DNV·GL

FUTURE BILLING METHODOLOGY

Stage Gate Report

Cadent

Report No.: PP114D803D-5, Rev. 1
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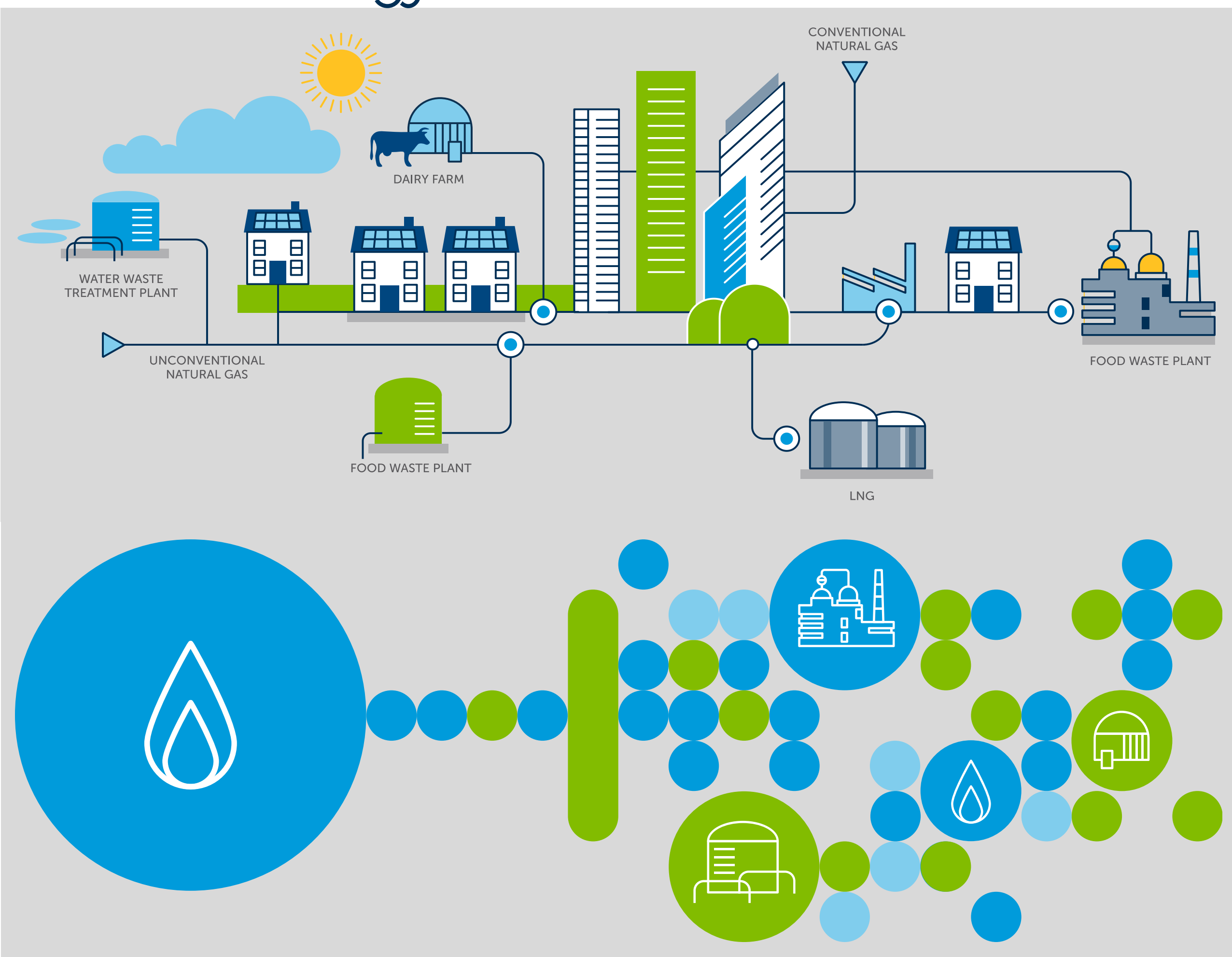
Future Billing Methodology



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Objective: Deliver evidence to Cadent to comply with the requirements of the Ofgem Project Direction for the Future Billing Methodology NIC project.

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1 EXECUTIVE SUMMARY

Ofgem awarded the Future Billing Methodology (FBM) NIC project to Cadent (formerly National Grid Gas Distribution Ltd) on 30th November 2016. Ofgem introduced a stage gate under Project Direction which divided the project into phase one and phase two. This report summarises the output of phase one of the project in line with the requirements of the Ofgem Successful Delivery Reward Criteria (SDRC) 9.1(a). The document was jointly prepared by Cadent and DNV GL and it is divided into six parts:

- Part one provides the project overview and summarises the Ofgem Project Direction
- Part two focusses on industry engagement
- Part three covers the initial cost-benefit analysis for the three FBM options
- Part four reports on the initial design and modelling work in preparation for the field trials.
- Part five outlines Cadent's assessment of the way forward for the FBM project
- Part six comprises references and appendices containing project documents and summaries of data developed by the project team.

The Ofgem Direction states that, at the end of phase one, Cadent shall prepare a report setting out the following from its industry engagement activities:

a) Industry's current views on the desire for change to the current approach.

b) Industry's current views on:

    i. What level of modelling validation is seen to be required; and

    ii. What regulatory (or other) changes are required to support the continuation of the Project beyond Work Pack 1.

c) Initial Cost Benefit Analysis of the three scenarios (noting that this will be finalised under Work Pack 4) to demonstrate that, following industry engagement, there remains a strong case to proceed with the Project.

d) Based on a, b, and c, Cadent's assessment of the best way to proceed with this Project.

A summary of how the project has delivered each of requirements (a) to (d) is given below.

Ofgem also brought forward £250,000 to support activities associated with preparation for phase 2. The project team has identified the measurement sites for the field trials around the biomethane inputs at Chittering and Hibaldstow. Site surveys have been carried out and detailed generic design packs have been prepared in accordance with Cadent's policies and specifications. This should enable the project to proceed smoothly and efficiently into phase 2 without undue delay and to adhere to the original three-year time-line set out in the NIC submission document.

a) <u>Industry's current views on the desire for change to the current approach</u>

Most stakeholders agreed that the Flow Weighted Average Calorific Value (FWACV) billing framework does present a barrier to the adoption of low-carbon gases to decarbonise heat. There was concern expressed over the impact to shippers, suppliers and gas distribution networks due to increased data management and implementation of changes to the billing system. In response, Cadent has been working with Xoserve to start identifying changes to the gas transporter billing system. If the Project proceeds beyond the stage gate, the results will be used in further engagement with shippers and suppliers to allow them to begin assessing the scale of related changes to their billing systems and interaction with customers.

b) <u>Industry's current views on:</u>

i. <u>The level of modelling validation is seen to be required</u>

Stakeholders agreed that the proposed measurement and validation field trials could provide an understanding of the zones of influence of LDZ embedded gas entry points. This will enable customers to be assigned to the correct input point and to be billed more accurately for the energy content of the gas that they receive. Many additional factors were suggested by stakeholders for inclusion in the Project including LDZ operation and smart meter configurations. Whilst many of the suggestions are outside the scope of this project, they have been noted and the key outcomes will provide more information.

A large proportion of stakeholder responses have referred to the need for a full end-to-end impact assessment for FBM implementation. As FBM is an innovation project, it is not possible to undertake a full impact assessment without first undertaking the learning and assessing the outcomes. As part of Work Pack 4, the key learning points will be disseminated to the industry in further stakeholder engagement.

A draft CBA has been prepared for phase 1 (see Part Three of this document). As part of the second phase, the CBA will be updated based on the outcomes of the field trials.

ii. <u>The regulatory (or other) changes are required to support the continuation of the Project beyond Work Pack 1</u>

FBM was designed to minimise changes to legislation, but as the project develops, it has been recognised that some changes to the G(CoTE) regulations may be required to support the Composite or Ideal option to allow the use of within-network CV measurement to support billing. Stakeholders have identified that industry codes (such as *Uniform Network Code* and *Offtake Arrangements Documents*) would need to be updated to reflect the changes in the billing framework. Whilst a detailed review of regulations and commercial codes is outside the scope of innovation funding, and hence outside the FBM project, the outcomes of the project will inform, at high-level, where changes to industry codes are required.

It was noted that the *Gas Safety (Management) Regulations*, GS(M)R, are currently being reviewed to increase the upper Wobbe Index limit (and hence the associated CV). This would reduce the current practice of ballasting LNG with nitrogen and allow for the importation of a wider range of LNG supplies. As the volumes of LNG are large, the target FWACV in the affected LDZs would increase; low-carbon gases would then require even more enrichment with fossil-based propane. Cadent believes that the proposed changes to GS(M)R enhances the mandate to explore different methodologies for billing.

In the same vein, it is recognised that GS(M)R and FWACV would need to be modified to allow the adoption of hydrogen-blend gases into the network.

c) <u>Initial Cost Benefit Analysis of the three scenarios (noting that this will be finalised under Work Pack 4) to demonstrate that, following industry engagement, there remains a strong case to proceed with the Project.</u>

The initial cost benefit analysis (CBA) seeks to compare the cost and benefits in GB of implementing any of the three FBM options against a status quo scenario, a counterfactual in which the FWACV billing framework is retained. Under the status quo, gas entering the network will continue to be processed to prevent the FWACV cap from being invoked. Low carbon and low calorific value gases will require the addition of fossil-based propane.

Cadent has undertaken a high-level analysis of the gas supply chain and costs and benefits have been identified and assessed in comparing the status quo with the FBM options. The initial CBA has built upon the original NIC Project Submission to:

- Take account of potential implementation costs for each of the three FBM options; *Pragmatic, Composite* and *Ideal*;
- Take fuller account of the cost of propanation of low CV gases such as biomethane;
- Monetise the carbon saving from the removal of propanation under FBM, and
- Monetise the carbon saving achievable from the expanded deployment of renewable and low carbon gases that we believe to be achievable by 2050 under FBM.

The Net Present Values (NPV) of each option have been calculated for selected National Grid 2017 *Future Energy Scenarios* (FES). Table 1-1 shows the results for the *Two Degrees* scenario; this is the most relevant as it best fits with the pathway of decarbonisation which is central to the aims of the FBM project. The results are also NPV positive and robust when calculated against the other three 2017 *FES, Steady State, Slow Progression and Consumer Power.*

Table 1-1 Summary of the Initial Cost Benefit Analysis for the 2017 Future Energy Scenario *Two Degrees*

FES:	**2017 Two Degrees**	**FBM:**	**PRAGMATIC**			**COMPOSITE**			**IDEAL**		
Cumulative NPV to end of year		Units	2030	2040	2050	2030	2040	2050	2030	2040	2050
NPV costs	Project	£m	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Implementation	£m	35.1	36.0	36.7	298.1	313.0	324.2	623.0	686.0	733.3
	Costs Total	£m	40.6	41.5	42.2	303.5	318.5	329.7	628.5	691.5	738.8
NPV benefits	Removal of propanation requirement	£m	271.9	941.3	1,712.3	241.8	911.2	1,682.2	170.6	840.0	1,611.0
	Carbon – propane removal	£m	54.2	330.7	837.1	50.6	327.2	833.6	39.6	316.1	822.5
	Carbon - FBM- Facilitated growth of renewable gas	£m	362.4	2,725.7	7,910.2	290.7	2,552.1	7,699.0	158.1	2,190.3	7,252.7
	Benefits Total	£m	688.5	3,997.7	10,459.6	583.2	3,790.5	10,214.9	368.3	3,346.4	9,686.2
Net NPV		£m	647.9	3,956.2	10,417.5	279.6	3,472.1	9,885.2	-260.1	2,655.0	8,947.5

d) Based on a, b, and c, Cadent's assessment of the best way to proceed with this Project

In Cadent's view, GB's gas distribution networks can and should play a vital part in the decarbonisation of heat towards 2050 and beyond. They are an existing high-value asset that already has the capability to transport all GS(M)R compliant gases and to respond to the significant diurnal and inter-seasonal swings in heat demand. We believe that the present LDZ FWACV regime presents a significant barrier to decarbonisation of GB's gas distribution networks. There is an implicit requirement for a standardised energy content of gas across each LDZ to avoid CV capping and associated distortion in the allocation of energy costs across the gas chain and between gas customers.

Our consultation with the gas industry under the Future Billing Methodology Project has demonstrated broad support for our views on the LDZ FWACV framework. Those respondents who disagreed with our views on LDZ FWACV have shown support for the proposed field trials to explore the possibilities for an alternative approach. We see this as a clear stakeholder mandate for proceeding with the FBM Project field trials, and to develop the proposed options for creating CV zones for a more direct attribution of gas energy in billing, which will enable the decarbonisation of GB's gas distribution networks.

Regarding potential customer impacts, we also note views recently expressed by Ofgem that the impact on energy consumers will be a critical factor in the decarbonisation of heat. This is where a potential FBM solution has great strength, in that the bulk of customers could continue to use their existing gas heating and cooking systems, costing GB energy consumers considerably less than a non-gas based approach to decarbonisation.

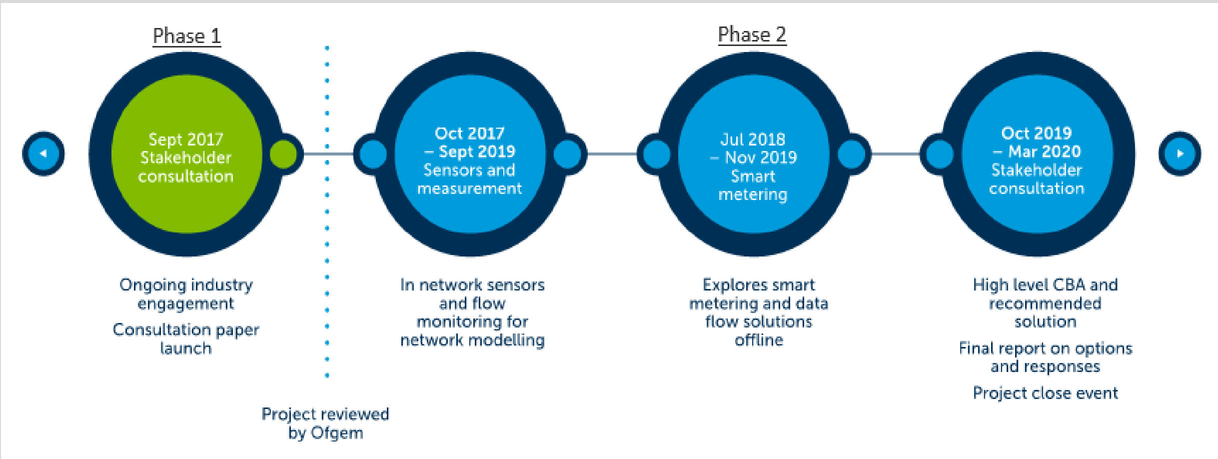
Recent energy industry reports from KPMG /8/, Policy Exchange /11/ and Imperial College London /12/ indicate that the electrification of heat could cost the UK up to £300bn in broad terms. Based on the initial indications from our CBA at this stage, we believe that the future implementation of a zonal CV billing framework could help facilitate the decarbonisation of a significant proportion of the GB heat load by 2050, because it is a key enabler for a range of gas-based solutions that would maximise the use of renewable gases and support the deployment of hydrogen. We believe this could save the UK well over £100bn in investment in electrification. We also see FBM as having a key role in underpinning future security of supply in an ever more diverse gas market.

In summary, based on:

- The positive feedback to the FBM project consultation;
- The strongly positive NPV from the initial CBA, and
- The indication that a gas-centred solution to decarbonising heat, facilitated by FBM, could cost GB energy consumers considerably less than a non-gas-based approach

Cadent's assessment is that the FBM project should progress through the field trials to its conclusion. This will deliver the learning required to make a fuller cost-benefit assessment of billing consumers using an FBM approach and equip the industry with an economically favourable option to decarbonise heat in a way that balances effectiveness with affordability for customers and continued security of supply.

Part One – FBM Project and Stage Gate Overview



2 INTRODUCTION

2.1 Purpose of this Document

Ofgem awarded the Future Billing Methodology (FBM) NIC project to Cadent (formerly National Grid Gas Distribution Ltd) on 30 November 2016. Ofgem introduced a stage gate under Project Direction which divided the project into phase one and phase two (see Section 3.2). For the project to progress past the stage gate and for phase two to commence Ofgem requires evidence of:

- The terms of reference for the industry engagement
- The numbers and types of participants in the industry engagement
- A compilation of the output from workshops, questionnaires and meetings held during the industry engagement (phase one)
- Initial cost benefit analysis
- Requirement for the validation of the network modelling

This document summarises the output of phase one of the FBM project and reports in line with the requirements of the Ofgem Successful Delivery Reward Criteria (SDRC) 9.1(a). The document is divided into six parts as follows:

- Part one provides the project rationale and overview, the purpose of the SDRC report and summarises the Ofgem Direction for the project
- Part two focusses on the industry engagement including the terms of reference for the consultation, the engagement process that was undertaken and the responses received from the consultation process
- Part three covers the draft cost-benefit analysis for the possible implementation of the three scenarios to be studied by the FBM project
- Part four reports on the initial design and modelling work that has been undertaken in preparation for the field trials.
- Part five outlines Cadent's view of the way forward for the FBM project
- Part six contains the references and appendices of supporting data and documents created as part of phase one of the project

Should Ofgem agree that phase one of the project has been delivered successfully, phase two will begin in September 2017. There is an option for Cadent or Ofgem to request a delay of up to six months to gather further evidence for phase one.

2.2 Project Rationale

2.2.1 Decarbonisation of Heat

The GB gas distribution system is a world class asset for transporting gas from the point of entry to the point of use. The FBM project is a key enabler for a sustainable cost-efficient, low-carbon means of fuelling domestic and commercial space and water heating.

Over 80% of the heat load in GB is currently delivered by gas and the variation in demand is both seasonal and diurnal (see Figure 2-1). If the heat load were electrified, the current electricity infrastructure would need significant investment in new low-carbon generation, reinforcement of transmission and distribution capacity and increased storage to meet peak demand. Alternatives to decarbonising electricity generation are installation of heat networks or consumer-based renewable technologies and both these options are disruptive to customers and require significant additional investment.

The FBM project aims to unlock the potential benefits of decarbonisation of the existing gas grid and open up an economical pathway for the decarbonisation of heat.

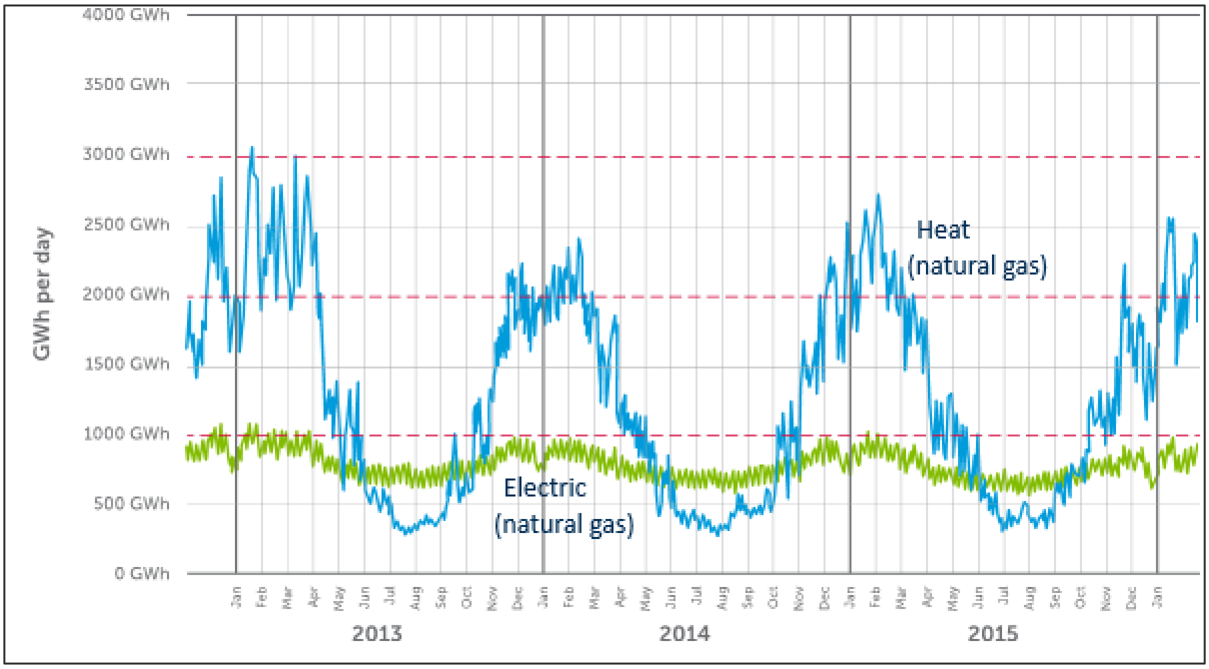


Figure 2-1: A plot of heat and electricity energy delivered to GB. Natural gas delivers 80% of the GB heat load and can accommodate the seasonal and diurnal variations in demand. A significant proportion of electricity generation is also gas fired.

The project promotes the use of the gas grid, returning benefits on existing investment by gas consumers, to provide an economic alternative to the costly re-engineering of electricity generation, reinforcement of electric networks and investment in the whole electricity supply chain. This also protects consumers from the significant cost outlay of changing appliances and heating systems.

2.2.2 Challenges of the Current Commercial Arrangements

The Flow Weighted Average Calorific Value (FWACV) and the 1 MJ/sm^3 capping mechanism has served the gas industry well during a period of relatively stable energy content. However, current and future energy contents are much more variable. The introduction of alternative sources of gas, such as biomethane – which has a lower CV than gas from the NTS – would create a distortion in the allocation of billed energy to consumers, unless the energy content of the biomethane source is artificially enhanced. This is currently achieved by the injection of propane at source by the biomethane producer. The addition of propane – a relatively carbon-rich fossil gas – to the biomethane stream negates the environmental benefit that would otherwise be realised. A recent report by Element Energy /1/ states that the addition of propane adds 0.3 p/kWh to the price of gas. The FBM project could therefore unlock significant financial and carbon savings from the avoidance of adding propane to low CV gases.

The need for artificial energy standardisation, and the additional cost it carries, creates a barrier to entry for renewable and alternative sources of gas which, typically, have lower energy content than gas from the UK Continental Shelf (UKCS) or LNG. This is unsustainable in a future gas market where multiple and diverse sources of safe gas, including lower-carbon sources such as biomethane/bio-synthetic gas and potentially hydrogen blend, could be used to fuel domestic and commercial space and water heating.

2.2.3 Low carbon gases

The heat energy from natural gas is released by combustion – this can range from small scale combustion in a domestic boiler to produce hot water and heat or to much larger scale gas turbines that generate electricity for the grid. Natural gas comprises different hydrocarbons (molecules made of carbon and hydrogen) and when they are burned in air an equivalent quantity of carbon dioxide and water is produced. The hydrocarbon in most abundance in natural gas is methane but there are decreasing amounts of ethane, propane, butanes and more complex hydrocarbons.

The combustion of fossil fuels (oil, coal or gas) releases carbon into the atmosphere that was previously locked away in the earth’s crust. Low carbon or “green” gases are made from carbon that is already in the ecosystem – biomethane, for example, could be made from anaerobic digestion of crops or agricultural waste that contain carbon that is naturally recycled. Fossil fuels are therefore adding carbon dioxide to the carbon cycle and this contributes to global warming. A schematic of the difference between fossil carbon and recycled “green” carbon is shown in Figure 2-2. The image also illustrates the role of carbon capture and storage under the current proposals to create hydrogen networks by passing natural gas through steam methane reformers; the carbon content from the hydrocarbons is returned to underground storage in the form of carbon dioxide thus removing it from the ecosystem.

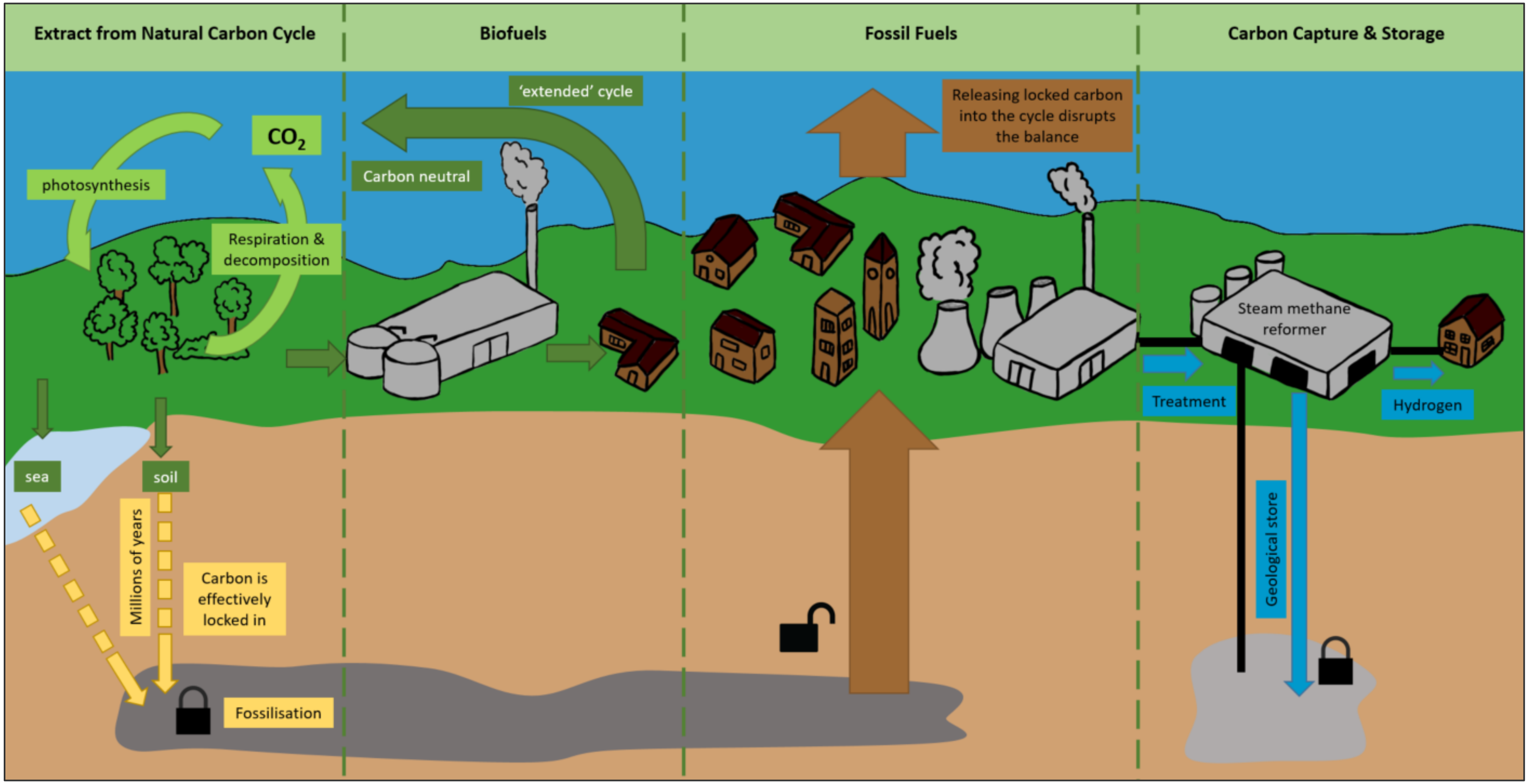


Figure 2-2: Schematic diagram to show the difference between fossil and "green" carbon. The carbon capture and storage option is proposed for hydrogen networks – the natural gas is converted to hydrogen and the carbon dioxide is locked away in geological storage

2.2.4 Other Benefits

The FBM project would bring inherent customer and stakeholder benefits in terms of a more robust and fair energy attribution to customer bills. It is pivotal to facilitating alternative gas sources and the use of more cost-effective energy sources, including indigenous shale gas and hydrogen.

