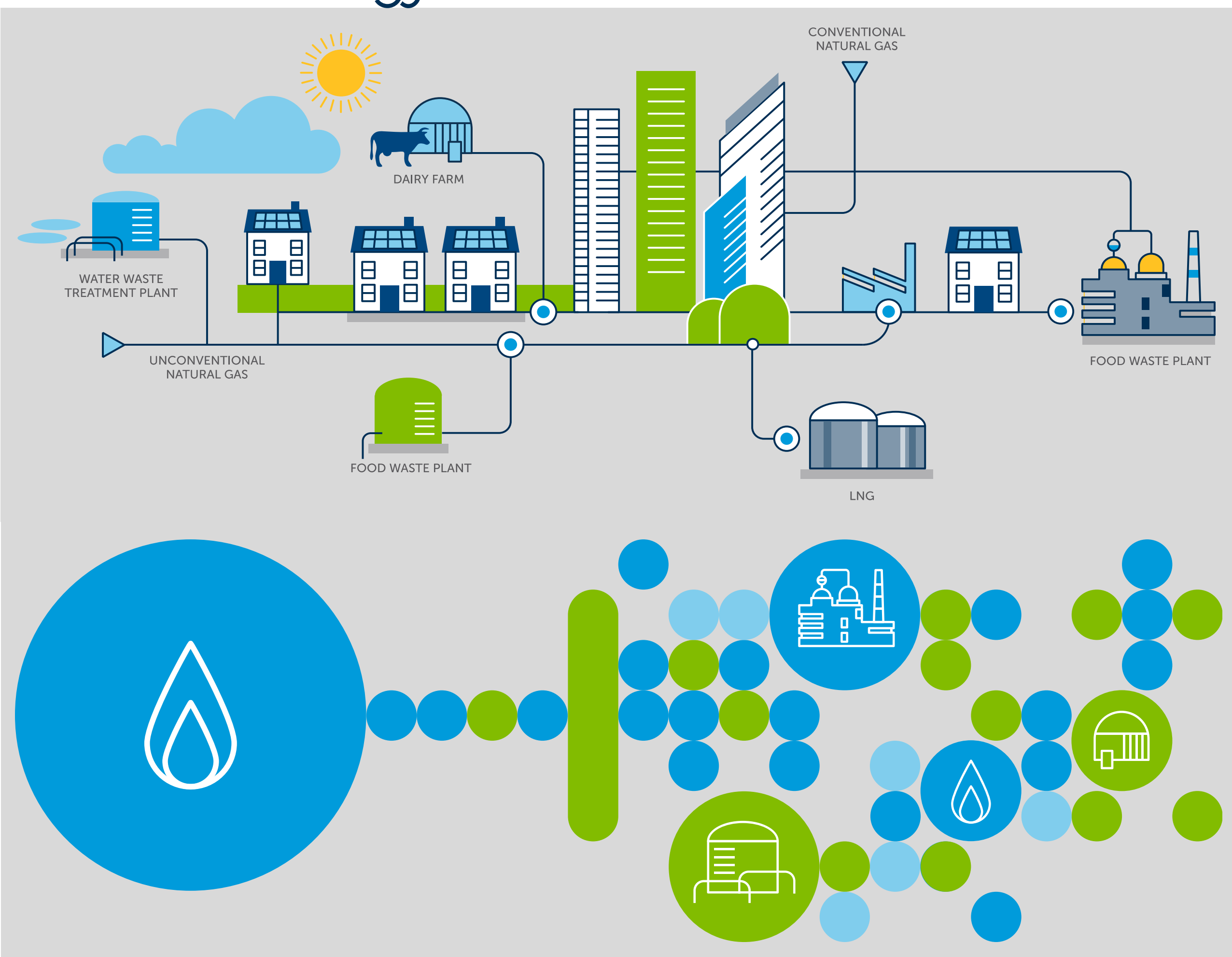
FUTURE BILLING METHODOLOGY

MS11 Smart Metering Laboratory Trials Report (SDRC 9.4)

