalisation rate.
- The table shows the RIIO-2 proactive expenditure; the ratio of NPV to RIIO-2 spend shows how much NPV per £ spent in RIIO-2 the options generate. A positive figure means the investment is cost beneficial. The higher the figure the most cost beneficial the option is.

The table clearly shows that the Option to undertake targeted proactive replacement is cost beneficial, with an NPV relative to the baseline of **XXXX** and **XXXX** payback.

We have completed sensitivity testing of these results:

- Uplifting the reactive costs to only 5% as compared to the evidenced assumption of 20% does not affect the results that the targeted replacement option is cost beneficial. It reduces the NPV relative to the baseline by **XXXX** to **XXXX**.
- Removing the avoided misread revenue figure reduced the NPV from **XXXX** to **XXXX**. That is without this benefit included the programme is still cost beneficial.

It is not cost-beneficial to undertake proactive replacement of all meters as shown in CBA Option 2, with an NPV relative to the baseline of **XXXX**.

We have also used the NOMs modelling to undertake illustrative CBA for this investment case.

We have undertaken 3 illustrative scenarios using NOMs modelling:

- CBA Scenario 3 – Engineering Volume in NOMs;
- CBA Scenario 4 - Maintain Stable Risk in NOMS; and
- CBA Scenario 5 – Maximise whole life benefits in NOMs

These have not been included in our CBA data tables because the NOMs baseline scenario differs from the manual CBA baseline option. That is, we cannot submit a single CBA with two different baselines.

Illustrative CBA Scenario 3 involves the same volumes and work-activities as our Option 1, but the CBA has been generated by the NOMs model. The illustrative results give a net negative NPV for this option of **XXXX**. However, the NOMS methodology does not adequately reflect the obsolescence issues described in this investment case – specifically with regards to increased likelihood of (long term) meter outage due to inability to repair. As such the benefits reported through the NARMs methodology will also be understated.

The model allows investment based on short term repair activities which may not be feasible due to the obsolescence of a proportion of our meter stock. The lack of resilience in our system, also means that the standard NOMs modelling underestimates the consequences of any failures.