The project is relevant and timely for GDNs planning for the RIIO GD2 price control review in 2021. It is also an enabler for other on-going NIC projects, the benefits of which will not be fully realised if the limitations of the current LDZ FWACV billing framework are not addressed.

2.2.5 Project Approach

The FBM project is a proof-of-concept study to investigate options for potential commercial arrangements that will enable the decarbonisation of the gas network, and hence heating, in GB. Ofgem has divided the project into two phases with a stage gate in August 2017. An overview of the whole project is described in Section 3.

Phase one has involved a period of industry and stakeholder consultation (see Sections 4 and 5), a cost benefit analysis (see Section 6), some network modelling to study the zones of influence of embedded connections and associated work on preparing for field trials in the Cadent network (see Sections 7 and 8). Recommendations from Cadent on the best way forward for phase two are given in Section 9.

During phase two, installation of biomethane tracking equipment and other sensors in the networks is planned around two biomethane injection points. Site surveys have already been carried out in the areas around the Chittering biomethane injection point in East Anglia LDZ and the Hibaldstow biomethane injection point in East Midlands LDZ. CV measurement equipment will be installed in a few locations in the Hibaldstow and Chittering networks to explore the option of transferring CV directly to consumer smart meters. The sensors installed as part of the field trial will be monitored for a year and the data used to develop network modelling procedures to determine the zones of influence of the biomethane inputs. Having developed the proof of concept for the three project scenarios, the project will carry out a more detailed cost-benefit analysis and make recommendations for a future billing methodology.

2.2.6 Summary of Project Rationale

Any future billing methodology should enable gases that comply with the Gas Safety (Management) Regulations (GS(M)R) to be injected into the gas grid without further processing. The gas network already has the capacity to flow all GS(M)R compliant gases and to meet large seasonal and diurnal fluctuations in demand – the future use of the gas grid to decarbonise heat can therefore be regarded as a low regrets option.

2.3 Glossary of Terms

Term	Meaning
AQ	Annual Quantity
ATEX	Name commonly given to two European Directives for controlling explosive atmospheres
CBA	Cost-Benefit Analysis
CHP	Combined Heat and Power
CDM	Construction (Design and Management) Regulations, HSE, 2015
C&I	Control and Instrumentation
COB	Change Overview Board
CV	Calorific Value
CVDD	Calorific Value Determination Device
DNV GL	Project partner of Cadent
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations
EUC	End-User Category
FAQ	Frequently Asked Question
FBM	Future Billing Methodology
FES	Future Energy Scenario (National Grid publication)
FWACV	Flow Weighted Average Calorific Value
GB	Great Britain
G(CoTE)R	Gas (Calculation of Thermal Energy) Regulations – govern calculation of gas CV for billing
GD1	Present gas distribution price control period ending in March 2021
GD2	Second gas distribution price control review under RIIO
GHG	Green House Gas(es)
GDN	Gas Distribution Network
GRP	Glass-Reinforced Plastic
GS(M)R	Gas Safety (Management) Regulations – governs the safety of the GB gas supply
LDZ	Local Distribution Zone (gas distribution networks in GB comprise 13 LDZs)

Term	Meaning
LNG	Liquefied Natural Gas
LPG	Liquefied propane gas
NEA	Network Entry Agreements
NDM	Non-Daily Metered
NIC	Network Innovation Competition
NPV	Net Present Value
NTS	National (Gas) Transmission System
OAD	Offtake Arrangements Document
RHI	Renewable Heat Incentive
RIIO	Ofgem regulatory framework: Revenue = Incentives + Innovation + Outputs
scmh	Standard cubic metres per hour
SDRC	Successful Delivery Reward Criteria
SMP	Supply Meter Point
UKCS	United Kingdom Continental Shelf
UNC	Uniform Network Code

3 PROJECT OVERVIEW

The Future Billing Methodology (FBM) project is an Ofgem Network Innovation Competition (NIC) project /2/ that aims to explore options for a fair and equitable billing methodology for the gas industry which will be fit-for-purpose in a lower-carbon future. It aims to integrate diverse gas sources without needing to standardise energy content and will inform the industry on billing options for a sustainable gas future. Three options, Pragmatic, Composite and Ideal, will be explored using measurement, network modelling and smart meter data transfer. Industry engagement and a cost-benefit analysis also form an important part of the project.

The method proposed for the NIC project is to explore three options for reforming the current Flow Weighted Average Calorific Value (FWACV) billing methodology is shown in Figure 3-1.

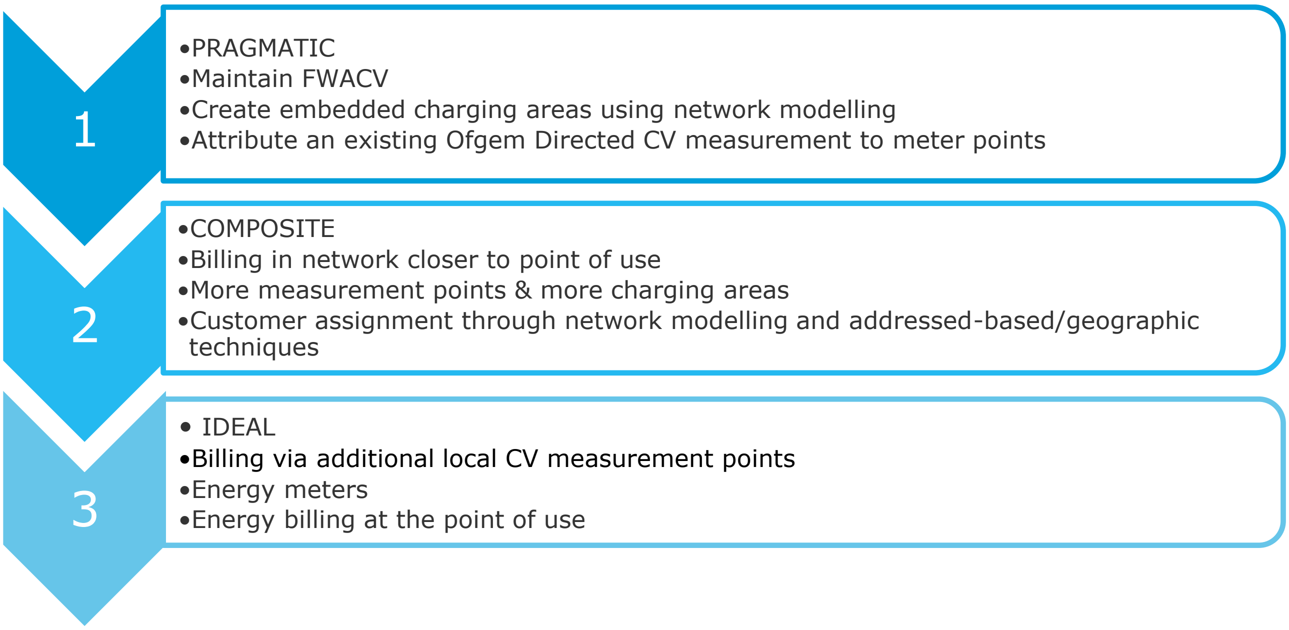


Figure 3-1: Three options to be explored under the Future Billing Methodology NIC project

The description of the three Project options below reflects some evolution in thinking since the original NIC project submission. It should be possible to deliver the three Future Billing Methodology scenarios broadly within the existing regulatory structure. However, we have identified at high level where changes may be required.

Option 1 Pragmatic – would maintain the existing FWACV methodology for most customers in the LDZ. This option develops a network modelling process to create specific new charging areas around embedded entry points with a materially different CV. Network modelling of the zone of influence exerted by the different CV input point will drive attribution of the specified fixed zone entry point CV to Supply Meter Points (SMP) within that CV zone. All consumer bills would be based on existing Ofgem Directed CV measurement sites at the offtakes from the Gas National Transmission System (NTS) (for the FWACV area), or the Directed CV measurement point of the different CV entry point. Charging areas would be specified accordingly within the Offtake Arrangements Document. No change to G(CoTE) Regulations is envisaged for this option.

Option 2 Composite – Would involve the installation of CVDDs (Calorific Value Determining Devices) at approximately 10,000 sites (majority at distribution district governors but some would be at "within mains network" locations to allow for areas of downstream interaction) to create specific CV zones for every input source to the LDZ. This option would involve identification of isolated single fed systems and network analysis to identify other smaller charging areas. The allocation of SMPs to a fixed zone/measurement point, would completely supersede the FWACV methodology. In addition to further changes to the OAD to recognise all charging areas within each LDZ, this option may also require changes to the G(CoTE) Regulations to allow within-LDZ CV measurement to be used directly for billing purposes.

Option 3 Ideal – this option explores a wholly smart-metered network, which would build on the Composite option. It will explore the transmission of CV data to smart meters, so that the consumer could ultimately be billed directly on current gas energy use, rather than measured volume and allocated CV. If implemented, this would require additional CVDD installations to compliment those already installed under the Composite option, to underpin a more specific attribution of CV to customers' smart meters. It is estimated that approximately a further 34,000 CV measurement points[1] would be installed. This would include the identification of isolated single fed areas and network analysis to create appropriate charging areas for the allocation of the SMP to an appropriate local CVDD. This is a longer-term option that would be an enabler for whole-scale smart gas energy metering.

The Project seeks to explore the Pragmatic, Composite and Ideal options by undertaking field trials involving the installation of sensor equipment on the network. For over a year, measurements will be taken from the field measurement sites in the area around the Chittering biomethane injection point near Cambridge in East Anglia LDZ and around the Hibaldstow biomethane injection point near Scunthorpe in East Midlands LDZ. The data collected will be used to evaluate the suitability of existing network models to predict the zones of influence exerted by specific injection points. In addition, a technology trial will deploy a hosted environment to prove the assignment of network CVs to individual smart meters. It is recognised that the zones of influence will be dynamic and will vary depending on demand and network configuration; the method for assigning customers to a charging zone is likely to be probabilistic but this will be confirmed as part of the project.

The project will be delivered in four work packs:

- Work pack 1 is industry engagement
- Work pack 2 covers sensors and measurement, network modelling and CV allocation
- Work pack 3 involves assigning CV measurements to smart meters
- Work pack 4 is further industry engagement on the FBM options, a cost benefit analysis and recommended solution

Work packs 1, 2 and 4 are split into two phases across the Ofgem stage gate; this report covers phase one.

It is important to note here that the Future Billing Methodology project will deliver the "proof-of-concept" only. Whilst the Project will identify required changes to codes and regulations, and inform the final project CBA for a potential future implementation phase, it will not provide a detailed specification for implementation, nor associated modifications to regulations, or the Uniform Network Code, as these

[1] based on an assumption of 500 customers per within-network sensor i.e. 22,000,000 / 500 = 34,000 so 44,000 in total requiring 34,000 additional points over composite option.

work areas are outside the remit of Innovation funding under RIIO. A detailed implementation specification should be the subject of a separately funded industry change programme, should a recommendation for change from this project be agreed by the industry.

3.1 Successful Delivery Reward Criteria

Ofgem use project-specific Successful Delivery Reward Criteria (SDRC) to measure and track the delivery of NIC projects. The list of SDRCs forms part of the NIC submission document. Each SDRC must comply with the principles set out in the NIC governance document /3/ and should be:

- Linked to meeting identified targets for the outputs that will be expected to be delivered through the Project;
- Linked to meeting identified Project milestones on at least an annual basis;
- Linked to achieving the proposals it puts forward for the generation of new knowledge to be shared amongst all Network Licensees; and
- SMART - specific, measurable, achievable, relevant and time bound.

This SDRC report (SDRC 9.1a) is the first to be issued for the Future Billing Methodology project and it is based on milestone 9a of the Full NIC Submission document. It provides the evidence required by Ofgem to comply with the Project Direction as detailed in Section 3.2 below. The deadline for submission is 11 August 2017.

3.2 Ofgem Project Direction

Ofgem introduced a stage gate under Project Direction /4/ which divided the project into phase 1 and phase 2. For the project to progress past the stage gate and for phase 2 to commence Ofgem require evidence of:

- The terms of reference for the industry engagement
- The numbers and types of participants in the industry engagement
- A compilation of the output from workshops, questionnaires and meetings held during the industry engagement (phase 1)
- Initial cost benefit analysis
- Requirement for the validation of the network modelling

The Ofgem Direction states that at the end of SDRC 9.1a, the Funding Licensee (Cadent) shall prepare a report setting out the following from its industry engagement activities:

a) Industry's current views on the desire for change to the current approach.

b) Industry's current views on:

   i. What level of modelling validation is seen to be required; and

   ii. What regulatory (or other) changes are required to support the continuation of the Project beyond Work Pack 1.

c) Initial Cost Benefit Analysis of the three scenarios (noting that this will be finalised under Work Pack 4) to demonstrate that, following industry engagement, there remains a strong case to proceed with the Project.

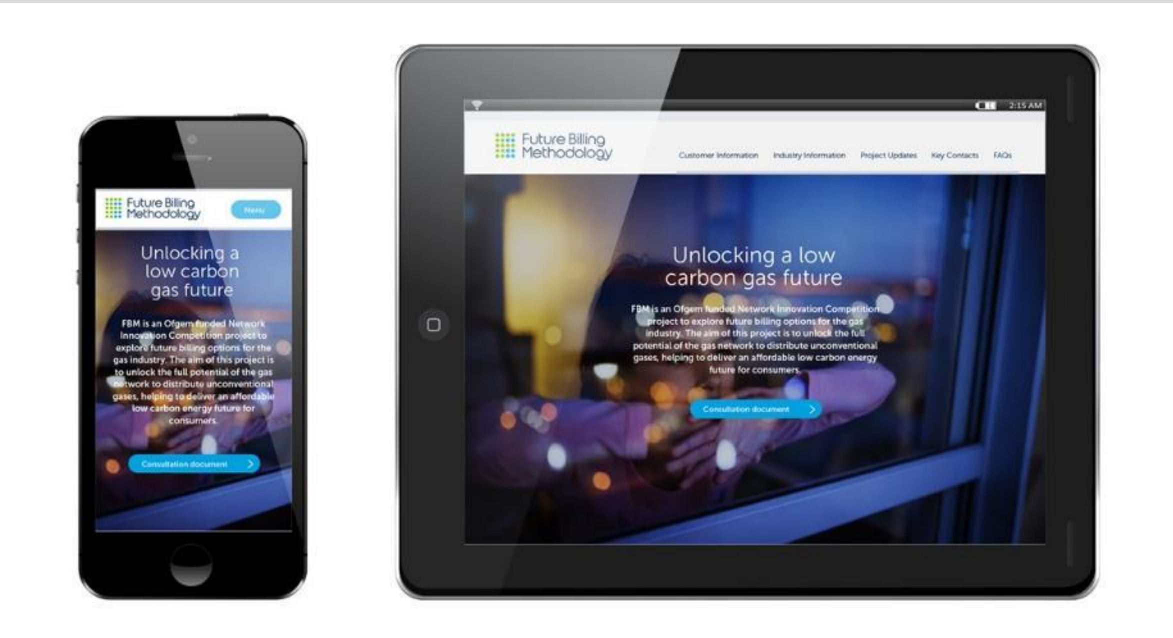
d) Based on a, b, and c, Cadent's assessment of the best way to proceed with this Project.

References to 'industry' includes, but is not limited to gas distribution networks (GDNs), National Grid group companies, shippers, suppliers, Xoserve and Ofgem.

Following project approval on 30 November 2016 and subsequent project direction, the project team has commenced industry engagement, undertaken network modelling for sensor site identification with associated site surveys and completed the development of generic engineering / installation design packs. Alongside this work, a draft high-level CBA has been developed. Funding of £250,000 has been bought forward from phase two of the project to support the activities associated with the delivery of phase one and to prepare the project to move into delivering phase two.

This document is Cadent's response to the Ofgem Direction and it provides further detail on the work completed to demonstrate that there is a strong case to proceed with this Project.

Part Two – Industry Engagement and Consultation Responses



Future Billing Methodology

4 INDUSTRY ENGAGEMENT

An important part of the FBM project is engagement with industry to understand the impact and limitations of the existing FWACV framework and how the implementation of the FBM pragmatic, composite and ideal options would affect industry in the future. The industry engagement described in this document covers phase one of the project under Ofgem Direction, however, it will continue into phase two beyond the stage gate. The engagement covered the writing of the terms of reference, stakeholder identification and mapping, a launch event, a range of meetings both face-to-face and webinars, presentations at events/industry committees and the publication of documents on a project website.

4.1 Terms of Reference

The terms of reference for the industry engagement for phase one of the Future Billing Methodology project were set out in the consultation document which was published at the project launch in London on 2 March 2017; the consultation document is available from the project website at www.futurebillingmethodology.com.

4.2 Stakeholder Engagement process

The Future Billing Methodology NIC bid document stated that the industry engagement exercise would be hosted by Cadent to explore the view, issues, constraints and future requirements of a change to the current billing methodology on the industry and stakeholders. The engagement process would take the form of a combination of workshops, meetings, a discussion paper and associated questionnaire to understand the stakeholder impact of:

- Maintaining and changing the current FWACV system
- Creation of embedded charging areas with the FWACV system
- Increased number of charging areas
- CV measurement at every meter

This section outlines the initial stakeholder engagement and stakeholder analysis that was undertaken by the project team as part of the work to satisfy Ofgem that the industry is supportive of the FBM project.

4.2.1 The Process for Stakeholder Analysis

A workshop was held by Cadent with participation by DNV GL to identify stakeholders in the Future Billing Methodology project. Once stakeholders were identified, each one was placed on a chart to show their potential impact on, and interest in, the project; the groupings were qualitative as shown in Figure 4-1.

Stakeholders were then prioritised using a scale of 1 to 10 for impact and 1 to 10 for interest. For example, Xoserve received an influence/interest rating of 10/10 whereas propane producers received a rating of 6/10. Stakeholders in the top right hand quadrant were further mapped onto an influence/commitment diagram to estimate their current commitment to changing the FWACV billing system. These “key players” were targeted for inclusion in the consultation process.

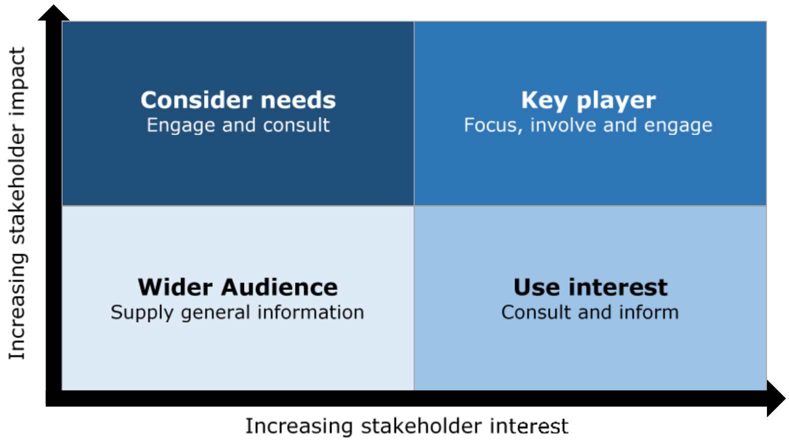


Figure 4-1: Initial Stakeholder Mapping

4.2.2 The Stakeholders

Following the stakeholder analysis and mapping process, Cadent contacted stakeholders to identify the correct people within each organisation to attend the launch event on 2 March 2017 and respond to the industry consultation. A total of 46 people responded positively to the invitation for the launch event. The types of organisation and numbers from each are shown in Table 4-1.

Table 4-1: Stakeholder groupings and numbers for the project launch event on 2 March 2017

Stakeholder Grouping	Organisation with number of Launch Event attendees in brackets
Gas Transporters	Public gas transporter – NGN (3), WWU (1), SGN (3) & NGGT (1). Cadent (Project Licensee, 11) Independent gas transporter - ES Pipelines Ltd (1)
Government	BEIS (4), Committee for Climate Change (1), Ofgem (2), MP (1)
Business systems	DCC (1) & Xoserve (1)
Finance	Anaerobic Digestion Privilege Finance (1)
Consultants	Progressive Energy (1) DNV GL (Project Partner, 8)
Producers	Severn Trent Water – Green Energy (3), ET Biogas Ltd (1), BioCow (1), Olleco (1), Manor Farm Green Energy (1)
Professional Body	IGEM (1)
Shipper/supplier	EON (1), Engie (1), First Utility (1), EDF (1), SSE (1) & Scottish Power (1)
Technical Equipment Supplier	Inficon (1), Siemens (1), Elster (1), Honeywell (1), ITM Power (1) & Orbital Gas Systems (2)
Trade Association	Green Gas (REA) (1), Energy Networks (2) & AD Bio Resources (1)

4.2.3 The Stakeholder Engagement Process

A series of events were held as part of the stakeholder engagement process for stage one of the project. The process was divided into three phases with the following objectives:

1. Engage stakeholders during the period up and just past the launch event on 2 March 2017
2. Receive as many responses as possible during the open consultation period which ended on 12 May 2017. The original deadline was 14 April 2017 but this was extended to allow additional time for respondents beyond the Easter holiday period.
3. Demonstrate support for the project after project consultation closes until submission of stage gate report to Ofgem in August 2017

A summary of the types of activity undertaken is shown in Figure 4-2. A more detailed list of the stakeholder engagement events and face-to-face meetings is shown in Appendix A.

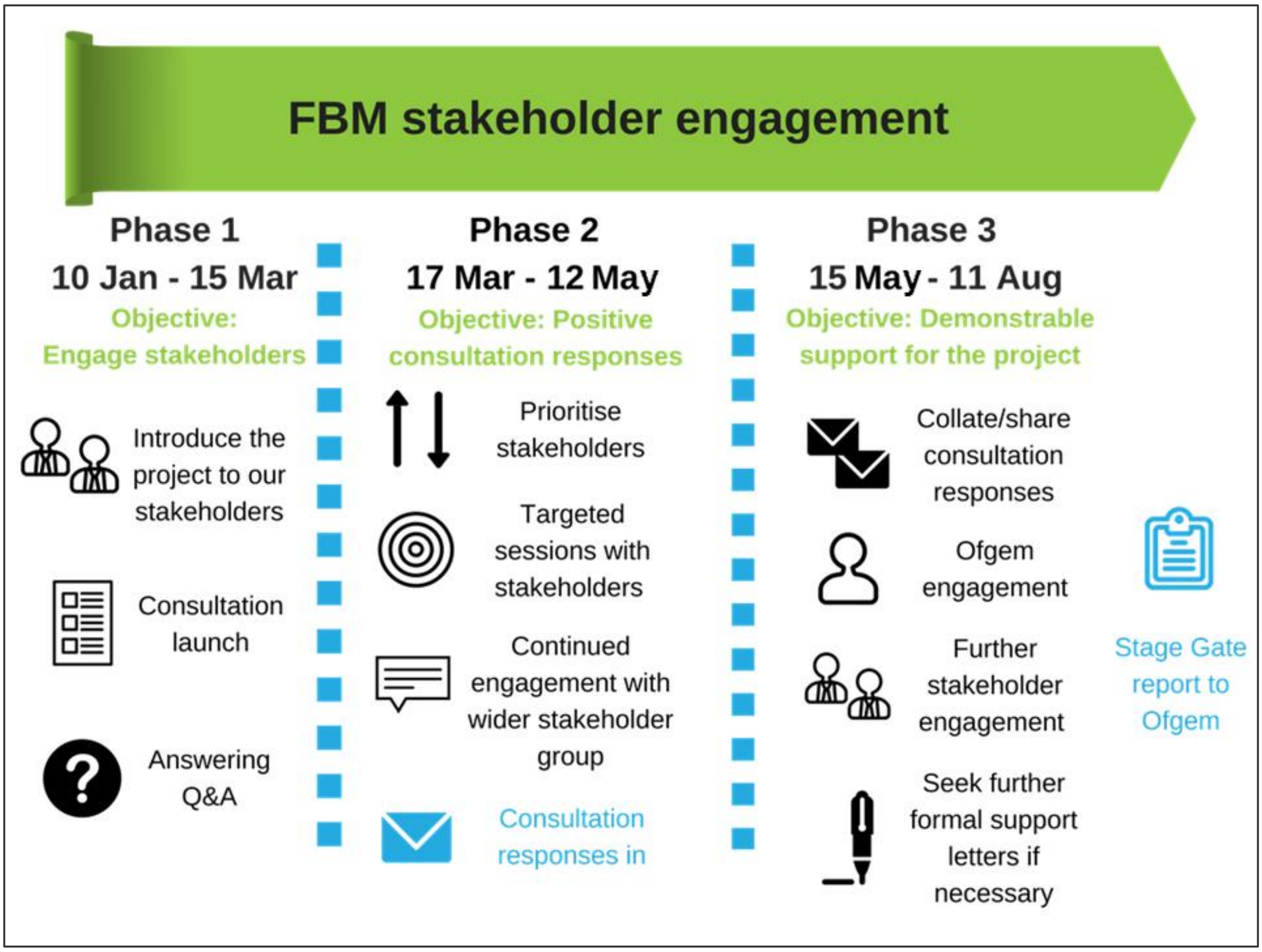


Figure 4-2: Activities carried out as part of the initial stakeholder engagement. A detailed list of all events is listed in Appendix A.

4.3 Consultation Document

The consultation document outlined the case for the project as outlined in Section 2.2. The full document is available on the project website www.futurebillingmethodology.com/industry-information.