Cadent Gas Ltd

Report No.: 114D803D-61, Rev. 1
Date: 1st March 2021

Future Billing Methodology



Project name:	Future Billing Methodology
Report title:	MS11 Smart Metering Laboratory Trials Report (SDRC 9.4)
Customer:	Cadent Gas Ltd, Brick Kiln St, Hinckley LE10 0NA
Customer contact:	David Chalmers, Project Manager, Network Strategy – Innovation Team
Date of issue:	1st March 2021
Project No.:	PP181622
Organisation unit:	Energy Measurement & Compliance / Software Consultancy
Report No.:	114D803D-61, Rev. 1

DNV GL Oil and Gas / Software
Technical Advisory / Software
Holywell Park,
Ashby Road,
Loughborough, Leicestershire,
LE11 3GR, United Kingdom.
Tel: (+44)2038165638

Applicable contract(s) governing the provision of this Report: Gas Network Innovation Competition

Objective: A report on the FBM proof-of-concept study of the Smart Metering system to support the Ideal Scenario where consumer billing is fully derived from the point of consumption using smart meters.

Prepared by:

pp Hazel Richardson

David Spalding
Director [Cytal]

pp Hazel Richardson

Richard Harker
Senior Developer [Cytal]

Hazel Richardson

Hazel Richardson
Senior Engineer [DNV GL]

Verified by:

Sarah Kimpton
Senior Principal Consultant [DNV GL]

Approved by:

Martin Maple
Head of Gas Consulting [DNV GL]

DNV GL Distribution:

☒ OPEN. Unrestricted distribution, internal and external.
☐ INTERNAL use only. Internal DNV GL document.
☐ CONFIDENTIAL. Distribution within DNV GL according to applicable contract.*
☐ SECRET. Authorized access only.
*Specify distribution:

Keywords:
Future Billing Methodology, Innovation, NIC

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	21-10-2020	Cytal Draft Report for Internal Review	RH	SK	
B	08-01-2021	DNV GL Draft Report for Internal Review	RH, DS, HR	SK	
C	11-01-2021	DNV GL Draft Report for Internal Review	RH, DS, HR	SK	
D	14-01-2021	DNV GL Draft Report for Internal Review	RH, DS, HR	SK	
0	18-01-2021	Draft Report	RH, DS, HR	SK	MM
1	01-03-2021	Final Report	RH, DS, HR	SK	MM

Table of contents

1 EXECUTIVE SUMMARY

The Future Billing Methodology project aims to unlock the potential benefits of decarbonisation of the existing gas grid to provide an economical pathway to the decarbonisation of heat as an alternative to investment in electrification, heat networks and demand-side renewable technologies. The primary focus of the project is evaluation of alternatives to the use of the Flow Weighted Average Calorific Value (FWACV).

The purpose of milestone 11 (MS11) is to report on the final setup and outcomes from the Smart Meter laboratory pilot, the aim of which was to demonstrate a proof of concept to help understand the feasibility of the Future Billing Methodology's Ideal Scenario in which Calorific Value (CV) is measured locally and distributed to consumers' gas smart meters. This report follows on from the previous milestone 6 report, Smart Metering System Simulation Specification /1/, which described the proposed functional specification for the pilot in detail.

Definitions of all technical terms and abbreviations are given in section 8, Key DEFINITIONS.

1.1 Proof of Concept

The trial demonstrates that the existing smart metering system design can use calorific value data to deliver locally calculated kWh billing information into the gas billing process. The trial successfully demonstrates the following four processes:

- The collection of calorific value data from sensors in the field, and the publishing of the data into a cloud database, averaging readings and hence demonstrating the concept of using locally-derived calorific value data.
- The transfer of average calorific value data from a cloud database into Gas Smart Metering Equipment (GSME) via the Gas Proxy Function (GPF) (simulated by a software comms hub simulator in the trial).
- The publishing of calorific value data from GSME to an In Home Display (IHD) simulated by taking data from the cloud and publishing it to a web interface in the trial.
- The transfer of calorific value and energy (kWh) data from a GSME via the GPF, back to the cloud, ready for processing, showcasing the potential for more accurate billing based on locally-derived calorific value data.