Eight questions were posed to gather the views of stakeholders on the need for changes to the billing framework to decarbonise heat in GB and on the proposed project approach. The eight questions were:

1. Do you agree that the existing LDZ FWACV methodology presents a barrier to a low carbon gas future and that alternative methodologies should be explored?
2. Do you agree that the Future Billing Methodology Project could provide the basis to deliver an economical and sustainable pathway to decarbonising heat for 2030 and 2050?
3. Do you agree that the proposed Measurement and Validation Field Trials could provide an understanding of the modelled zones of influence of LDZ-embedded gas entry points?
4. If your answer to Q2 and or Q3 was "No", what alternative or modified approach would you like to see considered?
5. What factors and impacts would you like to see considered through the Future Billing Methodology Project?
6. If implemented, how would the suggested changes to the existing LDZ FWACV billing regime benefit your company/organisation, eg what savings would the changes bring?
7. Do you envisage any legal or regulatory issues arising if any of the Future Billing Methodology options were to be implemented?
8. Do you have any other comments on the Future Billing Methodology Project? (eg issues not covered in the document)

The initial deadline for consultation responses was 14 April 2017 and this was later extended to 12 May 2017 to allow more time for the industry to consider and provide responses which are vital in shaping our thinking and further dialogue on this Project. Responses to the consultation are summarised in Section 5 and presented in full on the project website www.futurebillingmethodology.com.

The phase one industry and stakeholder engagement was delivered within these terms of reference.

4.4 Questions and Answers

4.4.1 Frequently Asked Questions

During the period of stakeholder engagement, a list of questions and answers was published on the website and kept up-to-date. These were divided into Frequently Asked Questions (FAQs) for the general reader and more detailed questions aimed at the gas supply industry.

The FAQs and the messages conveyed in the answers are shown in Table 4-2.

Table 4-2: Frequently Asked Questions (FAQs) and messaging on the FBM website

Frequently Asked Question	Message in the Response
How will this project impact my gas bill?	FBM is proof of concept so no change to gas bills unless implemented. Cadent is helping customers move towards a low carbon gas supply.
Are the alternatives to natural gas safe?	Reassurance that gas safety will not be compromised, as all gases must comply with GS(M)R.
How will this project affect the regulations?	No changes to the gas regulations planned, but the case for changes will be identified as part of the project learning
Apart from low carbon gases, what other options are available to provide low carbon heat for GB customers?	Electrification of heat via renewable generation, CHP networks. Heat pumps and consumer-based renewables. Disruption and expense for customers.
How could Future Billing Methodology help consumers to save money?	Maximise the use of the existing gas grid which has had significant investment by consumers avoid high electrification costs.
How would different calorific values of gas impact customers' appliances?	All gases will still be GS(M)R compliant and therefore safe for customers' appliances
Who is Cadent Gas Limited?	Information provided about name change National Grid Gas Distribution Ltd and the area of responsibility.
Why is Cadent leading this?	Cadent has 11 million customers and is committed to explore the best options for a low-carbon gas future
If this project moves to implementation in the future, what is the potential for carbon savings from alternatives sources of gas?	Information provided about quantity of carbon savings from initial analysis and unlocking billing framework for low carbon gas supply. This has been reassessed in initial CBA (see Section 6).
The calorific value (CV) of gas is currently averaged so consumers are all billed in the same way. So, if the calorific values are varied, what impact will this have on a customer's bill?	Continue to bill on the energy used. However, the billing framework needs to account for day-to-day changes in CV.

4.4.2 Industry Questions

The industry questions were grouped as follows:

- General questions about the project and the consultation process
- FWACV
- Impact on customers
- The three options and the field trials
- Miscellaneous

A full list of questions and answers is available on the project website www.futurebillingmethodology.com.

A summary of the questions and the message conveyed in the responses is shown in Table 4-3.

Table 4-3: List of Industry Questions and the Message in the Responses.

Industry Question	Message in the response
General Project Questions	
Apart from low carbon gases, what other options are available to provide low carbon heat for GB customers?	Continuation of FAQ response giving more detail on alternatives to low carbon gas and likely extra expense for consumers
If this project moves to implementation in the future, what are the potential for carbon savings from alternative sources of gas?	Continuation of FAQ response giving more detail on diversity of future gas supplies, which could result in lower unit costs
Why not concentrate on amending the gas regulations to support the removal of propane?	Removing the CV cap will increase cross subsidies - better to understand the zone of influences and bill customers for energy
What is the cost of propane input for biomethane supplied under RHI?	Our initial view is based on propane commodity costs. The current estimate is £2m per annum for propanation of 0.5% of the gas supply (based on commodity price difference only).
The implementation of the project could involve major changes to the system which are difficult to quantify for the cost-benefit analysis at this stage if we don't know exactly what will be needed?	Liaising and engaging with Xoserve is central to the project and further detail will be provided
Why isn't an implementation project being run in tandem with FBM to understand the implications of implementation more fully?	FBM is a proof of concept innovation project and it is cost effective to do the learning first. Implementation costs are outside the remit of innovation funding from Ofgem

Industry Question	Message in the response
Why are you doing this now when there is no clear policy direction?	We see it as part of our role to explore and create the options that could inform future policy in customers' best interests. FBM will facilitate the decarbonisation of heat using existing assets.
Who would pay for the costs of implementation?	Ultimately borne by gas customers. Cheaper than full electrification and other alternatives.
What is the timeframe for potential implementation?	FBM completes in 2020. Implementation will be no earlier than 2021/22
Questions relating to Flow-Weighted Average Calorific Value (FWACV)	
What range of calorific values is this project considering as likely to make up future gas supplies?	Gases must comply with GS(M)R but a possible range is 37 to 42 MJ/m3. Upper limit of GS(M)R is under review.
How would changing zones be accommodated through billing?	This forms part of the project learning and the potential impact on consumers' bills will be a key consideration.
What are the current variations in bills under the FWACV system?	Small variations exist under the current regime – these may be up to £17 per annum.
Can anything be done on FWACV or at the plant itself?	Simply removing FWACV cap and stopping enrichment will increase cross subsidies. FBM is a practical solution until universal energy metering is available.
Questions relating to customers	
How could Future Billing Methodology help consumers to save money?	Makes full use of the gas grid (already funded) and unlocks the transport of renewable gases.
The calorific value (CV) of gas is currently averaged so consumers are all billed in the same way. So, if the CVs of gas are varied, what impact will this have on a customer's bill?	FBM aims to continue billing gas customers on the energy that they use and this aims to take account of varying CVs. This will result in fairer billing.
How would different calorific values of gas impact customers' appliances?	Customer appliances will operate safely on all GS(M)R gases.
Will this project consider the possibility of assigning customers to two or more inputs for billing?	Yes – this will form part of the investigation of the zones of influence

Industry Question	Message in the response
Questions relating to the three FBM options and the field trials	
How accurate will the field trials be?	Measurement uncertainties provided. Oxygen sensors are appropriate for gas tracking.
Regarding the Ideal Option being explored under FBM, can the current specification smart meters already being installed in gas customers' homes hold CV data? If not, what is the timescale being envisaged by this option? Do you envisage a further roll-out of higher spec meters, at what cost to the customer?	Current SMETS2 smart meters have auxiliary input points - one of these will be used for live CV. The project will test the concept of providing Suppliers with CV data and outline future requirements for deploying smart energy meters.
Miscellaneous Questions	
Doesn't the next phase of SMART metering include new CV measurement? How does that fit with this project?	No smart energy meters yet but FBM could provide a foundation for an energy metered future.
What will happen if a source of gas supply is interrupted?	This will be studied - initial thoughts are that the area would revert to FWACV
What is the gas billing period?	The regulations do not specify any period but CV is currently daily for billing.
If it goes through to implementation, would fences need to be put around every biomethane plant to determine the zone of influence?	No – this is not practicable. The project will derive a scalable, replicable set of rules applicable to any LDZ

5 CONSULTATION PAPER RESPONSES IN SUMMARY

A consultation was held between 2 March 2017 and 14 April 2017. To allow extra time for the industry to respond, the deadline was extended to 12 May 2017. Based on the Stakeholder Engagement Process (See Section 4.2), 120 personnel across 80 organisations in the GB gas industry were invited to participate in the open consultation. There was a total of 16 respondents to the consultation from five different sectors of the GB gas industry. The respondents are summarised and colour coded in Table 5-1. The consultation was supported by other engagement activities (see Appendix A).

Table 5-1: Respondents to the Future Billing Methodology Consultation

Type	Organisation	Short Code
Production	CNG Services Limited	CNG
	Anaerobic Digestion & Bioresources Association	ADBA
	Renewable Energy Association	REA
Transporter	Northern Gas Networks	NGN
	SGN	SGN
	Wales & West Utilities	WWU
Shippers & Suppliers	Barrow Green Gas	BGG
	EDF Energy	EDF
	Npower	NPO
	Scottish Power Energy Management Ltd	SPEM
Industry Bodies	Energy UK	EUK
Technical & Academic	Cardiff University/CIREGS Research Group	CURG
	Smart DCC Ltd	DCC
	ITM Power	ITM
	Progressive Energy	PEN
	UK Hydrogen Fuel Cell Association	HFCA

The aim of the consultation document was to gather stakeholders' opinions and views on the industry engagement objectives (SDRC 9.1a):

- Industry's view on the desire for change to the current approach
- Industry's current views on the level of modelling validation required
- Industry's current views on the regulatory changes that may be required to support the project beyond work pack 1.

The consultation document introduces decarbonisation and FBM (Section 4.1) and requested stakeholders to respond to eight questions. The questions can be mapped to the industry engagement objectives as shown in Table 5-2.

A summary of the consultation responses has been given as per the industry engagement objectives along with a summary of Cadent's commentary. The full document is on the project website www.futurebillingmethodology.com.

Table 5-2: Consultation questions compared with the SDRC 9.1(a) requirements

Industry Engagement Objective - SDRC 9.1(a)	Q.	Consultation Questions
Industry's current views on: The desire for change to the current approach.	1.	Do you agree that the existing LDZ FWACV methodology presents a barrier to a low carbon gas future and that alternative methodologies should be explored?
	2.	Do you agree that the Future Billing Methodology Project could provide the basis to deliver an economical and sustainable pathway to decarbonising heat for 2030 and 2050?
	4.	If your answer to Q2 and Q3 was "Disagree", what alternative or modified approach would you like to see considered?
	6.	If implemented, how would the suggested changes to the existing LDZ FWAC billing regime benefit your company/organisation, e.g. what savings would the changes bring?
Industry's current views on: What level of modelling validation is seen to be required	3.	Do you agree that the proposed Measurement and Validation Field Trials could provide an understanding of the modelled zones of influence of LDZ-embedded gas entry points?
	4.	If your answer to Q2 and Q3 was "Disagree", what alternative or modified approach would you like to see considered?
	5.	What factors and impacts would you like to see considered through the Future Billing Methodology Project?
Industry's current views on: What regulatory (or other) changes are required to support the continuation of the Project beyond Work Pack 1.	7.	Do you envisage any legal or regulatory issues arising is any of the Future Billing Methodology options were to be implemented?
Other Comments	8.	Do you have any other comments on the Future Billing Methodology Project?

Notes:

(1) Responses to question 4 could fit into two of the three industry engagement objectives, hence it is double counted within the table above.

5.1 Industry's View on Desire for Change to the Current Approach

The first of the industry engagement objectives is to assess whether the industry believes that the current FWACV billing framework creates barriers to the adoption of low carbon gases. The desire for change depends on the following factors for each stakeholder:

- The opinion whether the current FWACV billing framework is a barrier to the adoption of low carbon gases (Section 5.1.1/Question 1, Table 5-2)
- The impact of any changes to the billing methodology to each stakeholder (Section 5.1.2/Question 6, Table 5-2)
- The perceived potential for FBM to lead to provide an economical pathway for decarbonising heat (Section 5.1.3/ Question 2 and 4, Table 5-2).

5.1.1 LDZ FWACV is a Barrier to the Adoption of Low Carbon Gas

Based on the responses to the consultation document, there is a broad acceptance that the existing FWACV billing framework presents a barrier to decarbonising the existing gas distribution networks (Figure 5-1).

The responses from shippers and suppliers were more mixed; this is understandable as it was noted by various stakeholders that this sector would be potentially impacted most by changes within the billing methodology. For the supplier responses, Cadent has provided the following additional commentary in Table 5-3.

Table 5-3: Additional commentary to supplier responses

Consultation Response	Cadent Commentary
Enrichment of biomethane with propane is a GDN requirement	Where supply is from traditional sources, FWACV is appropriate and proportionate. However, for low CV gas sources, enrichment is mandated to prevent triggering CV capping mechanisms and a disproportionate misallocation between network and energy (shrinkage) costs. (see Figure 5-2)
Biomethane enrichment can be dropped immediately	Cadent believes that dropping the requirement to add propane to low CV gas would trigger CV capping, resulting in a shrinkage bill impacting the customers (see Figure 5-2). This requirement protects customers from being overbilled for low CV gas.
LDZ FWACV is not a barrier to the decarbonisation of heat	The existing requirement to standardise energy content to prevent CV capping for low CV gases requires the addition of propane (a high-carbon fossil-based gas) which erodes the low carbon benefits of biomethane and other renewable gases, and so constrains decarbonisation.

Recent stakeholder workshop at which the current billing and propanation requirements were highlighted as key barriers to large scale production and injection of distributed and green gases

-WWU

The LDZ FWACV method is a significant barrier for a number of alternative fuel gases such as biomethane to being transported and utilised in the gas grid economically.

-CURG

Alternative billing methodologies should be explored to begin understanding the opportunities and challenges associated with attributing gas energy to gas flow at a more specific level.

-SGN

FWACV methodology can present a barrier to a low carbon gas future[…]this suggests that alternatives should be explored, to realise the benefits of green gas options in the network.

-EUK

Adding to propane to biomethane is costly and undermines the carbon-saving purpose of biomethane injection. A successful outcome for the FBM proof of concept project should facilitate the process of decarbonisation.

-REA

The existing LDZ FWACV methodology has no provision of hydrogen/natural gas blends and power-to-gas for absorbing surplus renewables This represents a short term, easily achievable route to decarbonisation

-HFCA

Figure 5-1 Selected Stakeholder responses from Production, Transporters, Industry Bodies and Technical/Academic

Embedded Biomethane without Enrichment

Gas Sources into LDZ

Source A: NTS Offtake

Flow Rate (mscm/day)	CV (MJ/sm³)	Percentage of LDZ Energy Flow	Gas Value per Day (A)
15	39.0	50.2%	£ 2,120,165

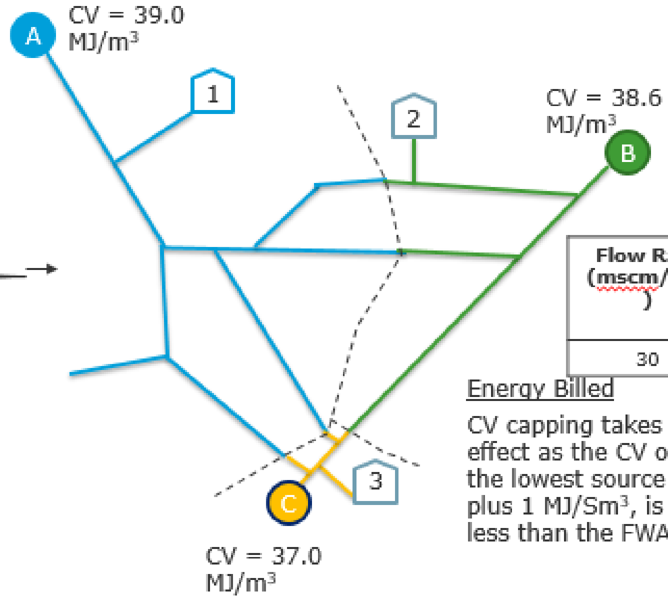
Source B: NTS Offtake

Flow Rate (mscm/day)	CV (MJ/sm³)	Percentage of LDZ Energy Flow	Gas Value per Day (B)
15	38.6	49.7%	£ 2,098,875

Source C: Biomethane

Flow Rate (mscm/day)	CV (MJ/sm³)	Percentage of LDZ Energy Flow	Gas Value per Day (C)
0.024	37.0	0.1%	£ 3,219

Simplified Local Distribution Zone



Flow Rate (mscm/day)	FWACV (MJ/sm³)	Gas Value per Day (A+B+C = D)
30	38.8	£ 4,222,719

Energy Billed

CV capping takes effect as the CV of the lowest source plus 1 MJ/Sm³, is less than the FWACV

Billed CV (MJ/sm³)	Billed Value per Day (E)
38.0	£ 4,135,806

Unbilled Energy per Day (D-E)
£89,913

Yearly Shrinkage Bill*
£10,468,678

* Assumed load factor of 33%
Gas Unit Cost taken as 1.305 p/kWh

Figure 5-2 Example of billed energy versus actual energy in a simplified LDZ where 0.1% of the energy flow is provided by a biomethane embedded connection without enrichment. Cadent used this example in their consultation responses to show how the CV capping mechanism is triggered and that the impact is disproportionate to the volume of low CV gas.

5.1.2 Impacts of FBM on Individual Stakeholders

This section describes the impacts on the individual stakeholder groups from responses when asked to state the potential impacts if the FBM were to be implemented (Question 6, Table 5-2). Three stakeholder groups responded on the expected impacts to their organisations.

- Producers stated that the proposed changes to the FWACV billing framework would bring both CAPEX and OPEX savings as it would be no longer required to enrich biomethane. Due to this reduction in project costs, more projects may be financed as less subsidy support per project would be required. In addition, the adoption of other low CV gases, such as hydrogen, natural gas blends and bioSNG, may increase.
- Transporters stated that the FBM project will provide an early demonstration of an updated billing methodology and identify the steps towards this along with high-level costs. It was viewed that it would lead to the adoption of other low CV gases. Increased accuracy in billing and energy reconciliation may be achieved, but there would be increased costs due to increased data management obligations, increased number of enquiries, additional network investment and reduced network efficiencies.
- Shippers and Suppliers were concerned that a change in billing methodology would only lead to increased costs due to increased customer communication, data requirements and billing complexity. It was recognised that the proposed FBM would reduce customer cross-subsidisation and increase billing accuracy. Whatever the conclusions of the FBM project, any proposed changes would need to be assessed holistically.

Two stakeholder groups responded on a higher-level relating to the overall gas industry:

- Technical and Academia views were that changes would lead, in addition to biomethane, to the adoption of natural gas blends and hydrogen. The FBM Project would serve as an early demonstration of the concept and will identify the changes required and the high-level costs.
- Industry Bodies recognised that changes would support decarbonisation and result in increased billing accuracy. However, it was highlighted that there would be costs and increased complexity in making changes to the billing systems along with the associated risks and potential to distort competition between suppliers through implementation costs.

The responses from many of the stakeholders are understandable as changes to the billing system will affect many stakeholders and, at the current time, the exact changes required are yet to be specified. The FBM project aims to assess whether the specification of a zone of influence around embedded LDZ connection is achievable and will identify the steps required to move to this approach. The project will be supported by a high-level positive CBA for each option, subject to the assumptions contained within it, and there will be further industry engagement as the project progresses.

5.1.3 FBM Provides an Economical Pathway for Decarbonising Heat

The potential for the FBM project to deliver an economical and sustainable pathway to decarbonise heat for the industry was assessed as part of question 2 of the consultation (Table 5-2). The responses from each of the stakeholder groups have been summarised as follows:

- Transporters identified that the gas transmission and distribution networks are existing infrastructure which have had significant investment over their operational life. Changes to the billing regime may lead to a cost-efficient method of decarbonising heat by using exiting gas infrastructure for injecting and transporting low CV gas. This is one of possible methods of decarbonisation which could lead to further innovation. Being able to inject biomethane without enrichment may lead to the adoption of diverse gas sources and enhance future supply chain security.
- Producers stated that FBM would result in removal of the requirement to enrich biomethane. This is considered a cost-effective method of increasing the adoption of biomethane and other renewable gases using the existing infrastructure and is-line with current consumer behaviour.
- Technical and Academia stated that FBM will allow the investigation and research into changes to the network which would lead to safely delivering "green-gas" and unlock the full potential of the existing infrastructure. It was noted by one stakeholder that the gas supply chain is complex and any change in regime will result in costs for stakeholders (whether one or many). The costs themselves should not be a barrier; as the most important factor overall is that any proposed solution is the most cost-effective and fair to customers.
- Industry Bodies thought that FBM may provide the basis for decarbonising heat and greening the existing gas network. However, the outcome would need to result in increased uptake of biomethane. There are many possible decarbonisation options including biomethane, full hydrogen conversion and electrification. A holistic view needs to be taken including costs and levels of disruptions across the whole supply chain.
- Shippers and Suppliers had mixed views. It is recognised that FBM has the potential to decarbonise the existing gas infrastructure. However, the full-extent of any potential benefits are currently unknown and would need to be supported by a full impact assessment and business case prior to implementation. Any impact assessments will need to compare the proposed FBM for decarbonisation against other alternatives (such as electrification, re-development of the gas network into local heat networks, hydrogen-conversion). Any conclusions drawn from the project will need to consider the scalability of the results. One respondent in this group suggested there was no case for the enrichment of biomethane.

Figure 5-3 shows a word picture of all the stakeholder free-text responses to "*do you agree the Future Billing Methodology project could provide the basis to deliver an economical and sustainable pathway to decarbonising heat for 2030 and 2050*" (Question 2, Table 5-2). The stakeholder responses were summarised and the word picture was created based on the frequency of words and phrases. The size of the word within the word picture is related to frequency (the greater the number of mentions, the larger the word). From the word picture, stakeholder responses were based on the following themes:

- Potential to decarbonise heat
- Usage of existing gas network infrastructure
- Current biomethane enrichment requirement

- Economic benefit
- Scalability

Table 5-4 summarises Cadent's commentary on the themes above.

Table 5-4: Summary of Cadent Commentary to question 2 responses

Consultation Response	Cadent Commentary
Potential to decarbonise heat	The responses support our view that FBM is worth exploring as a potential basis to decarbonise heat. Doubts were expressed over the potential for "green gas" to decarbonise heat. Cadent believes that with continued policy support up to third of the GB annual domestic gas demand could be supplied through biomethane and other renewable gases – a significant impact.
Usage of existing gas network infrastructure	Cadent agrees that the existing gas networks are high value, long-serving assets that are the product of long term investment with the capacity and flexibility to fulfil the peak heat demand and transport a range of GS(M)R compliant gases
Current biomethane enrichment requirement and CV capping mechanism	Cadent understands that biomethane enrichment imposes real costs relating to the injection of low carbon gases. However, this is a necessary interim arrangement to protect customers from the impacts of triggering CV capping (see Figure 5-2). Simply removing the CV cap would result in enduring cross-subsidy between customers.
Economic benefit	Cadent agrees that FBM project should be seeking the most cost-effective solution in the best interests of the customers and therefore should take a holistic view. Cadent's view is that prolonging the life of the gas distribution network is of wider value where this can lead to the decarbonisation of a significant proportion of heat demand at a fraction of the cost of the equivalent electrification. An initial high level CBA has been prepared for each of the three FBM options as a basis from which to begin comparison to other routes to decarbonising heat (see Section 6).
Scalability	The field trials will serve to establish whether zones of influence around embedded LDZ connections are achievable. The project is a "proof-of-concept" and should they be successful, the outputs will provide the essential learning required to extend the methodology across GB

Figure 5-3: Word picture of stakeholder responses to question 2

5.2 Industry’s Current Views on What Level of Modelling Validation is seen to be Required

Except for one stakeholder, all stakeholders indicated agreement that the proposed measurement and validation field trials could provide an understanding of the modelled zones of influence. Whilst there was general agreement, most of the responses were qualified further including some concerns about the limitations of the field trials:

- Five respondents note that FBM project will provide validation of existing models and understanding of the zones of influence around
- Five respondents commented on the scalability and replicability; two respondents noted that due to the variability of input feedstock to biomethane, the oxygen content will vary and that this would be carried into the analysis. It was mentioned by one stakeholder that each LDZ is subject to its own local intricacies and thus it would be difficult to generalise.
- Three respondents noted the importance of having robust and accountable models which if implemented would need to be audited and scrutinised by government bodies and Ofgem
- Two respondents noted that the impacts on customers need to be considered. The proposed methodology focuses on technical feasibility and not the broader impacts.

Table 5-5 summarises the Cadent commentary relating to the qualifications provided by the stakeholders.

One respondent initially disagreed with the statement: “proposed measurement and validation field trials could provide an understanding of the modelled zones of influence of LDZ-embedded gas entry points”. The respondent was contacted and provided with further clarification regarding the proposed field trials. The respondent responded positively to the clarifications and is keen to be involved with the project during Phase 2.

Table 5-5: Summary of Cadent commentary for stakeholder responses to question 3

Consultation Response	Cadent Commentary
Scalability	The FBM project has been designed to assess whether zones of influence around embedded LDZ connections can be defined in a robust and replicable way. The outcomes and conclusions from this project can then provide key learnings that can be applied any potential future implementation.
Replicability due to the variable oxygen content of biomethane	Oxygen present within biomethane is being used as a tracker to show which parts of the network receive biomethane. Due to NTS entry agreements, gas within the NTS has <10ppm (which is less than 2,000 ppm limit specified in GS(M)R). It is expected that biomethane will have up to 10,000 ppm (due to the GS(M)R class exemption) and it is expected that oxygen content within biomethane will always be greater than 10 ppm. Cadent is confident that the specified oxygen sensors can reliably differentiate between these concentrations of oxygen and, therefore, reliably track the flow of biomethane from its embedded entry point.
Robust and accountable models that can be audited	All GDNs have computer models of their gas distribution networks that are validated against measured pressures and flows for operational and capital investment planning. The Project looks at the application of these existing models for the development of a new methodology that would more closely align the billed CV with the CV of the gas supplied.
Impact on customers	As the level of demand changes and the operation of the network changes, the zone of influence of any supply will change. The use of measurements aims to build up a profile of how often areas of a network are impacted by gas from an unconventional supply. From this understanding of the flow of the gas within the network, a time-based probability of the impact of an example biomethane site can be generated and a fixed zone boundary identified for the purposes of billing. For the Pragmatic and Composite options, the procedure for customer meter readings will be unchanged but the bills will more reflect the energy used.

Stakeholders were asked to provide factors that they would like to see considered through the FBM project. Around 30 different factors were identified and these were grouped into the following themes:

- Cost benefit analysis and end-to-end impact assessments
- Future (concern about FBM remaining flexible and scalable in the future)
- Implementation (assessment of the required changes to IT systems, reconciliation and timeline for transition)
- LDZ operation (flexibility of operation, seasonality and intra-day flow, impact of new sites coming online, various embedded sources within one new CV zone, customers on the borders of the new CV zones, transportation charging)
- Legislation and Codes (impact of widening of GS(M)R if the LDZ FWACV remains unchanged, the changes to legislation and codes if the billing methodology is changed)
- Smart metering and CV measurements (future smart meter configurations, suitability of electric smart meters, low cost CV measurement and the potential for CV measurement to be incorporated within boilers)
- Supplier impact and data flows (data frequency, data volume, loss of data protocols, practicality on of administration, the impacts on shippers' and suppliers' systems)
- Other factors for consideration included assessment of decarbonisation, hydrogen networks, hydrogen/natural gas blends and ensuring that the modelling methods are applicable more generally

Figure 5-4 shows the frequency of each of the themes above by the stakeholders in the consultation responses; the responses have also been spilt by stakeholder group. As the industry body group only comprises a single stakeholder, this stakeholder has been grouped with shippers and suppliers.

Table 5-6 summaries Cadent's commentary to the stakeholder responses on the themes presented in Figure 5-4.

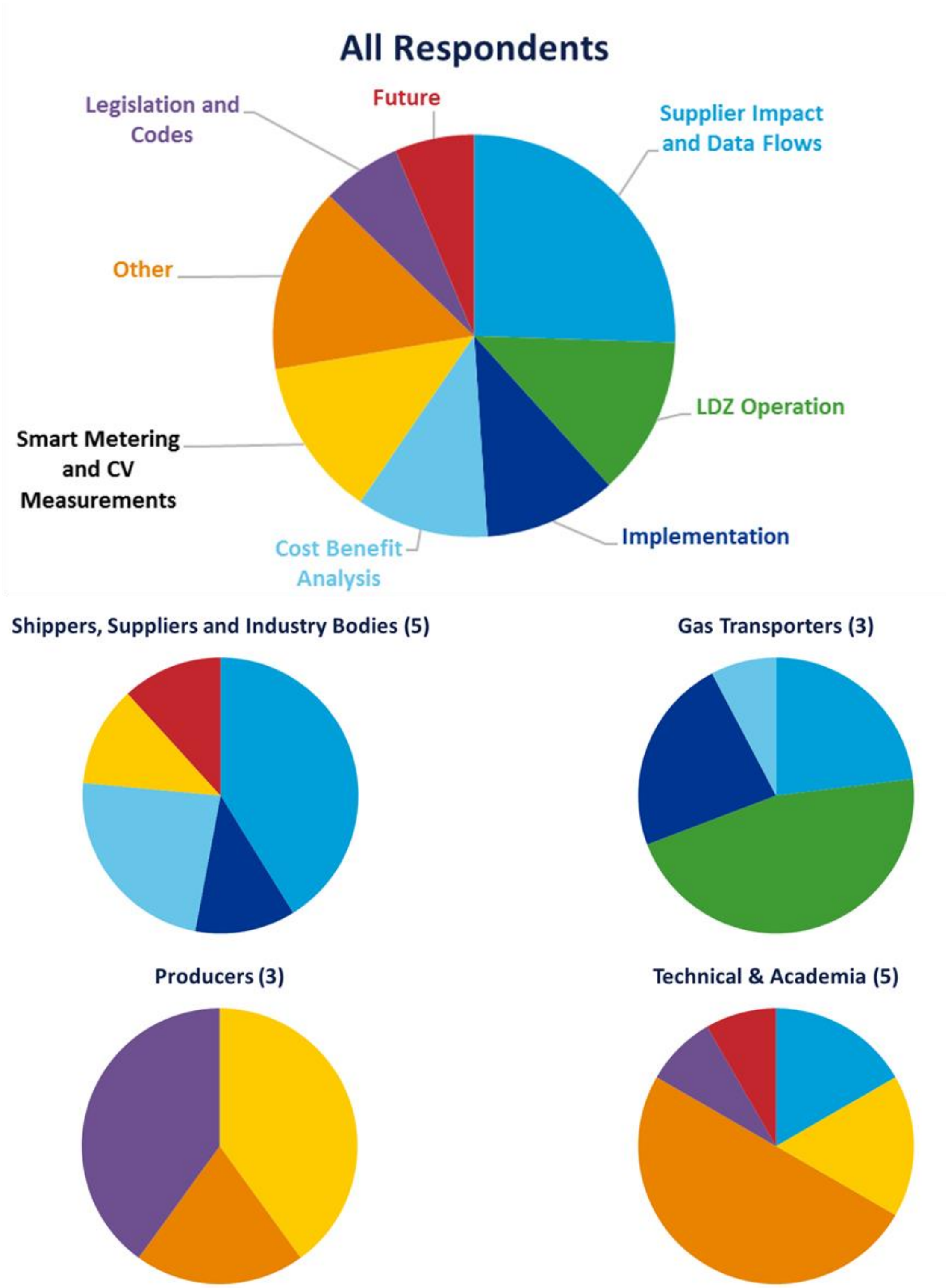


Figure 5-4: Pie chart showing frequency of factors mentioned by all respondents to questions 3 and 5. The results have also been split into stakeholder groups

Table 5-6: Summary of Cadent's commentary on responses to question 5

Theme	Cadent Commentary
Supplier Impact and Data Flows	Cadent understands the concerns relating to the potential impacts to shippers, suppliers and their billing systems. Cadent are in the early stages of investigations with Xoserve on potential options for implementation of CV-zone based billing. The work with Xoserve is assessing the potential of grouping consumers based on their system location and unique meter identifier (SMP). Once Xoserve have provided their initial findings, Cadent will share the output with the external industry subject to the caveats and assumptions contained within the document. Shippers and suppliers will be invited to comment.
LDZ Operation	Cadent understands the concerns of the transporters relating to loss of flexibility when operating the network. The central driver for FBM is to facilitate the decarbonisation of heat using the existing gas infrastructure. To achieve this, the use of diverse gas sources, including renewable biomethane, will need to expand significantly. This would drive changes in the way gas distribution networks are developed and operated. Whilst FBM is focused on the commercial and regulatory frameworks, the impact on the physical operation will be addressed through separate initiatives, with an expectation that cost efficiency will be a key consideration. Regarding impact on transportation charging, customers' absolute energy requirements would remain the same – customers receiving a low CV gas will record a higher metered volume than those receiving a high CV gas but the overall energy content, and hence the customer bill, remains unchanged. About 97% of transportation charging relates to capacity charges. Cadent expects that varying energy content will be accounted for in the Annual Quantity (AQ) review process for Non-Daily Metered (NDM) Supply Meter Points and via the Demand Estimation process which informs NDM End User Category (EUC) load factors used in capacity charging calculations.
Cost Benefit Analysis	Cadent agrees with respondents who have emphasised the need for a robust business case to be built around an end-to-end cost benefit analysis (CBA). A high-level CBA will be delivered as part of Work Pack 4. This high-level CBA will reflect the conclusions from the field trials together with the learning from liaising with Xoserve and further engagement with Shippers and Suppliers. As part of this initial industry engagement, a draft CBA has been created (see Section 6).
Smart Metering and CV Measurements	Cadent recognises that smart meters are not currently specified to receive the data required for the Ideal option although there are some redundant data fields that could be used. The aim of developing this option is to understand the implications of moving to regime where gas is metered based on energy (i.e. CV and volume is measured at the end user).

Theme	Cadent Commentary
Legislation and Codes	Cadent emphasises that the FBM project is a proof of concept that aims to establish whether CV zones can be reliably determined. Required changes to legislation, industry codes and commercial arrangements will be identified at a high level; the detailed drafting of any changes remains outside the scope of this project as per the Gas Network Innovation Guidance. Cadent concurs that the potential forthcoming change to GS(M)R may result in an increase of the upper allowable Wobbe Index and potentially higher target CVs to maintain FWACV. This will significantly increase propane enrichment to bring biomethane up to the FWACV. Cadent believes this potential change to GS(M)R strengthens the mandate for exploring alternatives to the current billing regime.
Future	The field trials will prove whether establishing zones of influence around embedded LDZ connections is achievable. The project is a "proof-of-concept" and, should it be successful, the outputs will provide the essential learning required to extend the methodology across the GB gas network. Information on the potential flexibility of the methodology will also be provided.
Other	Cadent understands that the future of the gas networks could be assessed from first principles (ie re-using the existing infrastructure for a local heat network). FBM project is assessing the possibility to decarbonise heat by using the existing gas networks by being able to inject biomethane and other renewable gases without propanation. The existing gas networks have had the benefit of customer investment for many decades. They already have the physical capability to transport all GS(M)R compliant gases; the capacity to deal with winter peak heat demand and the flexibility to handle large short-term fluctuations in heat demand. The design and execution of the field trials and analysis will take proper account of the physical attributes of the existing gas network in developing algorithms for defining CV zones. It is viewed by some stakeholders that the future deployment of hydrogen blends will aid the decarbonisation of heat. Cadent are supportive of this view.

5.3 Industry's Current Views on What Regulatory (or Other) Changes are Required to support the Continuation of the Project beyond Work Pack 1.

The FBM project was designed to be implemented without any changes to the current gas safety legislation (GS(M)R). Stakeholders were invited to state their opinions on required changes to legislation. Across all stakeholder groups, there were a variety of answers that can be summarized into the following categories:

- Three stakeholders stated that, in their opinion, there would be no change to the regulations; especially for biomethane. It was noted that FBM was designed to work within the existing regulatory framework, but guidance documents may be required.
- Four stakeholders stated that whilst FBM was designed to work within the current regulatory structure, a change in the billing methodology alone may not be sufficient. i.e. changes to GS(M)R will be required to allow methane-hydrogen blends. It was noted that the regulations should be reviewed and modified with or without the implementation of FBM if they were no longer suitable.
- Two respondents identified that is would be necessary to understand the changes that FBM would bring along with changes required for the impact of the other options. A decarbonisation solution with the least regulatory impact is important. i.e. what is the scale of the changes required for each of the pragmatic/composite solutions?
- Five respondents specifically identified that changes to the UNC/OAD and other industry codes would be required. Three respondents identified that there would be commercial issues and requirements around charging, billing and billing presentation to customers; modifications would be required and there may be legal issues surrounding the CV billed against the CV delivered
- Other comments include:
    - The impact on the smart metering rollout which is not compulsory (and its impact on the ideal option)
    - Maintaining consumer trust

A large proportion of respondents expected that the implementation of FBM would require changes to the current commercial arrangements and potentially a change to the legislation (i.e. for the adoption of hydrogen blends). Cadent recognises that changes to the billing and commercial arrangements will require significant changes to the UNC and OAD. It is also recognised that the Composite and Ideal options may require changes to the G(CoTE) Regulations to enable within-LDZ CV measurement to be used for billing purposes and further, that the ultimate implementation of gas energy metering would require fundamental changes to these regulations to enable smart meter-based billing.

At this point, it is important to reiterate that the FBM project is a proof-of-concept to prove that zones of influence around embedded connections can be modelled in a robust, scalable and replicable way. Cadent believes that, if the project is successful in achieving this, there would be significant benefits, both to gas customers and to energy consumers in general from continued use of the existing gas grids as part of the solution to decarbonising heat in Great Britain. The initial high-level CBA, covered in Part 4 of this report, reinforces this view.

5.4 Other Comments

Stakeholders were invited to provide any further comments relating to the FBM project (Question 8, Table 5-2). Not all stakeholders responded to this question. The additional stakeholder responses along with Cadent's commentary are in Table 5-7.

Table 5-7: Summary of stakeholder responses and Cadent's commentary to question 8

Theme	Stakeholder Response Summary	Cadent Commentary
Impact on the GB Gas Industry	Four respondents commented on the potential impact on stakeholders along the gas supply chain including the need for an end-to-end impact assessment and road map for implementation.	Cadent agrees that there will be impacts along the gas supply chain, no matter the route of decarbonisation. Many of these impacts relate to the proposed FBM and information required to create an implementation roadmap will be identified and reported as part of this project.
	One respondent stated that there had been limited consideration to shippers and suppliers to date but had noted that that stakeholder engagement had started to take place.	A webinar was held for shippers and suppliers and a presentation was given at a Transmission and Distribution UNCC Workstream meeting to raise awareness of FBM and to elicit views. Cadent are now in the early stages of investigations with Xoserve on potential options for implementation of CV-zone based billing. Once the initial findings have been provided, shippers and suppliers will be invited to comment. At the end of the project and once all the evidence has been gathered, there will be further opportunity for industry to comment and contribute.
	Three stakeholders mentioned that all the impacts would need to be considered prior to implementation and a full analysis of the end-to-end impacts would need to be completed.	As the aim of FBM is to prove whether zones of influence around embedded LDZ connections can be identified, a high-level CBA will be prepared as part of the project. A full end to end impact analysis will need to be considered later once the technical feasibility of the FBM has been proved.
	One stakeholder stated that implementation of FBM would require input from the Change Overview Board (COB).	This is a very useful comment regarding the COB. The role of the COB needs to be understood and explored.
	One stakeholder noted that the presentation of the project conclusions needs to be suitable for both policy makers and technical experts.	Cadent strongly agrees with this view and is working to achieve this.

Theme	Stakeholder Response Summary	Cadent Commentary
Potential Changes to GS(M)R	Two respondents mentioned other industry projects currently being undertaken within the industry (e.g. Real Time Networks and Opening up the Gas Market) and the proposed review of widening the WN limits specified within GS(M)R. These changes will further increase the need of FBM as propane injection is expected to increase due to high WN LNG being brought to the GB gas market.	Cadent concurs that the potential forthcoming change to GS(M)R may result in higher target average CVs to maintain FWACV. Cadent believes this potential change to GS(M)R strengthens the mandate for exploring alternatives to the current billing regime
Project Delivery	Two stakeholders commented that they were keen to see the implementation of the project.	Noted
Hydrogen Blends	One respondent was encouraged by the reference to hydrogen and hydrogen-blends within the document. They noted that with sufficient stakeholder encouragement, regulation and billing frameworks, the UK could potentially be an early adopter of hydrogen and hydrogen blends.	Cadent noted this comment and regards ongoing developments in hydrogen generation and deployment as vital steps towards a low carbon gas future.

5.5 Summary of Consultation Responses

The aim of the consultation document was to gather stakeholders' opinions and views on the industry engagement objectives (SDRC 9.1a). A summary of the industry's views against each of the industry engagement objectives is given below:

- **Industry's view on the desire for change to the current approach:**

  Generally, stakeholders agreed that the FWACV billing framework does present a barrier to the adoption of low-carbon gases to decarbonise heat. However, there was concern expressed over the impact to shippers, suppliers and GDNs due to the increased data management and changes to the billing system. Cadent have been working with Xoserve to start identifying the required changes to the gas transporter billing system. The results will be used in further engagement with shippers and suppliers and should allow them to begin assessing the scale of dependent changes to their billing systems and interaction with customers.

- **Industry's current views on the level of modelling validation required:**

  Stakeholders agreed that the proposed Measurement and Validation Field Trials could provide an understanding of the zones of influence of LDZ-embedded entry points. Many factors were suggested by stakeholders to be included within the project (including LDZ operation and smart meter configurations). Whilst many of the factors suggested were outside the scope of this project, the key learnings from this project will provide more information on those areas. As part of Work Pack 4, the key learnings will be disseminated to the industry in further stakeholder engagement to gain industry feedback. The key learnings will also inform the industry of the next steps, should the FBM project be successful, towards implementation.

  A large proportion of stakeholder responses have referred to the need for a full end-to-end impact assessment for FBM to be implemented. Due to its nature as an innovation project, it is currently not possible to undertake a full impact assessment without first undertaking the FBM project and assessing its outcomes. A draft CBA has been prepared for Phase 1 (see Section 6). As part of the second phase, the CBA will be updated based on the outcomes of the field trials.

- **Industry's current views on the regulatory changes that may be required to support the project beyond work pack 1:**

  FBM was designed to minimise changes to legislation, but as the project develops, it is recognised that some changes to regulations may be required to support the Composite or Ideal option, should either be implemented. Stakeholders have identified that industry codes (i.e. UNC and OAD) would need to be updated to reflect the changes in the billing framework. Whilst a detailed review of regulations and commercial codes is outside the scope of Ofgem Innovation funding, and hence outside the FBM project, the learning outcomes of the project will inform at high-level where changes to industry codes are required.

  Cadent recognises that the adoption of hydrogen and hydrogen-natural gas blends for transportation in gas distribution networks would need to be supported by a change in GS(M)R to allow greater than the current 0.1 mol% hydrogen limit. However, without FBM, the deployment of hydrogen would not be a realistic option other than on isolated and single-source networks.

  As part of a different industry project, GS(M)R is currently undergoing a review to widen the allowable WN limits. Some stakeholders identified that widening the allowable WN would allow for the importation of LNG; which is known to have a higher WN than gas taken from the NTS.

Importation of high WN gases will increase the target FWACV in affected LDZs and therefore low CV gas inputs would require more propane to be added to counter this. Cadent believes this increases the mandate to explore different methodologies for billing that would overcome the need for standardisation of gas energy content across the LDZ.

In addition to the points discussed through this section, one stakeholder stated that other options for decarbonisation had been previously explored in the NIC bid, but the alternative options were not clearly explained within the consultation document itself. It is noted that there are other options to decarbonise heat in GB from electrification coupled with high efficiency electric heat pumps to full hydrogen conversion, local heat networks and a range of consumer based renewables. Any proposed method (or methods) to decarbonise heat must ultimately replicate the physical capacity, flexibility, reliability and responsiveness currently provided by the existing gas network. Achieving this at a national scale would involve very significant investment, upheaval and modification of consumer behaviour. Whatever options are taken forward, whether with or without FBM, this will result in a cost impact to some or many stakeholders along the gas and energy supply chains. The best solution would strike the right balance between three key factors:

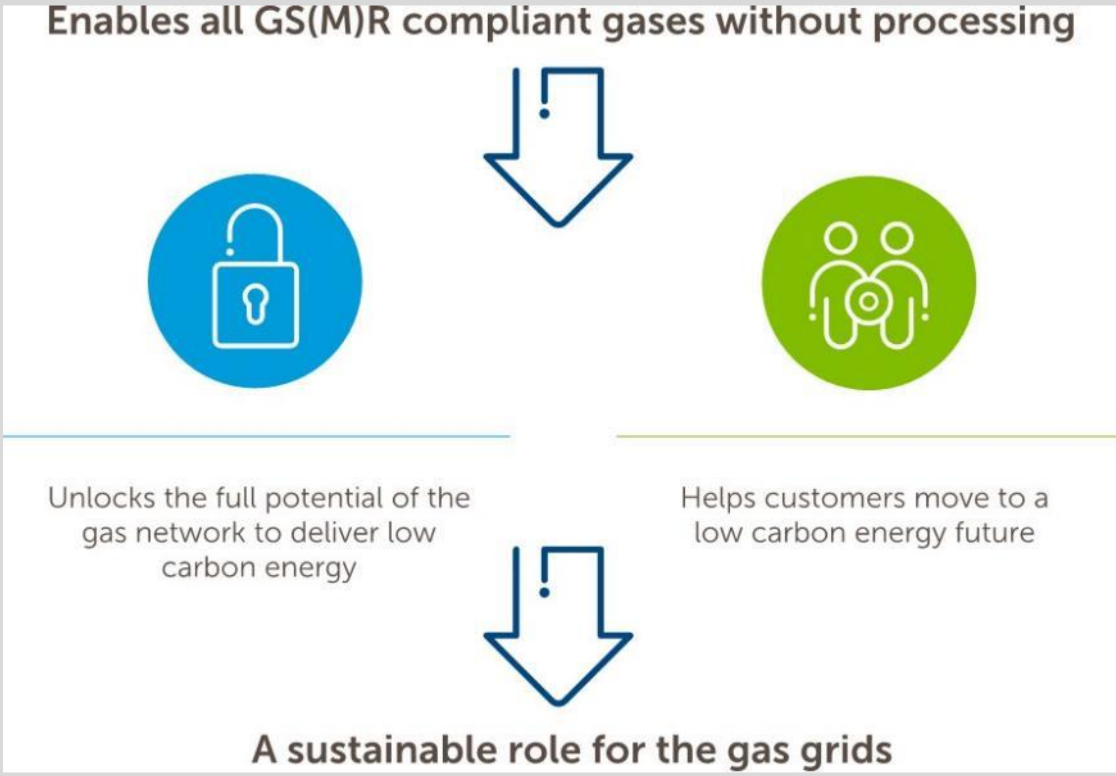
- Decarbonisation potential;
- Cost of implementation, including wider disruption to non-energy infrastructure; and
- Security of supply;

whether that turns out to be a single option or a mixture of solutions. The FBM project provides possibly, compared to the other options, a low impact route to decarbonising the GB heat demand as it utilises the existing infrastructure and end-user appliances. Any changes to national infrastructure are very complex, expensive and disruptive to consumers.

5.6 Summary Findings

There is a clear level of support shown in responses to our FBM Project consultation for exploring the proposed FBM options. Based on this and the strongly positive results of the initial Project CBA (see Section 6), we believe that we have a clear mandate to progress this Project through the field trials and analysis, and to develop the proposed options for further stakeholder engagement and work towards completion of the final project CBA. The stakeholder engagement process will be ongoing and Cadent will continue to engage with existing and new stakeholders throughout the project. Cadent's assessment of the way forward beyond the Ofgem stage gate is given in Section 9.

Part Three – Initial Cost-Benefit Analysis



Future Billing Methodology

6 INITIAL COST-BENEFIT ANALYSIS

6.1 Introduction

The Future Billing Methodology Project, under the Gas NIC, is a "Proof-of-Concept" which explores three potentially evolutionary options for enabling the decarbonisation of GB's gas distribution grids, based on the creation of CV zones for billing. As part of Ofgem's January 2017 Project Direction, Cadent was asked to provide an initial Cost-Benefit Analysis (CBA) of the three scenarios (noting that this would be finalised under Work Pack 4) to demonstrate that, following industry engagement, there remains a strong case to proceed with the Future Billing Methodology Project. This section aims to do the following:

- Explain the approach taken in carrying out the initial CBA
- Summarise the initial CBA results
- Assess the potential for the FBM project in the context of decarbonising heat in GB.

6.2 CBA Methodology

6.2.1 Context

The CBA seeks to compare the cost and benefits in GB of implementing any of the three FBM options against a status quo scenario, a counterfactual in which the FWACV billing framework is retained.

Under the status quo, gas entering the network will continue to be processed to prevent the FWACV cap from being invoked. Low carbon and low calorific value gases will require the addition of propane. Currently, nitrogen is added to LNG to reduce the Wobbe Index but the resultant CV is fortuitously the same as the prevailing FWACV. However, if the maximum value of the Wobbe Index under GS(M)R is increased, then it is possible that nitrogen will also need to be added to the gas to reduce the CV as shown in Figure 6-1.

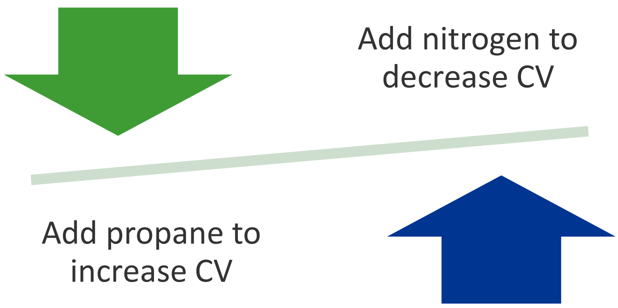


Figure 6-1: Maintaining the FWACV by increasing and decreasing the CV of the gas supply to the LDZs. This picture assumes that the upper GS(M)R Wobbe Index limit will be increased from the current value.

There are three evolutionary project options - pragmatic, composite and ideal, as previously described in Section 2 and the ease of implementation, costs and benefits are summarised in Table 6-1.

Table 6-1: The three FBM options

Option	Description	Ease of Implementation	Costs	Benefit
Pragmatic	CV zones for embedded inputs only	High	Low	Early realisation of benefits
Composite	CV zones for all inputs & replaces FWACV	Medium	Med	More robust protection from cross subsidy Minimise CV shrinkage in complex distributed supply models
Ideal	CV attributed to smart meter	Low	High	As for composite and long term enabler for fully smart gas networks

The following sections set out how we have identified relevant costs and benefits to be assessed in comparing the status quo with the FBM options. The Net Present Values of each option have been calculated for selected National Grid 2017 Future Energy Scenarios (FES).

6.3 Identifying costs and benefits

6.3.1 Costs

As a starting point of our assessment, we have undertaken a high-level analysis to map out the potential impact of FBM options along the gas supply chain (see Figure 6-2).

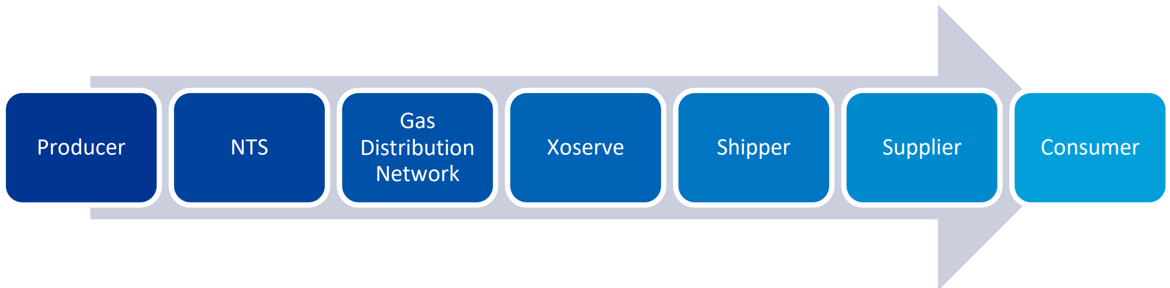


Figure 6-2: Stakeholders along the gas supply chain.

We consider the impact of FBM is that, for each option, a change in the billing methodology requires (or enables) stakeholders along the value chain to change existing activities or processes, or to undertake new activities, which can lead to additional costs, or benefits (in the form of cost savings). Table 6-2 below maps out the impacts of FBM options, compared to the status quo, along the gas supply chain – and forms the basis for our modelling of costs and benefits.

Table 6-2: Implementation impacts for each FBM option. Future gas supplies are shown in *italics*, costs are red and benefits are green.