1.2 Technical Considerations

Technical challenges/limitations for future implementation of the ideal scenario for the Future Billing Methodology project include:

- **Frequency of data**

  In SMETS2 Great Britain Companion Specification (GBCS) Smart Metering terms, the gas meter is a 'sleepy device', if we were to send calorific value data to the meter every 30 minutes then this would be all the meter could do every time it 'woke up' and polled for data, leaving no time to send other data/messages to the meter. Therefore, during this trial, we chose to write the calorific value data four times per day, i.e. every six hours.

- **Battery life**

  Increasing the amount and frequency of data will have an impact on meter battery life. The frequency of data polls used for this trial is greater than meter manufacturers would normally reasonably expect, and consequently may likely impact the intended 10-year life lifespan of the battery in the gas meter. This would require gas suppliers to visit sites more often to change batteries, possibly close to the meter's natural end of life. Gas suppliers and manufacturers would need to consider these needs and costs.

- **GBCS use case for kWh retrieval**

  Currently, no GBCS use case exists to retrieve kWh from a GSME. This would require a change to the industry specifications and appropriate implementation/testing. For the trial, an appropriate script was created to enable this functionality, as we were able to configure a software comms hub simulator to do this.

- **DCC traffic load**

  Increased upstream data reading traffic load will put additional load on the DCC network. Any proposed increase in capacity would be subject to a cost benefit analysis and weighed against the other ambitions in the DCC's business plan. Current innovations on the roadmap include half hourly settlement, next day switching, development of 4G CHs, SMETS1 enrolment and double band Communication Hubs (CH).

- **Meter reading**

  In order to use the current gas meter functionality, gas suppliers may have to change the method they use to include calorific values. The type of log retrieved for billing purposes does not contain converted kWh data, therefore the gas supplier would need to select another service or ask for the historic energy consumption log in addition to the billing log. The alternative is for the SMETS2 specifications to be modified to add additional services. It should be noted, the capability to retrieve and display calorific value corrected data is already available in IHDs, CADs and Prepayment Metering Interface Devices (PPMIDs).

- **Change management**

  The data and service requirements would need to be agreed at an industry level between all stakeholders. If modifications to SMETS2 and GBCS are required, the change cycle would take of the order 12-18 months to approve and implement in the Smart Energy Code (SEC). The costs of these changes cannot be estimated without understanding the specific meter and system changes required which would be driven by gas suppliers.

- **Xoserve settlement changes**

  Calculation of annual quantities is based on meter readings supplied by gas suppliers. These meter readings are currently supplied as volume readings in cubic metres or cubic feet and converted using the relevant calorific value. The data can be read daily for Class 3 consumers, but the data is rolled up and supplied into settlement less frequently. This process could continue in the Ideal Scenario and indeed would need to remain in place for Class 4 consumers which do not have, or want, smart meters. There are also considerations related to meter reading disputes and arbitrations.

The costs of these changes cannot be estimated without understanding the specific meter and system changes required which would be driven by gas suppliers.

1.3 Recommendations

The Future Billing Methodology Project smart meter trial has demonstrated that the capability exists, in principle, to deliver locally-derived calorific value data to gas smart meters (GSME), and to convert this to a kWh value which could then be used for direct billing purposes. Such an arrangement could potentially provide a future platform to support a phased transition to full gas energy smart metering.

The trial study has further identified that to apply this in practice, GSME would need to be uprated to have active capability, rather than the existing “sleepy” default setting, with commensurate battery arrangements. However, more significantly, a GBCS use case would be required to enable retrieval of kWh data from GSME, which would require a change to the industry specifications, together with the appropriate pre-implementation testing, etc.