Stakeholder	Status Quo (retain FWACV)	FBM Implementation – impacts under each option		
		Pragmatic	**Composite**	**Ideal**
Producer	Continued processing to standardise CV for UKCS, interconnector and *shale* Embedded inputs of biomethane, LNG boil-off gas, *bio-syngas, hydrogen blend and shale* *Increased nitrogen ballasting if GS(M)R upper Wobbe Index is increased*	Remove the need for propanation of embedded inputs to meet target LDZ CV	Remove the need for processing to meet target LDZ CV including nitrogen ballasting if GS(M)R upper Wobbe Index limit is increased	Remove the need for processing to meet target LDZ CV including nitrogen ballasting if GS(M)R upper Wobbe Index limit is increased
NTS	No saving - continued management to minimise CV shrinkage	No change	Flow management removal to minimise CV shrinkage	Flow management to minimise CV shrinkage
	No saving – continued use of energy tracking	Small impact on energy tracking costs due to increased number of CV zones	Modification to energy tracking process	Modification to energy tracking process
Gas Distribution Network	No saving – continued management and monitoring of the distribution network	No extra equipment Network analysis for defining zone of influence Managing additional low carbon gas connections	Network analysis for defining zone of influence Additional CVDD Change to G(CoTE) regulations Managing additional low carbon gas connections	Network analysis for defining zone of influence Additional CVDD Change to G(CoTE) regulations Managing additional low carbon gas connections
		Minimal GDN opex	Increase in opex	Increase in opex

<table>
<tr><th rowspan="2">Stakeholder</th><th rowspan="2">Status Quo (retain FWACV)</th><th colspan="3">FBM Implementation – impacts under each option</th></tr>
<tr><th>Pragmatic</th><th>Composite</th><th>Ideal</th></tr>
<tr><td>Xoserve</td><td>No saving - NTS/GDN transportation billing remains the same</td><td>Billing system implementation</td><td>Billing system implementation</td><td>Billing system implementation – transfer of some costs to DCC</td></tr>
<tr><td>DCC</td><td>Current development plan</td><td>No change</td><td>No change</td><td>Upgrade DCC for additional data transfer</td></tr>
<tr><td>Shipper or supplier</td><td>No saving - shipper billing to supplier. continues as is.</td><td>Revised interface with Xoserve</td><td>Revised interface with Xoserve</td><td>Revised interface with Xoserve</td></tr>
<tr><td rowspan="2">GB Consumer</td><td rowspan="2">No saving – consumer gas billing remains the same, however, inability to decarbonise the existing gas grid forces alternative approaches to decarbonisation such as electrification or distributed alternatives resulting in significant increase to energy bills (gas distribution decommissioning costs?). Active decommissioning of above 7 bar and then a range of decommissioning approaches for the remainder of the gas distribution system.</td><td rowspan="2">Fairer gas bills.

Greener gas supply and avoidance of some costs for decarbonisation of heat</td><td rowspan="2">Fairer gas bills.

Greener gas supply and avoidance of more of the costs for decarbonisation of heat</td><td>Fairer gas bills.

Greener gas supply and avoidance of more of the costs for decarbonisation of heat</td></tr>
<tr><td>Smart meters – FBM confers additional benefit to smart meter roll-out</td></tr>
</table>

6.3.2 Benefits

We consider the principal benefits from the FBM project to be:

- Cost savings from the removal of propane enrichment
- Monetised carbon savings from the displacement of propane by renewable gases
- Monetised carbon savings achievable through an increased uptake of renewable gases informed by the FBM project outcome and implementation of the recommended option.

In addition, we consider that there is a potential benefit from reducing CV shrinkage costs but, for the initial CBA assessment, this has not been quantified; however, it is anticipated that this benefit will be quantifiable after further engagement with National Grid Gas Transmission in phase two of the project.

If the upper Wobbe Index limit of GS(M)R is increased, then this will also increase the CV of gas. Large volumes of LNG will then enter the transmission and distribution systems with reduced or no nitrogen ballasting and the FWACV in some, or all, LDZs will increase. Low carbon and low CV gases will need additional propanation as the target LDZ CV will be higher.

6.4 CBA Modelling

We have based the initial CBA on the FBM Net Present Value (NPV) Model used for the initial project submission in 2016, and have continued to use National Grid's Future Energy Scenarios as a basis for projecting benefits that can be expected to accrue from implementation of each of the FBM options. However, we have reassessed the basis for the costs and benefits and have made some updates to the FBM NPV model used in the NIC bid submission; the changes are set out in Table 6-3.

6.4.1 FES version update

We have retained the use of the gas supply projections from National Grid's *Future Energy Scenarios* as a platform for evaluating projected benefits of the FBM Project. However, we have updated the 2016 scenarios with those published in July 2017, in which the 2016 *Gone Green* and *No Progression* scenarios have been replaced with *Two Degrees* and *Slow Progression* respectively.

Although we have retained all four gas scenarios in the FBM NPV Model, we have focused on *Two Degrees* and *Slow Progression* for CBA results, as we regard these to be the most relevant for assessing the benefits of gas decarbonisation. *Two Degrees* was the most relevant scenario as it best fits with the pathway of decarbonisation which is central to the aims of the FBM project. *Slow Progression* shows a more conservative picture and can be used to assess the sensitivity for the CBA.

Each of these gas supply scenarios sees changes over the 2016 versions, but most relevant here are changes to the renewable gas assumptions. Each scenario shows an updated profile compared with 2016, with lower supply to 2037, but higher thereafter and now extended to 2050. For the NIC bid submission, Cadent used the 2016 FES which only projected to 2040 and flat volumes for gas supply were assumed between 2041 and 2050.

Table 6-3 : Updates to FBM NPV model over that used in the NIC submission document

Item	Update
FES Version	Updated from 2016 to 2017
FES Volumes – conversion to energy	Converted from billions of standard cubic metres of gas (BCM) to energy (TWh) using an assumed CV of 39.46 MJ/m^3
Implementation costs	Enhanced identification of potential implementation costs included for Pragmatic, Composite and Ideal options
Benefits - propane savings	Saving from removal of propane-enrichment requirement for low CV gas reassessed using information from *Element Energy*/1/ January 2017 report to account for full additional costs
Benefits - carbon abatement value from propane removal	Inclusion of monetary value of carbon savings from removal of propane, using table 3 of UK Government published values /9/ for carbon content of propane and biomethane and traded values of carbon for future years to 2050
Benefits: Carbon abatement value from increased uptake of renewable gases	Inclusion of Cadent's vision to achieve the uptake of 108 TWh of renewable gases via GB gas distribution grids by 2050 and the monetised carbon savings that would be achieved by this in place of natural gas, using the same evaluation method as above for propane removal
General	Discounting approach unchanged. General changes to formatting and ordering of sheets to improve clarity and transparency of methods. Consolidation of inputs in one sheet with indexing facility to adjust 2016-17 input values to a 2017-18

6.4.2 FES Volumes – Conversion to Energy

To support our updated assessment of the future benefit from the removal of propane enrichment (see Section 6.4.3), we have converted National Grid's FES volume-based supply projections in the FBM NPV Model to energy values by using a CV of 39.46 MJ/m^3 (this was the GB system average CV for 2015-16).

6.4.3 Implementation Costs

As we are still at a very early stage in the FBM Project, implementation costs remain highly uncertain. However, we have structured inputs in the FBM NPV Model to take account of various sub-categories of capex and opex, to reflect the cost lines that we would expect to see and to phase these costs correctly for discounting purposes. The cost sub-categories under capex are set out in Table 6-4 and those under opex are shown in Table 6-5. Where we have costs estimates from third parties, we have applied those. Elsewhere, where we have information that can help to create a cost estimate, we have applied this and stated the assumption. Otherwise, we have applied an initial high level assumption, principally to act as a "ground marker" to drive more detailed assessment as we work towards the final project CBA for delivery in late 2019. The FBM NPV model now provides a toolkit to support a more detailed assessment for the final CBA in work pack 4.

Table 6-4: Implementation cost categories included under capex in the FBM NPV model

Capex	Description of cost line	Assumption
NTS/GDN (Xoserve) billing systems	Xoserve changes to gas transporter billing system to deliver each FBM Option	As per Initial Assessment from Xoserve
Update to GEMINI / Energy Tracking Process	Updates system & process for recording of daily CV measurement to support additional CV zones for each FBM Option	High-level initial assumption of half the cost of Xoserve billing changes
GDNs develop CV Zone : SMP X-Ref file	Aim is to create a physical link between Supply Meter Point and GDN network model node to support a robust definition of CV zones	High-level initial assumption
Shipper/Supplier billing systems	Changes to client systems to reflect CV zone structure under each FBM Option	Based on early work under UNC Review Group 0251 in 2009
Gas Code / Regulations Updates *	Changes to Uniform Network Code (incl. Offtake Arrangements Document) and G(CoTE)Regs for each FBM Option	Cadent - high-level initial assumption
DCC System & SMART code updates *	Changes to facilitate CV attribution to smart meters under Ideal Option	Cadent - high-level initial assumption
GBNA update	Update to Cadent network analysis model to support CV zone modelling (Other GDNs use Synergy, which has capability now)	DNV GL estimate
CVDD & Flow metering	Supply & installation of additional within-LDZ CV measurement and flow meters to support CV attribution under Composite & Ideal Options	DNV GL Estimate – based on Orbital cost exercise, but would be subject to tender
Cloud Set-up Cost	Set-up CV zone and CV data repository for Composite and Ideal Options	DNV GL estimate based on other projects

***Included under capex here as a one-off cost the in NPV model for simplicity of phasing**

Table 6-5: Implementation cost categories included under opex in the FBM NPV model

Opex	Description of cost line	Assumption
GDN Initial allocation	GDN set-up activities to create and validate CV zones for each FBM Option	DNV GL initial estimate
Initial billing support - Xoserve	Set-up activities for delivering changes to gas transporter billing systems	Initial assumption – mirrors GDN set-up cost
Initial billing support - Shippers/suppliers	As above – for client systems	Initial assumption – mirrors GDN set-up cost
GDN Annual review	Anticipated annual review of CV zone structure to ensure continuing robust CV attribution	DNV GL initial estimate
Annual billing support - Xoserve	Ongoing additional Xoserve activities related to CV zone based billing (no future efficiencies assumed at this early stage)	As per Xoserve Initial Assessment
Annual billing support - Shippers/suppliers	Ongoing additional client activities related to CV zone based billing (no future efficiencies assumed at this early stage)	Initial assumption – mirrors GDN annual review cost
35 day Ofgem test (per CV device)	Required under the G(CoTE)Regs – cost estimates for this are based on a streamlined validation process which eliminates some physical activities	DNV GL initial estimate – based on streamlined validation process proposed by Orbital for discussion
GPRS Cost	Cost of maintaining GPRS service for CV data polling	DNV GL estimate – based on other projects
Data Cloud Maintenance	Ongoing cost of virtual data repository	DNV GL estimate – based on other projects
DCC set-up resource for CV data handling	DCC Start to handle gas CV data	Initial view from DNV GL - activity is already within DCC specification and should therefore carry no incremental cost
Increased DCC cost (ongoing data handling)	DCC ongoing CV data handling	As for above

6.4.4 Benefits: Propanation Savings

Our initial NPV assessment for the FBM Project NIC submission in 2016 based its evaluation of the savings achievable from removing the need to enrich low CV gases such as biomethane purely on the differential between the bulk commodity costs of propane and natural gas. For this CBA, we have enhanced our evaluation method, in the light of external information on the wider costs associated with propane enrichment including additional equipment requirements (see Appendix B). Section 3.2.2 of the January 2017 *Element Energy* report /1/ provides an overall incremental cost of 0.3 p/kWh for propanation, based on an additional annualised cost of £150k for a typical biomethane plant injecting 500 scmh into the gas distribution grid.

The 0.3 p/kWh unit saving value is multiplied by the projected volume of renewable gas in the selected National Grid FES to produce a stream of raw benefits to 2050 in £m, commencing the year after implementation of the relevant FBM Option. This is then subject to discounting, as described in Section 6.5 below.

6.4.5 Benefits: Carbon abatement from removal of propanation

In addition to the cost saving from removing the need for propanation of low CV gases, we have monetised the carbon abatement benefit that would result from the displacement of propane by biomethane as explained in Section 6.4.6. Biomethane is virtually zero carbon, as it recycles carbon already within the environment in a short-term cycle as opposed to natural gas and propane which are fossil fuels. We also assume that biomethane plants would increase their output to meet their gross volumetric injection targets once propanation is removed. We have used metrics published in table 2a of UK Government data (see reference /9/) to quantify the carbon abatement benefit, as shown below.

Table 6-6: UK Government factors used to quantify carbon benefits

Biomethane ($kgCO_2e$)		Note
GJ	0.10850	Scope 1 rate from UK Government GHG Conversion Factors for Company Reporting /9/
MJ	0.0001085	
kWh	0.0003906	
Conv.	277.777778	

Carbon emissions and savings ($kg(CO_2)/kWh$)		Note
Biomethane (CV=37 MJ/m^3)	0.0003906	
LPG	0.2141904	BEIS Guidance, Table 2a /9/
Saving (biomethane over propane)	0.2137998	Carbon benefit of displacing propane with biomethane
Natural gas (CV = 39 MJ/m^3)	0.1836453	BEIS Guidance, Table 2a /9/
Saving (biomethane over natural gas)	0.1832547	Carbon abatement quantity from incremental renewable gas to 2050

Having quantified the carbon abatement in tonnes of CO_2 equivalent, we price this benefit using the central case traded carbon values for each year to 2050 from UK Government data (Table 3 in reference /9/) to produce a stream of raw benefits to 2050 in £m, commencing the year after implementation of the relevant FBM Option. This is then subject to discounting, as described in Section 6.5.

6.4.6 Benefits: Carbon abatement value from increased uptake of renewable gases

We believe that the removal of the requirement to enrich low CV gases such as biomethane and other renewable gases will act as a catalyst to achieving a significant increase in the deployment of these gases in the gas distribution grid and we have created a scenario in the FBM NPV Model which reflects the potential of 108 TWh[2] of renewable gas by 2050. We have quantified the incremental benefit using the differential carbon rate between natural gas and biomethane (shown Table 6-6) and monetised this in the same way as described in Section 6.4.5 above.

6.5 General

6.5.1 Discounting

We have retained the discounting approach prescribed in the NIC Governance Document and which was used in the initial NIC project submission. For years 0 to 30 we have used a discount rate of 3.5% with 3% thereafter.

6.5.2 Indexation

Indexation has been included to ensure that input costs can continue to be assessed on a consistent basis as the FBM NPV Model is further developed throughout the Project.

6.5.3 Exclusions from the Initial CBA

At this early stage, we have excluded two potential costs related to the increased uptake of renewable gases that we expect FBM will facilitate:

- Marginal cost of renewable gas production, and
- Potential system reinforcement costs to facilitate the injection of significant future volumes of renewable gases at embedded locations

These are excluded these because of the uncertainty which surrounds them, and because we would need a fully costed counterfactual case(s) for other decarbonisation options, such as electrification and/or heat networks, which could play out in a number of permutations.

For marginal costs of production of renewable gases, we initially considered using the RHI as a basis for assessment. However, this would imply that the incremental costs of renewable gas production would continue to be higher than fossil gas costs into the future. Rather, we believe that a combination of factors (economies of scale, reductions in required hurdle rate of return, reduction in construction risk premium, etc.) combined with expected increases in fossil fuel prices, could well see renewable gas production costs becoming comparable with fossil gas costs by the mid-2020s. Furthermore, the future inclusion of the cost of carbon within fossil gas prices could make renewable gas production economically favourable.

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[2] The potential of 108 TWh of renewable gas by 2050 is derived in a Cadent bio-resources study that is in preparation and which will be published shortly

For system reinforcement, it is logical to assume that the connection of numerous additional embedded renewable gas inputs will require significant changes in the way in which we construct and operate gas distribution networks. However, at this early stage, the range of potential approaches to providing off-peak capacity to support flat embedded supply profiles has yet to be developed and costed, and the most cost-effective solution for one connection could be quite different from another. At this stage, there is not the data to make any meaningful assessment of these potential costs.

In the other direction, we could expect to see potential benefits from the future removal of LNG ballasting with nitrogen from changes to GS(M)R proposed by SGN's NIC Project "*Opening up the Gas Market*" /10/, which would be supported under Composite and Ideal FBM options. Without FBM this will drive a requirement for increased propane enrichment for low CV gases such as biomethane. However, removal of LNG ballasting costs is a benefit for the SGN project that should not be double-counted here.

6.6 Wider considerations

Recent energy industry reports from KPMG /8/, Policy Exchange /11/ and Imperial College London /12/ indicate that the electrification of heat could cost the UK up to £300bn in broad terms. Based on the initial indications from our CBA at this stage, we believe that the future implementation of a zonal CV billing framework could facilitate the decarbonisation of a significant proportion of the GB heat load by 2050, because it is the key enabler for a range of gas-based solutions that would maximise the use of renewable gases and support the deployment of hydrogen.

We believe this could save the UK well over £100bn in additional investment in electrification. We also see FBM as key to underpinning future security of supply in an ever more diverse gas market.

6.7 CBA Model Results for the *Two Degrees* and *Slow Progression* Scenarios

Summary tables from the *Two Degrees* and the *Slow Progression* 2017 FES result are shown in Table 6-7 and Table 6-8. The results are also NPV positive and robust when calculated against the other three 2017 *FES, Steady State, Slow Progression and Consumer Power.*

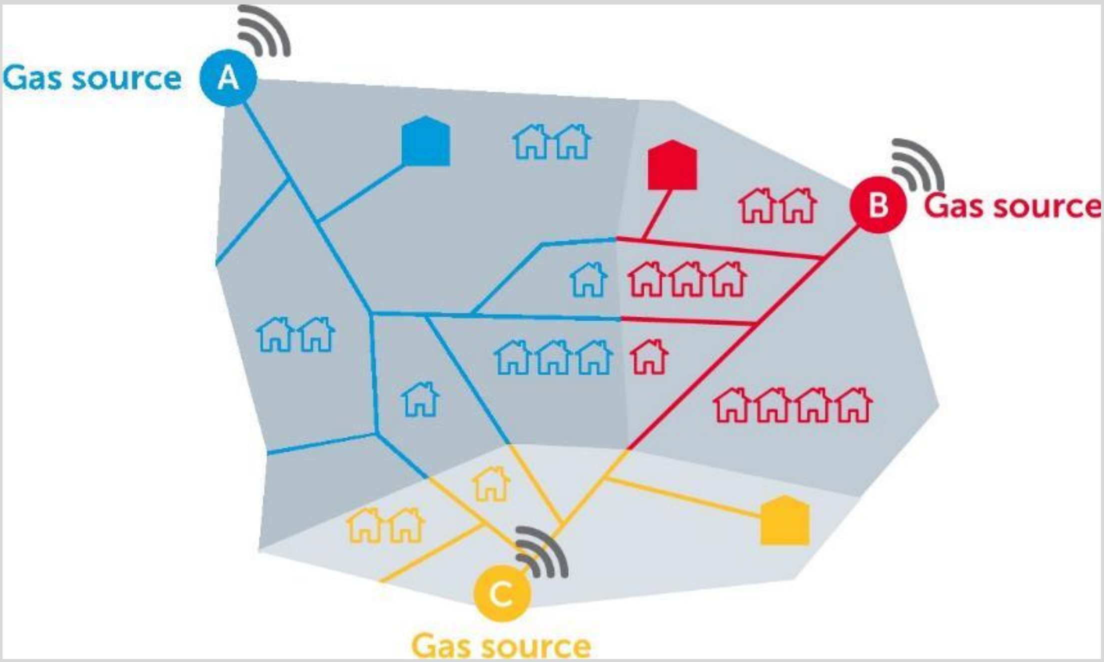
Table 6-7: Summary Table for the Cost Benefit Analysis for the 2017 Future Energy Scenario *Two Degrees*

FES:	2017 Two Degrees	FBM:	PRAGMATIC			COMPOSITE			IDEAL		
Cumulative NPV to end of year		Units	2030	2040	2050	2030	2040	2050	2030	2040	2050
NPV costs	Project	£m	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Implementation	£m	35.1	36.0	36.7	298.1	313.0	324.2	623.0	686.0	733.3
	Costs Total	£m	40.6	41.5	42.2	303.5	318.5	329.7	628.5	691.5	738.8
NPV benefits	Removal of propanation requirement	£m	271.9	941.3	1,712.3	241.8	911.2	1,682.2	170.6	840.0	1,611.0
	Carbon – propane removal	£m	54.2	330.7	837.1	50.6	327.2	833.6	39.6	316.1	822.5
	Carbon - FBM- Facilitated growth of renewable gas	£m	362.4	2,725.7	7,910.2	290.7	2,552.1	7,699.0	158.1	2,190.3	7,252.7
	Benefits Total	£m	688.5	3,997.7	10,459.6	583.2	3,790.5	10,214.9	368.3	3,346.4	9,686.2
Net NPV		£m	647.9	3,956.2	10,417.5	279.6	3,472.1	9,885.2	-260.1	2,655.0	8,947.5

Table 6-8 Summary Table for the Cost Benefit Analysis for the 2017 Future Energy Scenario *Slow Progression*

FES	**2017 Slow Progression**	**FBM:**	**PRAGMATIC**			**COMPOSITE**			**IDEAL**		
Cumulative NPV to end of year		Units	2030	2040	2050	2030	2040	2050	2030	2040	2050
NPV costs	Project	£m	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
	Implementation	£m	35.1	36.0	36.7	298.1	313.0	324.2	623.0	686.0	733.3
	Costs Total	£m	40.6	41.5	42.2	303.5	318.5	329.7	628.5	691.5	738.8
NPV benefits	Removal of propanation requirement	£m	157.1	514.3	916.7	138.7	495.9	898.3	96.7	454.0	856.4
	Carbon – propane removal	£m	31.1	178.3	442.6	28.9	176.2	440.4	22.4	169.7	433.9
	Carbon - FBM- Facilitated growth of renewable gas	£m	188.4	1,417.4	4,113.4	151.2	1,327.1	4,003.6	82.2	1,139.0	3,771.5
	Benefits Total	£m	376.6	2,110.0	5,472.6	318.8	1,999.2	5,342.3	201.4	1,762.6	5,061.7
Net NPV		£m	336.0	2,068.5	5,430.4	15.2	1,680.7	5,012.6	-427.1	1,071.1	4,323.0

Part Four – Field Trial Preparation



Future Billing Methodology

7 INITIAL MODELLING AND DESIGN WORK

7.1 Overview

The consultation responses show that there is a wide level of Industry support for the validation of the modelling technique. Cardiff University were the only respondent who raised a concern stating they ‘believed that it would be difficult to get mathematical models to agree with the field trial measurements, and that it would be a significant challenge to designate CV zones with clear boundaries’. In response, DNV GL opened a dialogue with Cardiff University and clarified the modelling and field trial methodology. The network analysis software tool, Synergi, has the capability to model energy use and transported gas CV. The boundaries will be evaluated during the project to define a fixed boundary for the application in charging areas.

The FBM project was designed to develop an understanding of the zones of influence of gas supplies from specific input points. Initially, the zones of influence have been identified using Cadent’s existing network analysis models. However, to give confidence in the proposed modelling technique for billing purposes, these zones of influence will need to be validated by measurements. The network models will be validated using recorded data from:

- Governor inlet and outlet pressures
- Indication of volume flow through some of the governors
- Tracking of biomethane at entry and through the network using oxygen sensors

As part of stage 1 of the FBM project, a funding allowance of £250,000 was provided to develop generic designs for the field trials and to facilitate rapid implementation after Ofgem approval to progress to stage 2.

A schematic of the field trials was shown in the NIC proposal and it is reproduced in Figure 7-1. The Hibaldstow network covers a wide geographical area and is shown at the top of the diagram. The Chittering network is local to the Cambridge area and it is shown at the bottom of the diagram.

When installing or modifying any equipment or assets on the Cadent network there are several procedures and specifications that need to be adhered to before work can commence. The approach is risk-based and the evidence and paperwork needs to be approved and appraised by registered experts to ensure the safety and integrity of the gas network and the gas supply. For the FBM project, detailed design packs that comply with three management procedures /5/6/7 (see Figure 7-2) will be required. In stage 1 of the FBM project, work was started on

- The initiation of the process for approval and appraisal of equipment that is new to the Cadent network
- Generic designs for each of the three categories of sites.

In stage 2 of the project, the generic designs will progress to site specific designs that will require individual approval and appraisal prior to installation of equipment for the field trial.

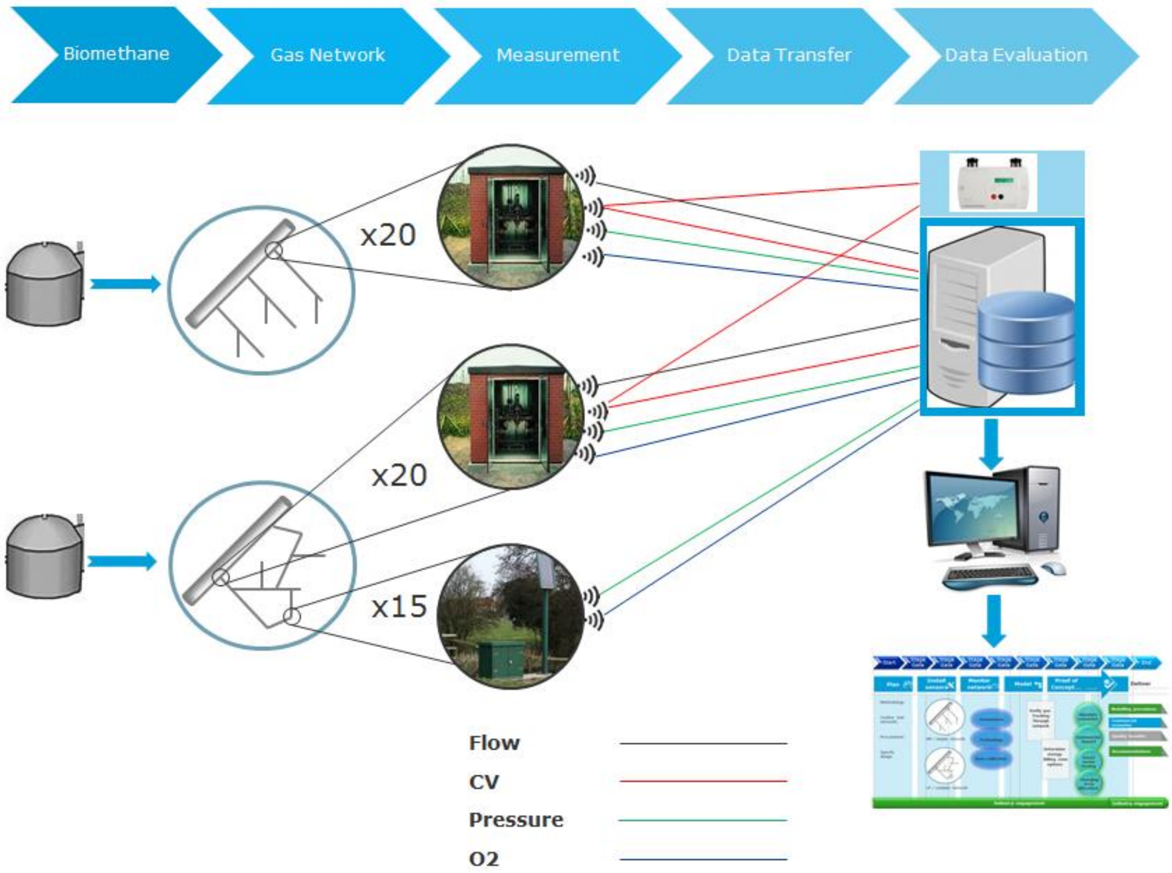


Figure 7-1: Schematic diagram of the field trials to show the types of measurements and the data transfer

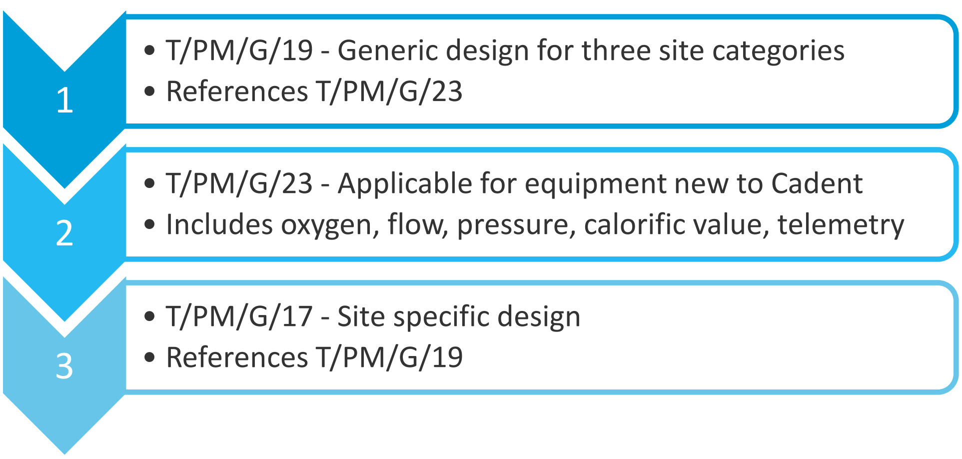


Figure 7-2: Cadent Management Procedures for Approval and Appraisal of Sensor Installation Designs

7.2 Methodology for Determining the Field Trial Site Locations

All Gas Distribution Networks (GDNs) have computer models of their gas transmission and distribution networks that are validated against measured pressures and flows (where available) for operational and capital investment planning. The FBM Project looks at the application of these existing models for the development of a new methodology that would more closely align the billed CV with the actual CV of the gas supplied. The installation of sensors will provide data to provide additional validation support, to demonstrate that network modelling can be used to show the movement of different gases through the network.

The field trials will involve installation of sensor equipment at 40 governor stations associated within the Chittering and Hibaldstow biomethane entries and a further 15 installations at street level in the low pressure network feeding from Chittering – the total of 55 sites have been broken down into three categories:

1. 36 governor stations with biomethane tracking, pressure and flow measurement split between Chittering and Hibaldstow
2. 4 governor stations with biomethane tracking, pressure, flow and calorific value measurement split between Chittering and Hibaldstow
3. 15 street level installations with biomethane tracking and pressure measurement at Chittering

The initial modelling and design work was carried out in several stages:

1. The possible conditions for the operation of each network during the period of the field trials was considered.
2. Network analysis modelling was undertaken to understand the predicted penetration of the Chittering and Hibaldstow biomethane supplies into the mains networks at varying demand conditions.
3. The results from the analysis were used to determine a list of more than 40 governor stations that are both within and outside the predicted zones of influence for Chittering and Hibaldstow.
4. A list of 15 street locations and some possible alternative sites at Chittering were identified.
5. Where possible, options were provided for sensor locations to allow final selection based on site survey suitability results.
6. Detailed maps and locations for each site were generated to facilitate site surveys
7. Site survey check lists were drawn up and agreed by Orbital Gas Systems (the contractor designing, supplying and installing the equipment) and DNV GL
8. Cadent provided supervision for the site surveys by Orbital Gas Systems and DNV GL. The surveys took place over several days (during March & April) and were carried out in compliance with the Cadent *Safe Control of Operations* procedures
9. A final selection of 40 governor station and 15 street sites was drawn up which optimised the position on the network for understanding the zones of influence and the practicality of installing the equipment.
10. Orbital Gas Systems worked with the project team to identify and agree the management procedures and design packs required.

11. Orbital Gas Systems worked with the project team to identify and agree the selection of sensor equipment and the generic installation design solutions.
12. As this is an innovation project, much of the equipment has not been installed on the Cadent network previously therefore T/PM/G/23 design packs were generated for sign-off by Cadent.
13. Due to the number and similarity of sites, generic T/PM/G/19 design packs were generated.

This methodology has ensured that the FBM project team are fully prepared to implement stage 2 of the project in a timely manner.

7.3 Sensors

The sensors to be installed comprise:

- Oxygen to track biomethane from Chittering and Hibaldstow
- Pressure and governor regulator position to give an indication of flow
- Calorific value

7.3.1 Biomethane Tracking Using Oxygen Sensors

GS(M)R requires the oxygen content of natural gas to be less than 0.2 mol% and network entry agreements to the NTS typically specify an oxygen limit of 0.001 mol%. However, there is an HSE exemption to GS(M)R allowing biomethane to enter the distribution networks with oxygen content of up to 1 mol% (see footnote [3]). It should be possible to track biomethane using high oxygen content as a marker.

Sensors that can discriminate between 10 ppm (the GS(M)R limit) and 10,000 ppm (the HSE exemption for biomethane) are commercially available and already in use at entry points to the NTS and by biomethane producers. A spot check on the oxygen content of biomethane leaving Chittering and Hibaldstow confirmed that the oxygen content was between about 2000 and 3000 ppm (see Figure 7-3); this varies depending on the biogas clean-up process.

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[3] The HSE has allowed a class exemption to GS(M)R to allow network conveyance of gas with an oxygen content ≤ 1% (molar) at pressures up to 38 bar. The exemption certificate will be held by HSE.
This now means that gas conveyors will no longer need to request bespoke exemptions to GS(M)R where:

- Pipes used to convey gas with an oxygen content up to and including 1% (molar) are operated at pressures below 38 bar; and,
- The gas conveyed complies with all other requirements and prohibitions imposed by regulation 8(1) of the GS(M)R.

In the absence of a current industry standard for biomethane quality the gas distribution networks (GDNs) have all confirmed that, as part of their network entry controls, they will insist on the application of activated carbon filters by biomethane producers prior to network injection of biomethane. HSE is satisfied that this precautionary approach will ensure the removal of contaminants to a safe level until such time as an applicable industry standard becomes available.

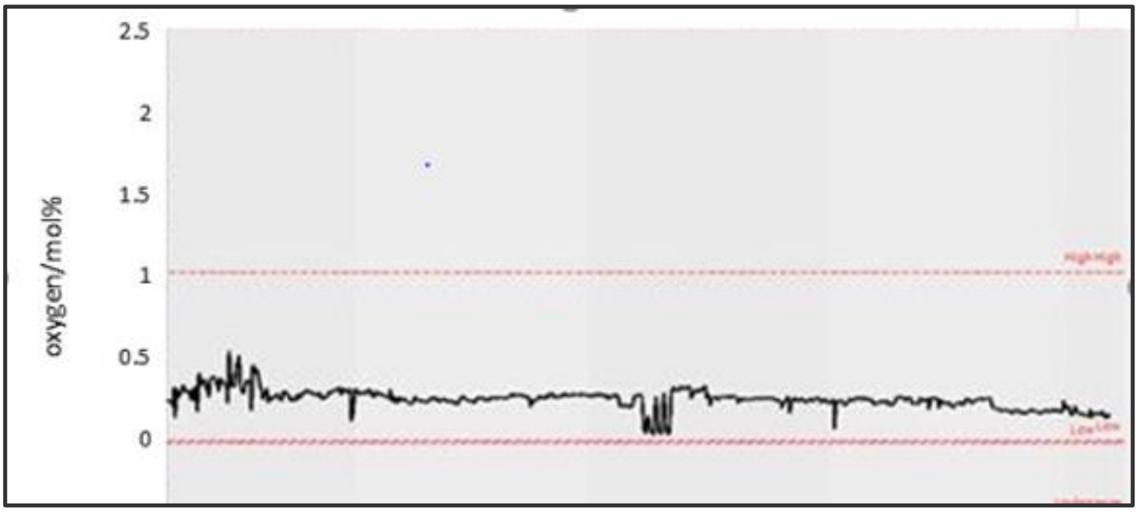


Figure 7-3: Oxygen concentration from one of the biomethane sites over a four-month period

The oxygen sensor is manufactured by Systec (see Figure 7-4) who are based in the US and the UK. It is suitable for installation in zone 0 hazardous areas and therefore suitable for use in this project.

The EC91 Systec analyser can detect oxygen levels from as low as 1 ppm up to higher percent levels in natural gas.

The sensor itself is electrochemical and consists of an anode, electrolyte and air cathode together with a diffusion limited capillary. The rate of diffusion is related to the oxygen concentration. The electrochemical equation involves the oxidation of lead to lead hydroxide:

$$2Pb + O_2 + 2H_2O \rightarrow 2Pb(OH)_2$$

Figure 7-4: The Systec oxygen analyser to be used for tracking biomethane

7.3.2 Flow and Pressure Measurements at Governor Stations

An innovative and low-cost gas flow measurement technique was developed by Advantica (now part of DNV GL) in 2002; the method relates gas flow and pressures at the inlet and outlet to the open/closed percentage of the governor regulator – see Figure 7-5. This is the first application of this method since the initial field trial.

Figure 7-5: A typical dual stream governor for reducing pressure into the distribution networks

Figure 7-6: Close-up of the flow indicator installed on a governor station regulator

The valve travel is monitored by a transducer mounted through the regulator housing and in contact with the diaphragm (see Figure 7-6) and this is related to flow. The measured flow is also a function of pressure so each type of governor was characterised over a range of pressures. Part of the site selection criteria involved cross-checking the governors at Chittering and Hibaldstow against the existing database of categorised governor types.

7.3.3 Calorific Value Measurements

Calorific value will be measured at four selected sites to demonstrate transmission to smart meters. The sites have been selected to provide additional validation information to the network models.

CV will be measured by the GasPT which is an inferential device; the GasPT is also an approved device for measuring CV under Ofgem Direction at biomethane network entry points.

The GasPT determines the physical properties of natural gas:

- Calorific Value
- Wobbe Index
- Relative Density
- Compression Factor
- Methane Number (MN)
- Total Air Requirement (TAR)

Figure 7-7: The GasPT which will be using for determining the calorific value

7.3.4 Communications

The measurements will be transmitted at a suitable frequency to the DNV GL secure data cloud using GPRS mobile communications.

7.4 Assessments Using Network Models

7.4.1 Setting up the Models

Cadent provided network analysis models containing the Chittering and Hibaldstow biomethane supplies to DNV GL[4]. The possible conditions for the operation of each network during the period of the field trials was discussed between DNV GL and Cadent. The network modelling was undertaken to provide an initial overview of the predicted demand based probability of the penetration of the biomethane; the area of absorption generally increases with reductions in demand, assuming a constant flow rate from the unconventional gas source.

7.4.2 Site Selection Criteria

From the network analysis results maps were generated indicating the estimated furthest points in the networks that have the potential to receive biomethane under different demand conditions. Examples of these zone maps are given in Figure 7-8 and Figure 7-9.

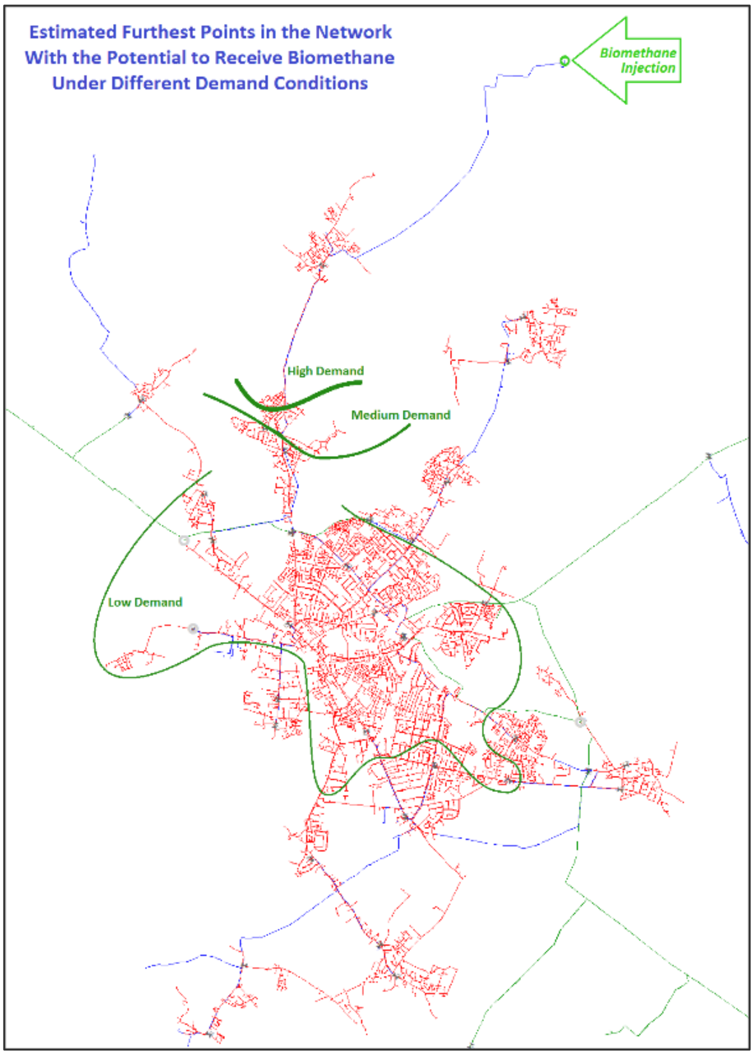


Figure 7-8: Zone of influence map for Chittering

[4] When the sensors are installed and data being received, these network analysis models will be updated to reflect the current pipework configuration and demand conditions.

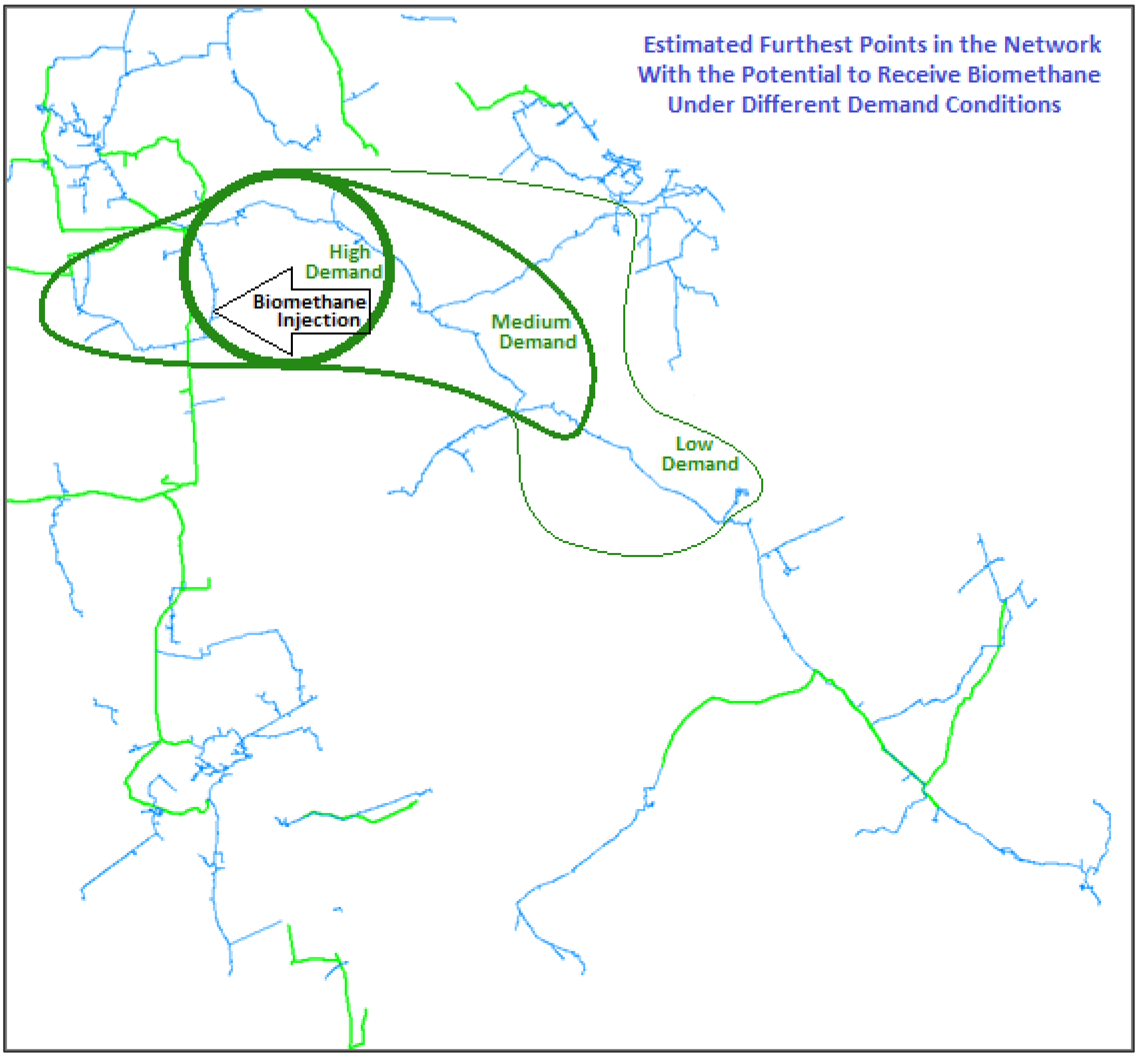


Figure 7-9: Zone of influence map for Hibaldstow

The results of the zonal analysis were used to determine:

- a list of more than 40 governor stations that were both within and outside the predicted zones of influence for Chittering and Hibaldstow.
- a list of 15 street locations sites within the network supplied by Chittering.

Where possible, options were provided for sensor locations to allow the final selection to be made by Orbital based on site survey suitability results. Maps and detailed site location plans, including pipe material and diameter, regulator type and pressures were provided to Orbital to facilitate site surveys and confirm site suitability, an example of this data including a desktop study of the sites selected is in Appendix C.

7.5 Site Survey Visits

The approach to site survey visits focussed on maximising the information and data gathered whilst minimising disruption to Cadent's operational staff.

An initial visit to a few representative governor and street sites in Chittering was organised in April 2017; this enabled Cadent, DNV GL and Orbital Gas Systems to plan the full site surveys properly and to minimise repeat visits. Information from the initial visit was used to develop a comprehensive check-list that would provide sufficient data for the generic design packs.

The full set of site visits was carried out in Chittering and Hibaldstow over two weeks in May 2017. For some sites, options for governor sites or street locations were available and the optimum site was chosen; this included consideration of:

- Governor type and flow ranges for flow measurements
- Availability and position of spare tapping points on governors for all sensors
- Pipe materials for the hot taps at street locations
- Location of pipe and the position of kiosks in the street
- Land ownership/access issues
- Safety both during the works and for the duration of the field trial

The sequence of events before, during and after the site surveys is shown in Figure 7-10.

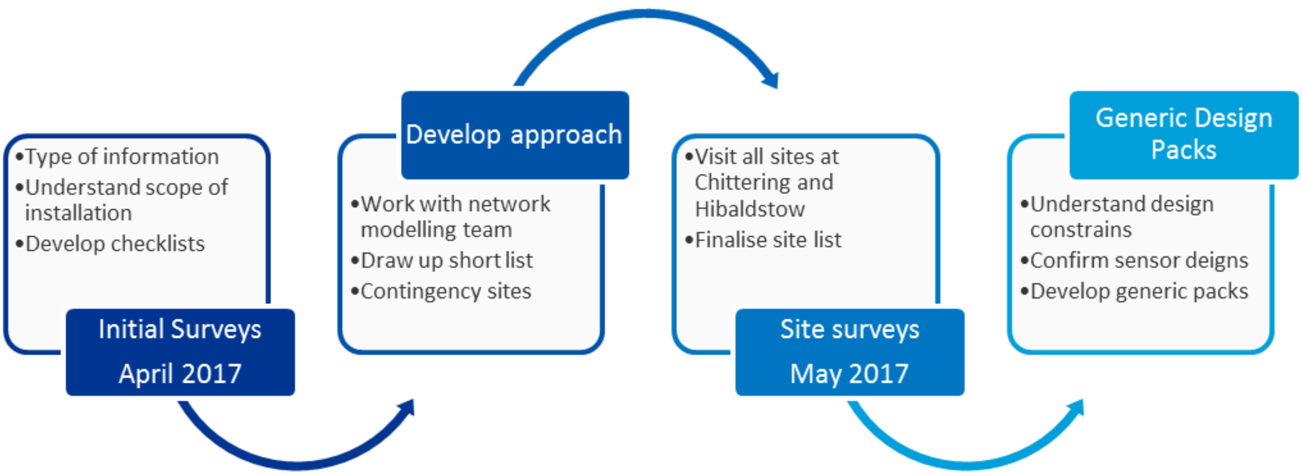


Figure 7-10: Sequence of Events for Planning and Carrying Out Site Visits

7.5.1 Chittering

A final selection of 17 governor stations and 15 street sites was drawn up which optimised the position on the network for understanding the zones of influence and the practicality of installing the equipment. Sites which satisfied certain criteria such as pipe diameter and pipe material were prioritised as well as sites that are on public rather than private land. Figure 7-11 below and Table 10-2 in Appendix D show the final measurement locations for Chittering.

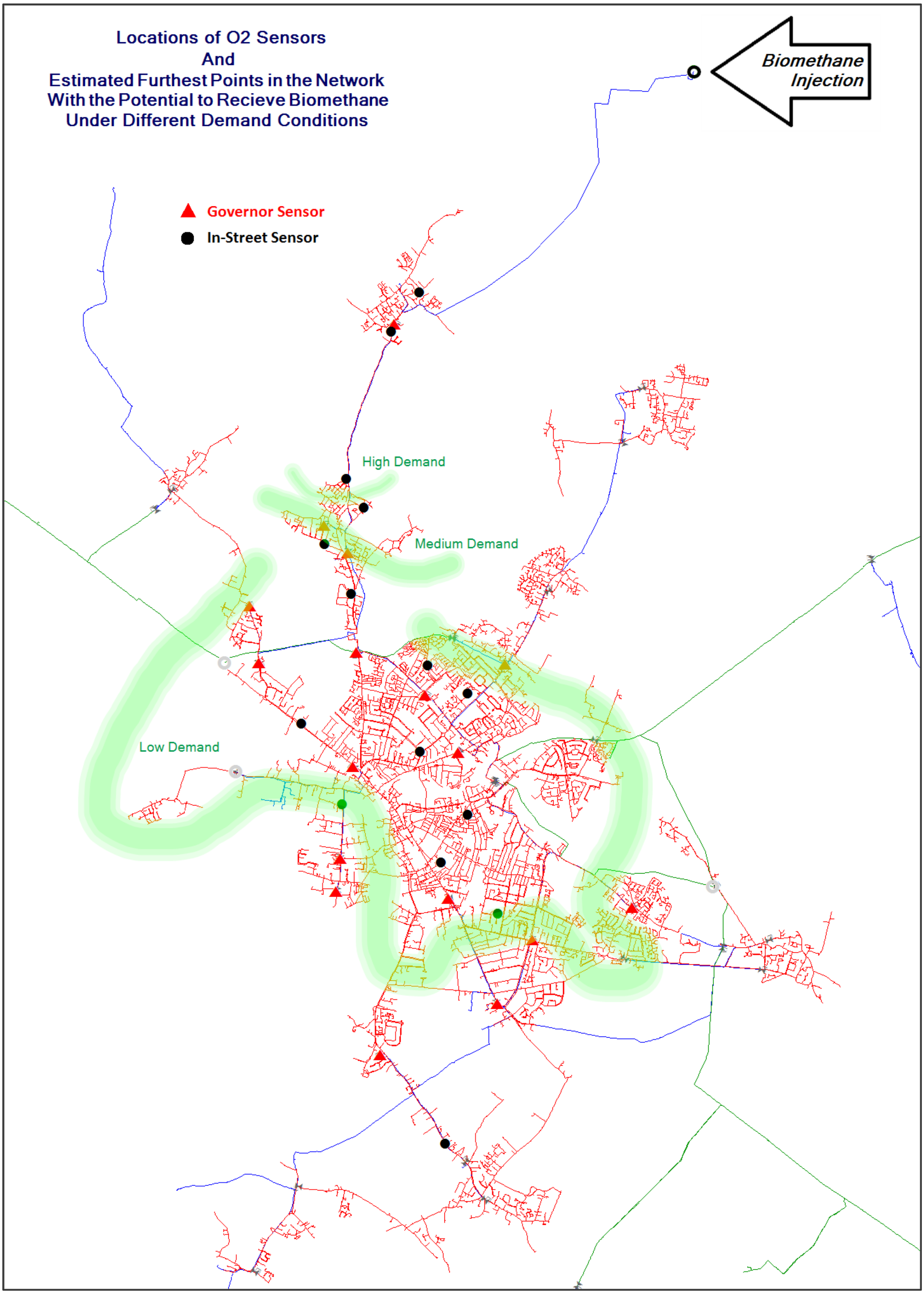


Figure 7-11: Locations of measurement sites in Cambridge for Chittering

7.5.2 Hibaldstow

A final selection of 23 governor stations was drawn up which optimised the position on the network for understanding the zones of influence and the practicality of installing the equipment. Sites which satisfied certain criteria such as high flow rates were prioritised. Figure 7-12 below and Table 10-3 in Appendix E identify the selected locations for Hibaldstow.

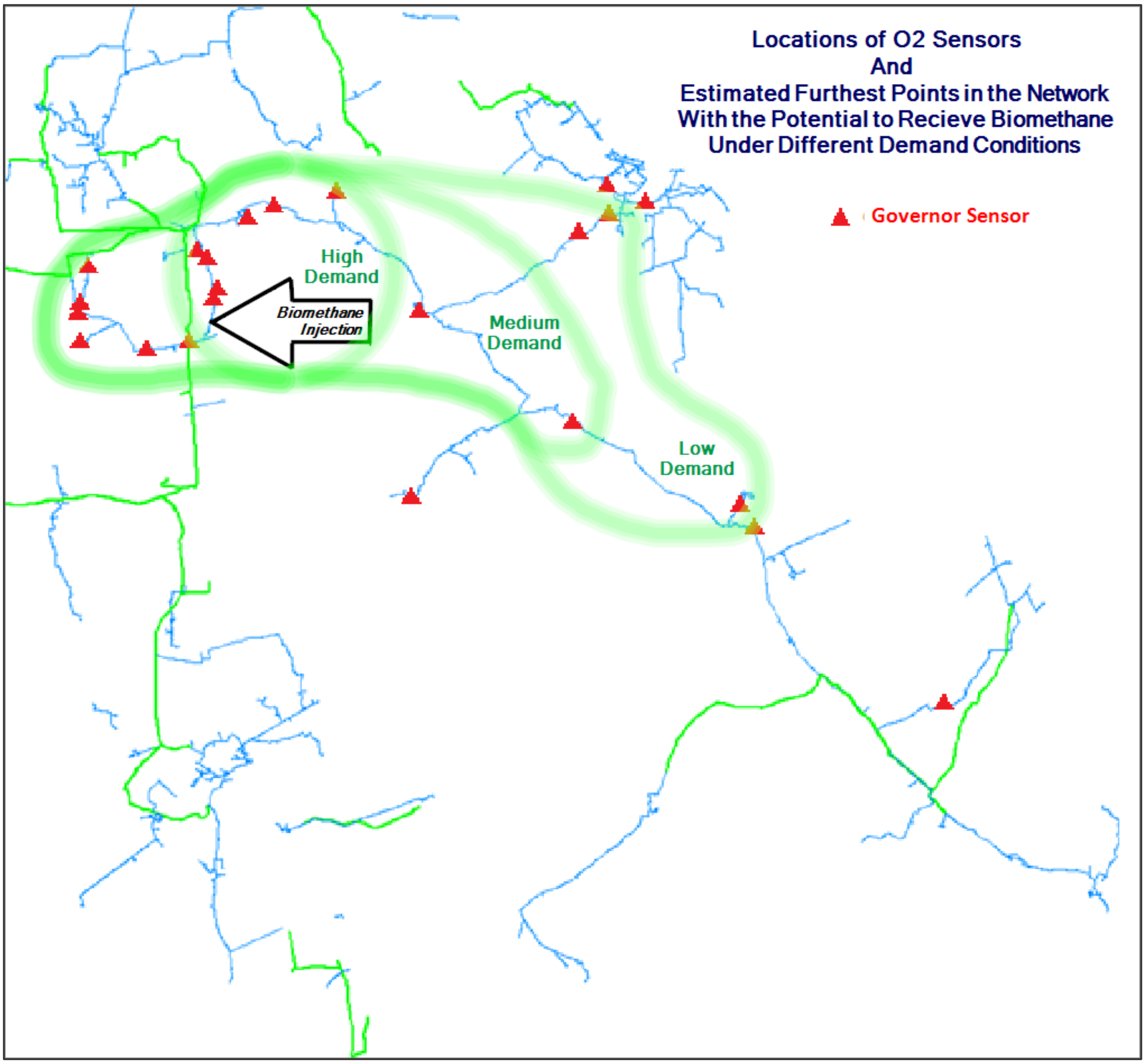


Figure 7-12: Location of the measurement sites for Hibaldstow

8 GENERIC DESIGN PACKS

The T/PM/G/19 generic design packs for the FBM field trials were created by DNV GL's subcontractor Orbital Gas Systems. The designs covered the installation of sensors in the governor stations and street level installations at Chittering and the governor stations at Hibaldstow. The design packs were developed using the following methodology:

- Clarification of project scope
- Information from the complete set of site surveys
- Information received from Cadent including copies of their standards, policies, specifications and engineering and hazardous area drawings of governor stations
- Data received from Cadent on the existence and position of other utilities in the locations identified for the street level installations in the Chittering area
- Discussions on siting and design of kiosks at street level including considerations of planning permission, wayleaves and other consents
- Consideration of tapping into different pipe materials (HDPE, cast iron, steel etc) and whether to develop a pit around the connection or to backfill
- Agreement on the optimum location for the equipment in governor stations
- Agreement on the makes and models of sensor and communication equipment
- Agreement on the assignment of responsibilities for installing the equipment including permits, permissions and qualification of staff undertaking the works
- High-level agreement on the most efficient method of working with scarce Cadent resources
- Consideration of ease of decommissioning at the end of the field trial

A technical query and action log was used by DNV GL to assign issues and queries to the appropriate person and then to track progress and status until satisfactorily resolved. Three-way weekly progress teleconference calls were arranged between DNV GL, Cadent and Orbital to ensure that all parties were kept up-to-date with progress and to discuss outstanding and upcoming issues.

The T/PM/G/19 generic design packs covered a range of different disciplines as shown in Table 8-1.

Table 8-1: Summary of generic T/PM/G/19 design packs prepared for the field trials

Discipline	Street Level	Governor Stations
Control and Instrumentation (C&I)	Sensors, hazardous areas, renewable power supply, commissioning etc	Sensors, hazardous areas, renewable power supply, commissioning etc
Civil Engineering	Yes (Excavation to pipe, plinth for kiosk etc)	Yes (fixing cabinet to wall)
Mechanical	Connections to pipework	Not required
Software	High-level software architecture common to both types of site	

8.1 Governor Station Installations

The installations at governor stations have been designed to have the minimum impact on Cadent's operations and to be contained within the footprint of the governor station. The additional sensors will be connected to the gas supply using existing tapping points on the governor pipework. The communications equipment and transmitters will be contained within a wall-mounted cabinet that will be built and tested in the factory to minimise time spent at site. As there are no power supplies at these sites, a renewable energy source will be installed on the roof of the governor buildings.

Further details of each design pack are given in Appendix F.

8.2 Street Installations

The street installations have undergone an iterative design process. The initial design included a pit that would be built around the tapping point on the gas main. The design evolved to more closely reflect Cadent's current design for pressure monitoring points in the distribution network. This design would not require a pit and involves:

- Excavating to expose the pipe
- Tapping into the gas supply
- Connecting a valve
- Laying pipework to the kiosk
- Back-filling the whole excavation and restoration to original condition

The advantage of this method are:

- Reduced cost and disruption
- Ease of installation in roads, kerbs and on private land
- Less interference from other utilities
- A Cadent main connection specification is already widely used (see Figure 8-1)
- Decommissioning will be simpler, quicker and less disruption to the public

Figure 8-1: Example of a connection to a gas supply using the existing Cadent specification

The street location kiosks are to be located adjacent to the hot taps. The areas for the kiosks have been carefully selected so as not to cause obstructions to properties, or create land permission issues. Where there is existing street furniture we have tried to locate the kiosks adjacent to these.

The kiosks themselves will consist of a hazardous area side and safe area side. Both compartments will have a door to access the inside. The compartments will be segregated with a GRP wall to prevent any ingress of gas into the safe area. An indication of the appearance of the street level installations at Chittering is shown in Figure 8-2.

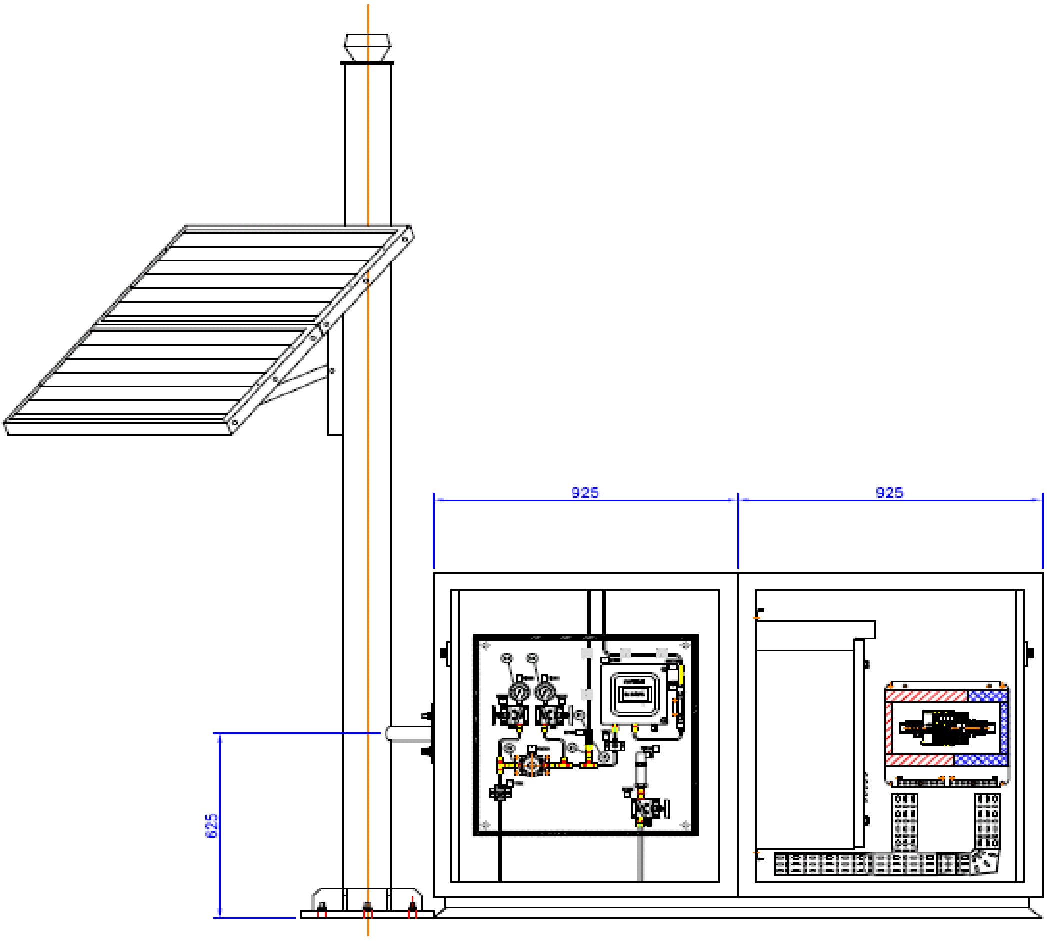


Figure 8-2: Engineering drawing of the kiosk, vent post and solar PV panels for the street level installations

Further details of each design pack are given in Appendix F. These currently include the pit design option but following further consultation with Cadent the connection to the pipeline will simply be backfilled. This simplifies the design and will reduce the time spent at the street installations during both installation and decommissioning.

Part Five – Future of the Project

Future Billing Methodology

9 CADENT'S ASSESSMENT OF THE BEST WAY FORWARD

In Cadent's view, GB's gas distribution networks can and should play a vital part in the decarbonisation of heat towards 2050 and beyond. They are an existing high-value asset that already has the capability to transport all GS(M)R compliant gases and to respond to the significant diurnal and inter-seasonal swings in heat demand. We believe that the present LDZ FWACV regime presents a significant barrier to decarbonisation of GB's gas distribution networks. There is an implicit requirement for a standardised energy content of gas across each LDZ to avoid CV capping and associated distortion in the allocation of energy costs across the gas chain and between gas customers.

Our consultation with the gas industry under the Future Billing Methodology Project has demonstrated broad support for our views on the LDZ FWACV framework. Those respondents who disagreed with our views on LDZ FWACV have shown support for the proposed field trials to explore the possibilities for an alternative approach. We see this as a clear stakeholder mandate for proceeding with the FBM Project field trials, and to develop the proposed options for creating CV zones for a more direct attribution of gas energy in billing, which will enable the decarbonisation of GB's gas distribution networks.

The consultation responses also provided valuable feedback on practical considerations and potential limitations of CV zone creation. This is helping to shape our thinking as we prepare for the measurement, analysis and modelling design phases of the FBM Project. We have already applied some consultation feedback in our early engagement with Xoserve to assess potential billing system design.

Respondents to our consultation also emphasised that the FBM Project should take account of the potential impacts on shipper/supplier billing and on customers' bills to seek the most cost-effective solution to decarbonising heat. We have been working with Xoserve to determine, at high level, the required changes to gas transporter billing and we will share our initial findings on invoicing impacts for discussion with shippers/suppliers as we progress our investigation.

Regarding potential customer impacts, we also note views recently expressed by Ofgem that the impact on energy consumers will be a critical factor in the decarbonisation of heat. This is where a potential FBM solution has great strength, in that the bulk of customers could continue to use their existing gas heating and cooking systems, costing GB energy consumers considerably less than a non-gas based approach to decarbonisation.

Our initial CBA has built upon our original NIC Project Submission to:

- Take account of potential implementation costs for each of the three FBM options; Pragmatic, Composite and Ideal;
- Take fuller account of the cost of propanation of low CV gases such as biomethane;
- Monetise the carbon saving from the removal of propanation under FBM, and
- Monetise the carbon saving achievable from the expanded deployment of renewable and low carbon gases that we believe to be achievable by 2050 under FBM.

As shown in Table 6-7 and Table 6-8, this initial FBM Project CBA indicates very significant positive cumulative NPV to 2050 for all three FBM options.

Recent energy industry reports from KPMG /8/, Policy Exchange /11/ and Imperial College London /12/ indicate that the electrification of heat could cost the UK up to £300bn in broad terms. Based on the initial indications from our CBA at this stage, we believe that the future implementation of a zonal CV billing framework could facilitate the decarbonisation of a significant proportion of the GB heat load by

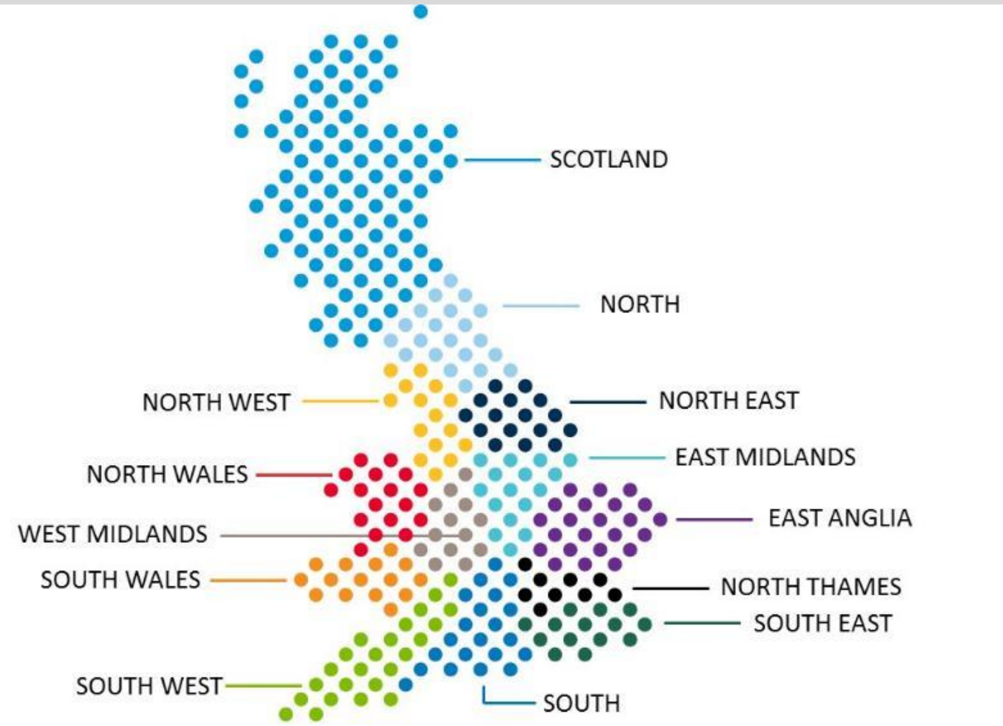
2050, because it is the key enabler for a range of gas-based solutions that would maximise the use of renewable gases and support the deployment of hydrogen. We believe this could save the UK well over £100bn in electrification. We also see FBM as key to underpinning future security of supply in an ever more diverse gas market.

In summary, based on:

- The positive feedback to the FBM project consultation;
- The strongly positive NPV from the initial CBA, and
- The indication that a gas-centred solution to decarbonising heat, facilitated by FBM, could cost GB energy consumers considerably less than a non-gas-based approach

Cadent’s assessment is that the FBM project should progress through the field trials to its conclusion. This will deliver the learning required to make a fuller cost-benefit assessment of billing consumers using an FBM approach and equip the industry with an economically favourable option to decarbonise heat in a way that balances effectiveness with affordability for customers and continued security of supply.

Part Six – References and Appendices



Future Billing Methodology

10 REFERENCES

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/2/	Future Billing Methodology NIC Submission 2016. https://www.ofgem.gov.uk/publications-and-updates/gas-nic-submission-national-grid-gas-distribution-future-billing-methodology
/3/	Ofgem *Gas Network Innovation Competition Governance Document.* Version 2. 02 April **2015** https://www.ofgem.gov.uk/sites/default/files/docs/2015/04/gas_nic_-_final_clean_0.pdf
/4/	Ofgem Project Direction https://www.ofgem.gov.uk/publications-and-updates/network-innovation-competition-project-direction-future-billing-methodology
/5/	National Grid *T/PM/G/23 Management Procedure for the Full Evaluation and Approval of Products, Equipment and Techniques up to 7 Bar*. June **2013**
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/10/	SGN NIC project *Opening Up the Gas Market.* Final Report. October **2016**
/11/	Policy Exchange *Too Hot to Handle? How to decarbonise domestic heating* by Howard, R and Bengherbi, Z. **2016**
/12/	Imperial College London, Sustainable Gas Institute *A Greener Gas Grid: What are the Options? White Paper* July **2017**

Appendix A Stakeholder Events

Date	Event Type	Message	Output	Outcome	Audience
Stakeholder preparation activities					
Jan - Feb 2017	Internal meetings/design launch event/presentation material and project publicity	Project team introduction and overview of stakeholder consultation	Invitation to project launch	Targeted invitations to project launch	FBM Project team
18 Jan 2017	Face-to-face meeting with Xoserve	Project overview and our view of Xoserve's role	Engagement with key stakeholder during period of change	Increased awareness and handover to Xoserve team	Chris Murray
27 Jan 2017	Issue invitations to project launch event	Prepare project overview, event material and event details	Attendance at project launch	Consultation response	All stakeholders
09 Feb 2017	Reminders issued				All not booked
20 Feb 2017	Reminders issued				All still not booked
Consultation Launch					
2 Mar 2017	Project Launch at Queen Elizabeth II Centre, London Presentation by project team to stakeholders and first showing of three-minute project video Question and answer session Consultation document published	Full project overview Opportunity for Q&A Consultation launch with clear guidance on what the project requires from attendees	Face-to-face engagement including casual conversation Consultation launched Q&A, understanding stakeholder position Handout material	Consultation response Good assessment of sentiment with diverse range of stakeholders	67 registered and 45 attendees

Date	Event Type	Message	Output	Outcome	Audience
2 Mar 2017	Follow up survey and webinar dates Project website went live with electronic copies of all material	Thanks for attending, here is the consultation, further ways to stay in touch, feedback from event	Consultation response	Consultation response	45 industry attendees
2 Mar 2017	Consultation/ website /dates for webinars	Sorry you couldn't attend, here is a link to the consultation, announce webinars	Engaging widely on the project	Consultation response	Stakeholders who did not attend the event
Follow Up After Project Launch					
8 Mar 2017	Anaerobic Digestion and Bioresources Association	Project overview	Engaging with us on the project	Updated Q&A, understanding stakeholder position	ABDA members (Biomethane working group)
8 Mar 2017	Face-to-face presentation to GS(M)R IGEM committee	Introducing FBM and the project and consultation has begun	Engaging with us on the project	Updated Q&A, understanding stakeholder position	GS(M)R IGEM Committee
06 Mar - 10 Apr 2017	Follow up calls and e-mail	Targeted messaging to individual stakeholders based on sentiment	Potential invitation to webinar or further workshop session or 1:1 meeting	Influencing resistant/neutral stakeholders to move to accepting position	Identified resistant/neutral stakeholders/any stakeholders with questions
13 Mar 2017	On the quarterly update call with British Gas	Project overview and rationale to British Gas and invite response to consultation	Engaging with us on the project	Took information away for further consideration	British Gas

Date	Event Type	Message	Output	Outcome	Audience
20 Mar 2017	E-mail reminder prompt 1 – consultation and invitation to open Q&A webinar (all other stakeholders)	Reminder that consultation is open and information we are looking for/why – ways to contact us Updated Q&A Open Q&A will be available	Sign up to webinar Download consultation	Consultation response	Range of stakeholders
22 Mar 2017	Shipper forum at Joint Office of Gas Transporters at the Distribution Network Charging Methodology Forum.	The consultation – answering Q&A	Read consultation, dial-in to further call	Updated Q&A, better understanding of stakeholder position	BG, nPower, Eon and EDF in attendance, occasionally Gazprom
29 Mar 2017	Webinar 1 - Introducing FBM project and notification that the consultation process is open	Engaging with us on the project	Updated Q&A, understanding stakeholder position	Consultation response	Gazprom ADBA
29 Mar 2017	Webinar 2 – Focus on shippers/suppliers – introduction to the project and notification that consultation is open	We want to engage with you specifically and address your questions/concerns	Better understanding of stakeholder position Dial-in to webinar	Positive consultation response	ENA, AD Privilege Finance, Energy UK, nPower, Scottish Power
29 Mar 2017	Anaerobic Digestion and Bioresources Association	Project overview and Q&A	Updated Q&A, understanding stakeholder position	Support for the project	ADBA Innovation and Research Forum

Date	Event Type	Message	Output	Outcome	Audience
05 Apr 2017	E-mail final reminder re consultation process. The deadline was extended from 14 April to 12 May 2017	Final reminder that consultation is open and information we are looking for and why – Ways to contact us to discuss further if desired	Consultation response with full information	Deadline for submission extended	All targeted respondents
06 Apr 2017	UNC Gas Transmission Work Stream at Elexon	Project overview and invited by shippers/suppliers from 29 March webinar		Questions taken away and responded via Q&A published on the project website	
24 Apr 2017	Face-to-face presentation at UK Biomethane Day	Talking about the project – we are still open to engagement	Continued engagement with stakeholders	Additional information to inform project	Various stakeholders for biomethane
27 Apr 2017	UNC Gas Distribution Work Stream meeting at Elexon	Project overview and invited by shippers/suppliers from 29 March webinar		Questions taken away and responded via Q&A which are published on the project website	
03 May 2017	HyDeploy industry workshop	Engaging with HSL and suppliers of gas measurement equipment	Continued engagement with stakeholders	Develop common understanding between HyDeploy and FBM	HSL and potential suppliers to HyDeploy project
09 May 2017	Face-to-face meeting with Xoserve	More detail about the project scenarios	Undertaking by Xoserve to examine scenarios in detail	Xoserve understand what may be required of them	Xoserve

Date	Event Type	Message	Output	Outcome	Audience
11 May 2017	Face-to-face meeting with Ofgem	Progress report on activities undertaken and what we will do next	Engagement and feedback from Ofgem	Proposed methodology for stage gate reporting agreed	Ofgem
Consultation Closes on 12 May 2017					
13 May 2017 onwards	Acknowledgement and thanks for responses	Thank you We are studying your responses What happens next	None	Stakeholders feel informed and that their views matter Survey results	All including non-respondents
13 May 2017 onwards	Consultation feedback: What's happening now	Results of consultation	None	Keeping stakeholders engaged with process	All industry
13 May 2017 onwards	Respond to consultation response	We are responding to your query in detail	Correspondence	Keeping stakeholder engaged	Cardiff University
21 June 2017	Face-to-face engagement with National Grid Gas Transmission	Project overview and opportunity for Q&A	Awareness of project and commitment to contribute on FBM	Key stakeholder engaged	NGGT
July 2017	Consultation feedback: What's happening now?	Keeping stakeholders informed	None	Stakeholder engaged with process	All industry

Table 10-1 List of events that took place during the initial stakeholder engagement

Appendix B Propane Enrichment Equipment

The continuing requirement for enrichment of low CV gases would increase costs and constrain the deployment of alternative gases up to the point where these gases dominate the supply in the LDZ. From which point, high CV minority gases such as LNG would need further nitrogen ballasting than is currently required. In summary, were there were no change to the FWACV billing regime then gas processing costs would continue to increase over time and decarbonisation would remain unachievable for longer. Figure 10-1 shows the additional equipment needed at an injection point where a low CV gas (such as biomethane) needs to be enriched with propane. The additional equipment, related control systems, management and safety systems will result in additional costs related to the production of biomethane.

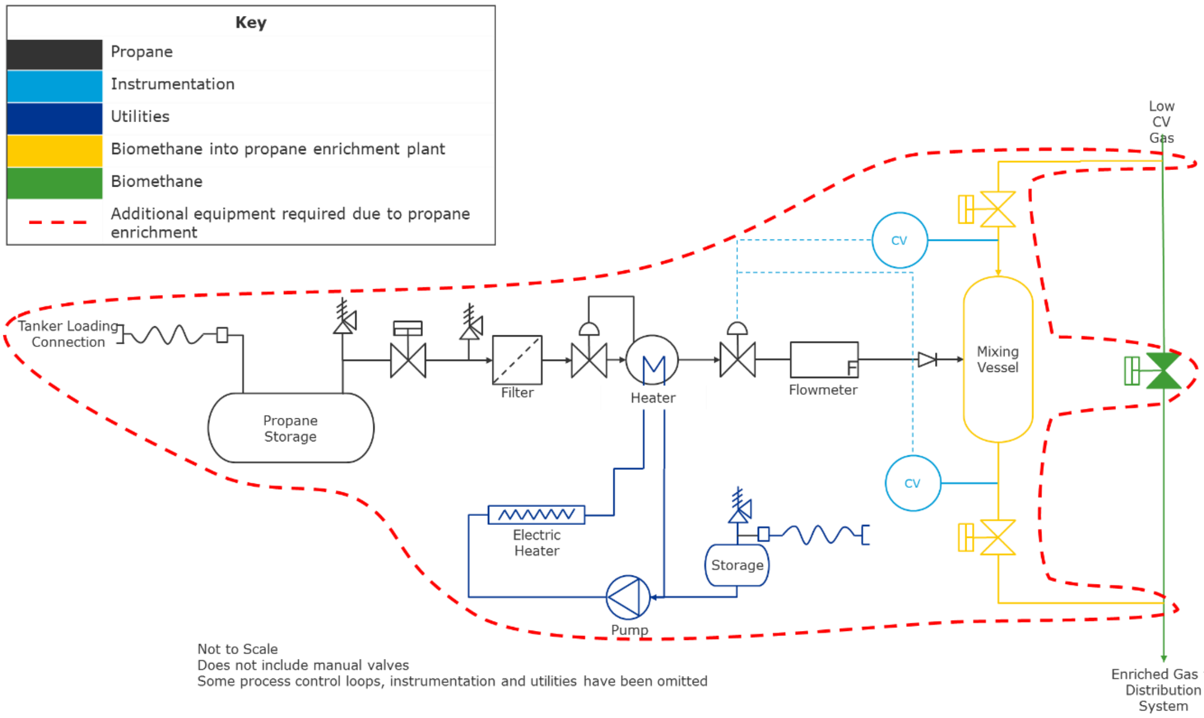
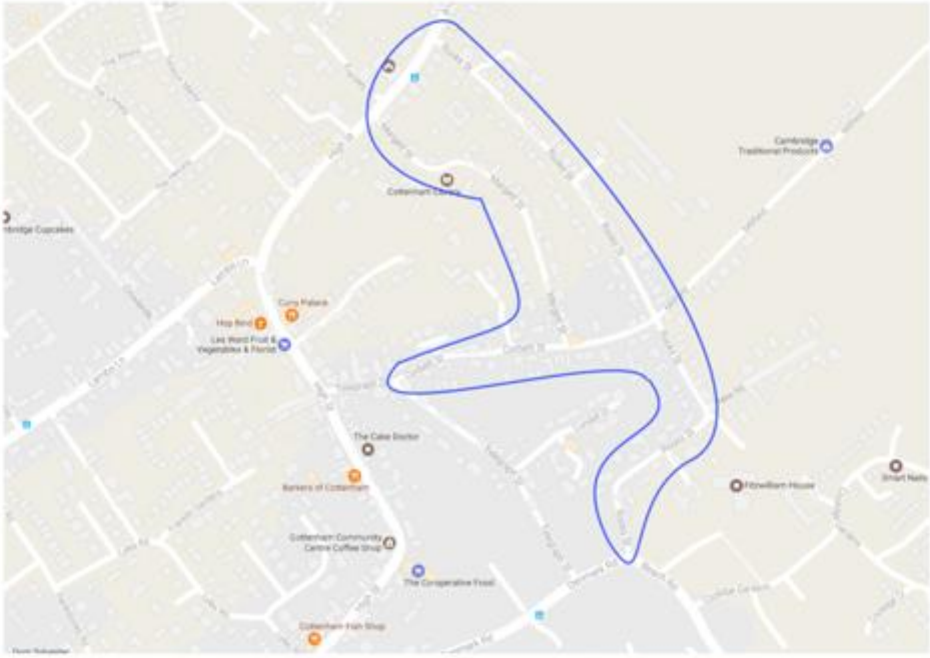


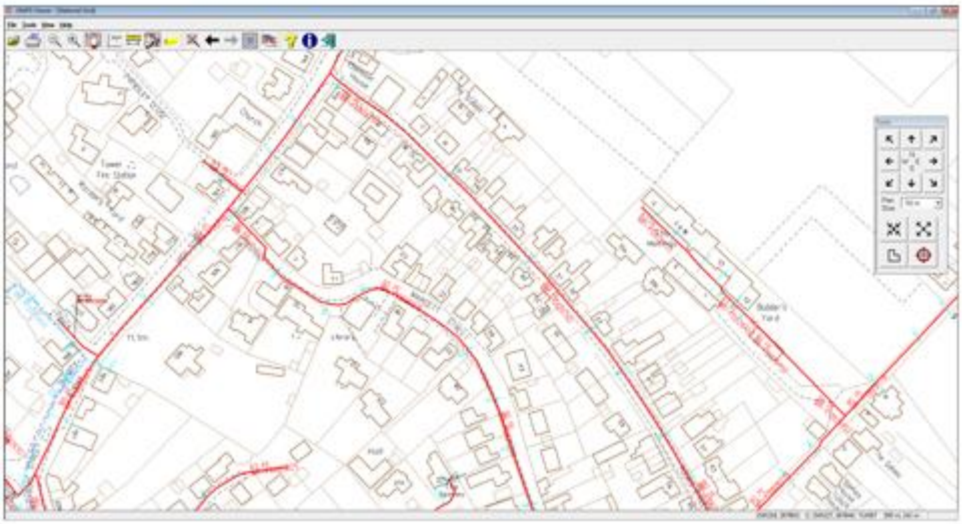
Figure 10-1: Additional Equipment Required for the Enrichment of Biomethane

Appendix C Example Site Selection Material

Sensor No.	Site Name & address	Pipe Ref	Diameter	Material	Covering
1	ONE OF:	ONE OF:			
	Rooks Street, Cottenham	MR-410626760	180mm	PE	Road
	Margett Street, Cottenham	MR-410626504	90mm	PE	Road / pavement
	Corbett Street, Cottenham	MR-410626661	125mm	PE	Road

1. North Cottenham (Rooks Street, Margett Street, Corbett Street)






Corbett St
Corbett St

Appendix D Final Sensor Site Selection Chittering

Site Number	Governor installations within Cambridge around the Chittering biomethane entry
1	Cottenham Village, CB24 8UB
2	Home Close, Histon, CB4 9JE
3	Homefield Park, Histon, CB24 9YN
4	Arbury Road, Cambridge, CB4 3XL
5	Cambridge Road, Girton, CB3 0GL
6	Recreation Ground, Girton, CB3 0FH
7	New Hall, Huntingdon Road, Cambridge, CB3 0DB
8	Botanic Gardens, Hills Road, Cambridge, CB1 2JD
9	Cranliegh Close, Trumpington, Cambridge, CB2 9NP
10	Hills Road, Cambridge, CB1 7RU
11	Perne Road, Camrbidge, CB1 3RU
12	Langdale Close, Cherry Hinton, Cambridge, CB1 9LP
13	Chesterton Rd, Cambridge, CB4 1NE
14	Milton Rd, Cambridge, CB4 0FE
15	Arbury Court, Cambridge, CB4 2EU
16	Grange Road, Cambridge, CB3 9DB
17	Kings Road, Cambridge, CB3 9DY

Site Number	Within Street Installations in Cambridge for the Chittering Biomethane entry
1	Corbett Street, Cottenham
2	North end of Histon Road, Cottenham
3	Orchard Road, Impington – between no. 4 and no. 32
4	Cottenham Road, Impington – north of Parlour Close
5	South end of Merton Road and Home Close, Impington
6	Villa Road, Impington
7	Huntington Road (A1307) near Howes Place, Cambridge
8	Clarkson Road, Cambridge
9	Gilbert Road, Cambridge
10	Park at end of Wynford Way, Cambridge
11	Woodhead Drive, Cambridge
12	Gresham Place, Cambridge
13	Young Street, Cambridge
14	Fanshawe Road, Cambridge
15	Shelford Road / Cambridge Road, Great Shelford

Table 10-2 List of measurement sites in Chittering in the East Anglia network

Appendix E Final Sensor Site Selection Hibaldstow

Table 10-3 List of measurement sites around Hibaldstow in the East Midlands network

Site Number	Governor Installations for Hibaldstow Biomethane entry
1	Messingham, DN17 3QP
2	Gravel Pit Rd, Scooter, DN21 3SU
3	The Green, Scooter, DN21 3UG
4	Eastgate, Scotton, DN21 3QR
5	Grove St, Kirton Lindsey, DN21 4BZ
6	Redbourne Rd, Hibaldstow, DN20 9NT
7	Ings Street/Church Street, Hibaldstow, DN20 9EG
8	Gainborough Lane, Sturton, DN20 9BZ
9	Messingham Lane, Scawby, DN20 9AJ
10	Barnard Ave, Brigg, DN20 8AP
11	Brickyard Lane, Brigg, DN20 8RE
12	Marsh Lane, Barnetby, DN38 6JW
13	North Kelsey Rd Caistor, LN7 6QN
14	Grimsby Rd, Laceby, DN37 7DF
15	Broadway/Laceby Rd, Grimsby, DN34 5QR
16	Hereford Avenue, Grimsby, DN34 5AL
17	Great Cotes Road, Grimsby, DN37 9HN
18	Louth Rd, Binbrook, LN8 6HY
12	Chapel St, Market Rasen, LN8 3AA
20	Grimsby Rd, Louth, LN11 0EA
21	Albion Place, Louth, LN11 9AE
22	Fortesthorpe Road, Alford, LN13 9BJ
23	A15/B1206, Redbourne Mere, Kirton in Linsey, DN21 4NN

Appendix F Design Packs

F.1 Control and Instrumentation T/PM/G/19 Design Pack

The generic control and instrumentation design pack comprised 12 sections as shown in Table 10-4.

Table 10-4 Content of Control and Instrumentation T/PM/G/19 Pack

Section	Title	Contents
1	G/19 documentation	Pack title page
2	Project brief	Functional Design Specification
3	Compliance statement	Hazardous area and standards/specifications compliance
4	Design calculations	Design and calculations (eg hazardous area, sample transit times)
5	Safety Integrity Level	FBM equipment has no safety function so not required
6	Manufacturers Data Sheets	Includes all oxygen, pressure, calorific value and other sensors, power, fittings, cables and communications equipment
7	Hazardous Area Certification	ATEX certification of components in the hazardous areas
8	Commissioning Procedure	Factory and site acceptance tests and pressure test procedures
9	Certification	Test and inspection certificates for components
10	Drawing register	List of drawings associated with the design
11	Drawings	Pack of all drawings associated with the design
12	Other	Design risk registers (Health and Safety, CDM & DSEAR) and copies of all technical queries

F.2 Civil Engineering T/PM/G/19 Design Pack

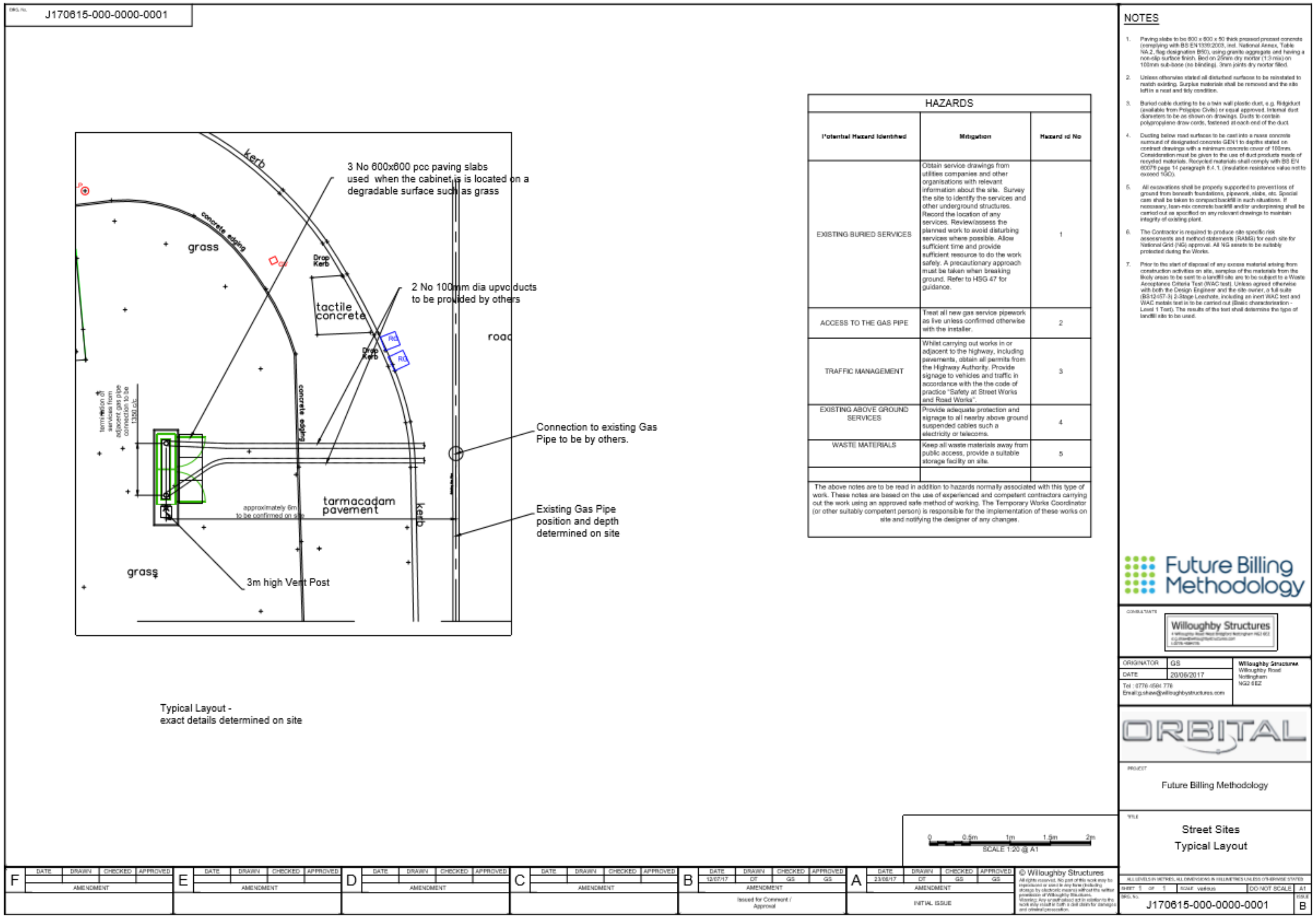
F.2.1 Governor Housing

The civil engineering design is a high-level drawing of the fixing of the sensor housing and power supply to the governor station wall.

F.2.2 Street Installation

The civil engineering design comprised three drawings (see Figure 10-2 to Figure 10-4) of a typical installation:

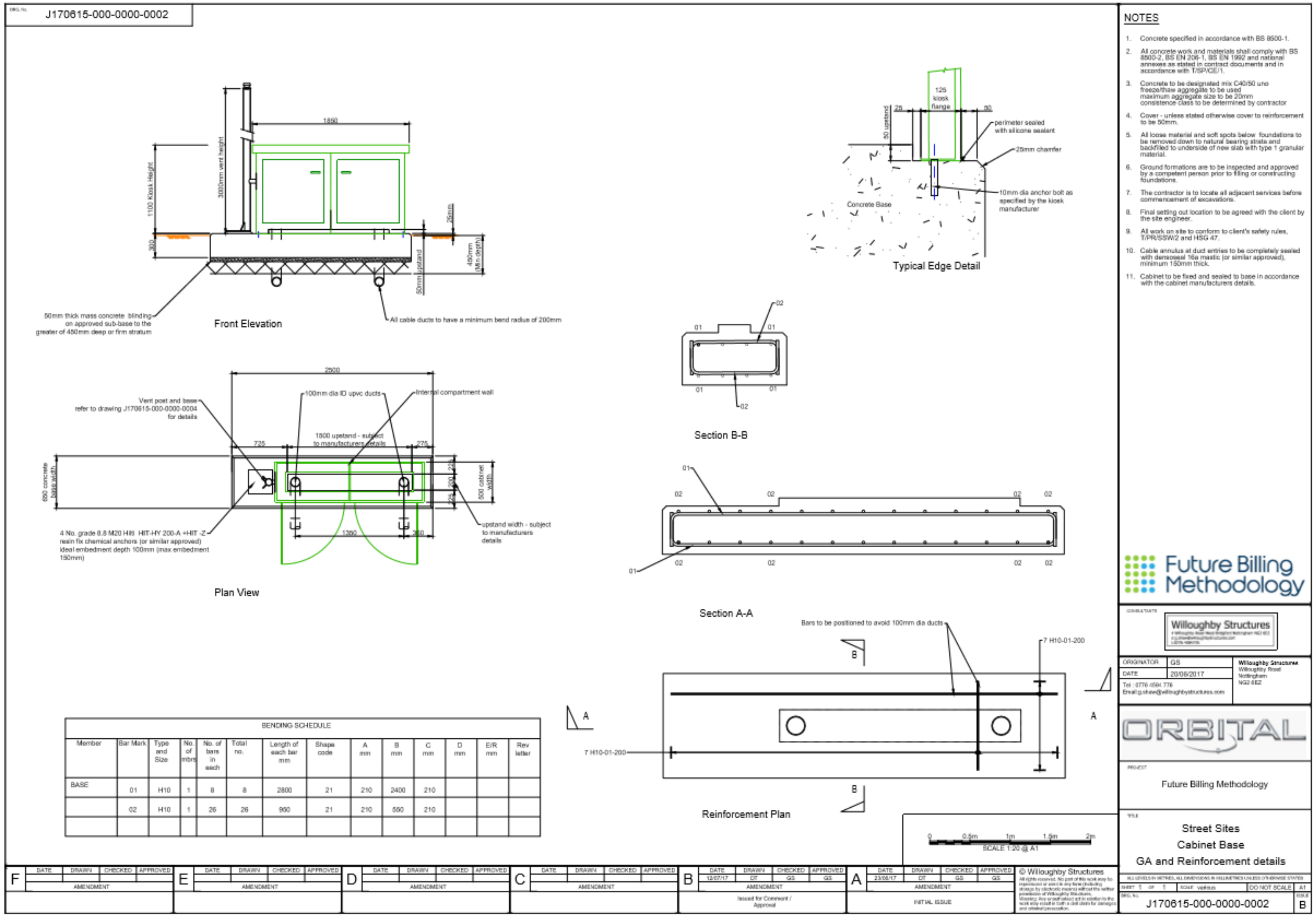
- Typical layout
- Kiosk design
- Vent post and solar PV panel



HAZARDS		
Potential Hazard Identified	Mitigation	Hazard id No
EXISTING BURIED SERVICES	Obtain service drawings from utilities companies and other organisations with relevant information about the site. Survey the site to identify the services and other underground structures. Record the location of any services. Review/assess the planned work to avoid disturbing services where possible. Allow sufficient time and provide sufficient resource to do the work safely. A precautionary approach must be taken when breaking ground. Refer to HSG 47 for guidance.	1
ACCESS TO THE GAS PIPE	Treat all new gas service pipework as live unless confirmed otherwise with the installer.	2
TRAFFIC MANAGEMENT	Whilst carrying out works in or adjacent to the highway, including pavements, obtain all permits from the Highway Authority. Provide signage to vehicles and traffic in accordance with the the code of practice "Safety at Street Works and Road Works".	3
EXISTING ABOVE GROUND SERVICES	Provide adequate protection and signage to all nearby above ground suspended cables such a electricity or telecoms.	4
WASTE MATERIALS	Keep all waste materials away from public access, provide a suitable storage facility on site.	5

The above notes are to be read in addition to hazards normally associated with this type of work. These notes are based on the use of experienced and competent contractors carrying out the work using an approved safe method of working. The Temporary Works Coordinator (or other suitably competent person) is responsible for the implementation of these works on site and notifying the designer of any changes.

Figure 10-2 Typical layout of a street installation - generic design only



Member	Bar Mark	Type and Size	No. of mbrs	No. of bars in each	Total no.	Length of each bar mm	Shape code	A mm	B mm	C mm	D mm	E/R mm	Rev letter
BASE	01	H10	1	8	8	2800	21	210	2400	210			
	02	H10	1	26	26	960	21	210	560	210			

Figure 10-3 Typical design of the street kiosk - generic only

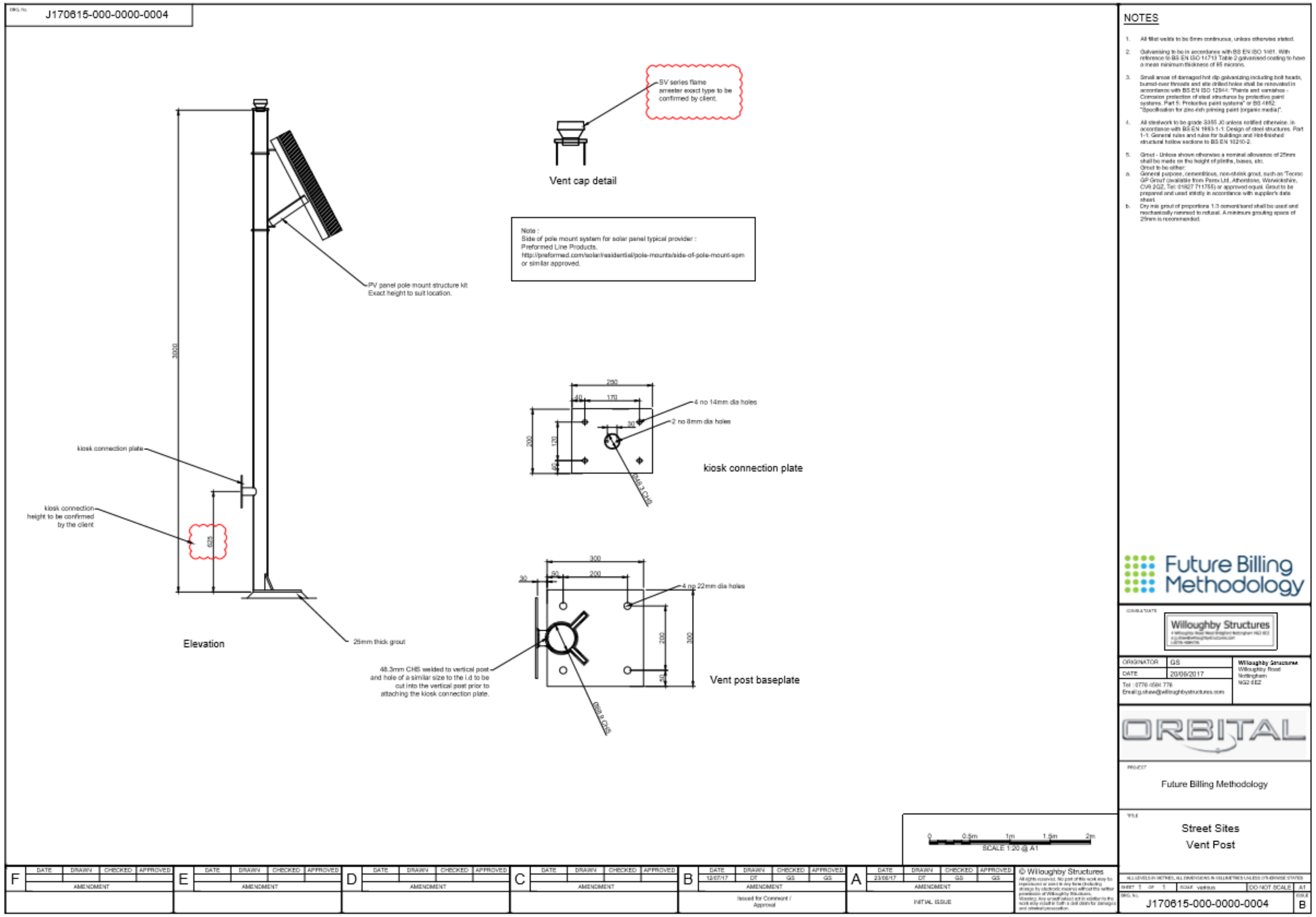


Figure 10-4 Typical design of the vent post and solar panel - generic only

F.3 High-Level Software Generic Design

The software generic design was high-level and described the architecture, the data flow chart and the database fields. A diagram of the software architecture is shown in Figure 10-5.

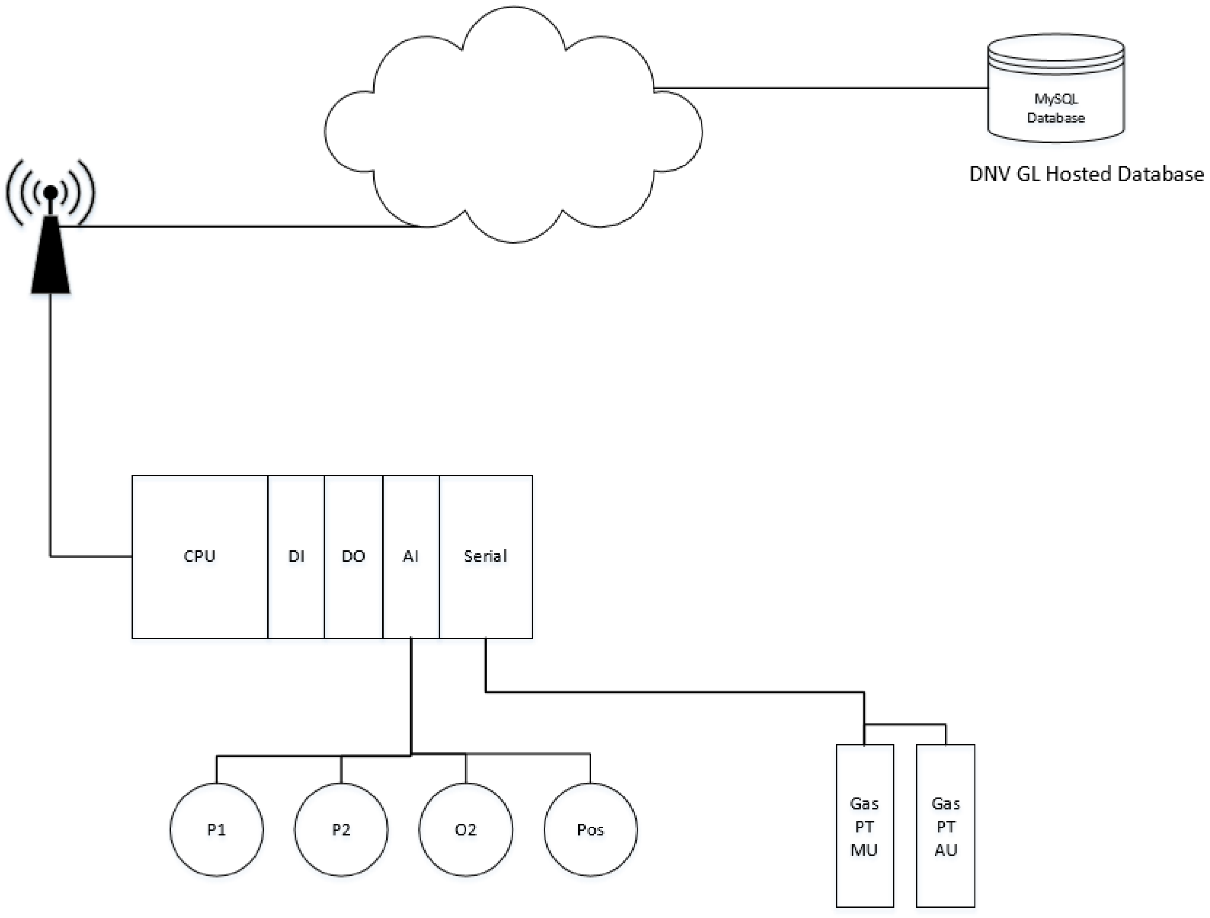


Figure 10-5 Diagram of the Software Architecture

F.4 Mechanical Design

The mechanical design applied only to the street installations and it was based on assumptions about minimum and maximum gas flows, temperatures and pressures, typical pipe materials and diameters and other details in the DNV GL specification document. The pack contained 19 sections as shown in Table 10-5.

Table 10-5 Contents of the mechanical design pack for the street installations. No mechanical designs are required for the governor kiosks.

Section	Title	Contents
1	Design conditions	Requirements specification, pipeline saddle fitting and technical query responses
2	Equipment, materials rating & specification	
3	Control philosophy, overpressure protection	Not required for this project
4	Pipe supports, anchors & guides	Not required for this project
5	Pressure testing	Procedure for pressure testing the electrofusion weld and pipework
6	Pipework stress analysis	Not required for this project
7	Cathodic protection	Not required for this generic design as pipeline is assumed to be PE
8	Hazardous areas	Hazardous area calculations and drawings for the typical street installation
9	Construction design codes	List of industry standards, Cadent specifications and other documents to which the work will be done
10	Design risk assessments	CDM risk assessment
11	Pipework sizing	Not required for this project
12	Filtration	Not required for this project
13	Metering	Not required for this project
14	Pre-heating	Not required for this project
15	Pressure and flow control	Not required for this project
16	Rotating machinery	Not required for this project
17	Pipelines routing	Drawings of gas sampling and tapping point for street installation
18	Overall safety consideration	Health and safety check lists
19	ATEX DSEAR	DSEAR risk assessment

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.