The above, together with increased DCC data traffic load, change management for the transition from the existing Xoserve settlement mechanism and impacts on supplier/retail billing systems would carry significant cost implications, which could not be estimated without understanding the specific meter and system changes required. This work would be outside the remit of gas transportation and driven principally by gas suppliers.

The FBM Project therefore recommends that in the light of the above, suppliers and the industry may consider whether it would be appropriate and generally advantageous to progress such changes in the future. These considerations should also include the implications of a future move to hydrogen transportation, which would involve the roll-out of hydrogen-specific GSME. If agreed, a separate industry engagement would be required to estimate the costs and timescales for implementing the necessary changes. This will be pointed to in the final cost benefit analysis for the Future Billing Methodology Project.

2 INTRODUCTION

The Future Billing Methodology (FBM) project aims to unlock the potential benefits of decarbonisation of the existing gas grid to provide an economical pathway to the decarbonisation of heat as an alternative to investment in electrification, heat networks and demand-side renewable technologies. The project studies integration of diverse gas sources without the need to standardise energy content, with the aim of identifying alternative Gas Supplier consumer billing arrangements in a sustainable future. The primary focus of the project is evaluation of alternatives to the use of the Flow Weighted Average Calorific Value (FWACV).

The Future Billing Methodology project is a proof-of-concept project which aims to identify the zones of influence around embedded biomethane injection points and to prove existing network models can be used to determine Calorific Value (CV) zones for billing purposes; this will unlock the potential benefits of decarbonisation of the existing gas grid. To verify that the existing network models could be used, sensors have been installed at 34 sites in the Hibaldstow and Chittering areas. These sites are a mixture of on-street locations and governor stations.

This document seeks to deploy a proof-of-concept study of the Smart Metering system to support the Ideal Scenario where consumer billing could be derived from the point of consumption using smart meters connected to a local in-network gas CV measurement point.

3 PURPOSE OF REPORT

The purpose of milestone 11 (MS11) is to report on the final setup and outcomes from the Smart Meter laboratory pilot, the aim of which was to demonstrate a proof of concept to help understand the feasibility of the Future Billing Methodology's Ideal Scenario in which Calorific Value (CV) is measured locally and distributed to consumers' gas smart meters. This report follows on from the previous milestone 6 report, Smart Metering System Simulation Specification /1/, where the proposed functional specification for the pilot was described in detail.

4 SMART METERING TRIAL SYSTEM

4.1 Trial Objectives

The smart metering trial system is a proof of concept set-up to demonstrate the potential for linking calorific value field measurements and smart meter data to generate accurate consumer billing. The trial objectives are as follows:

- Implement and commission the smart metering trial system design as detailed in the Smart Metering System Simulation Specification report (MS06) /1/.
- Run the trial in the DNV GL Technology and Assurance Laboratory in Peterborough[1], [2]. Maintaining and monitoring the equipment and communications systems. Manage the acquisition, maintenance, storage and access to data produce by the data on a daily basis.
- Demonstrate a proof of concept that potentially links consumers' smart meters to the billing system by outlining what is currently possible between field measurements and smart meters.
- Outline the requirement for future developments of smart meters and communications systems to deploy the Ideal scenario (or as close as possible to the Ideal scenario using current technology) including links between the Smart DCC.
- Liaise with industry stakeholders to identify potential issues and estimate the costs of implementing necessary changes to smart meters, communications infrastructure, Smart DCC systems and retail energy Suppliers' billing processes.

[1] The pilot is now being run in the DNV GL Loughborough laboratories due to the closure of the Peterborough facility

[2] The trial was scheduled to be run over 36 weeks which was reduced to 4 weeks due to the closure of the Peterborough facility and field trial installation delays due to COVID-19.

4.2 System design

Figure 1 illustrates the final system configuration.

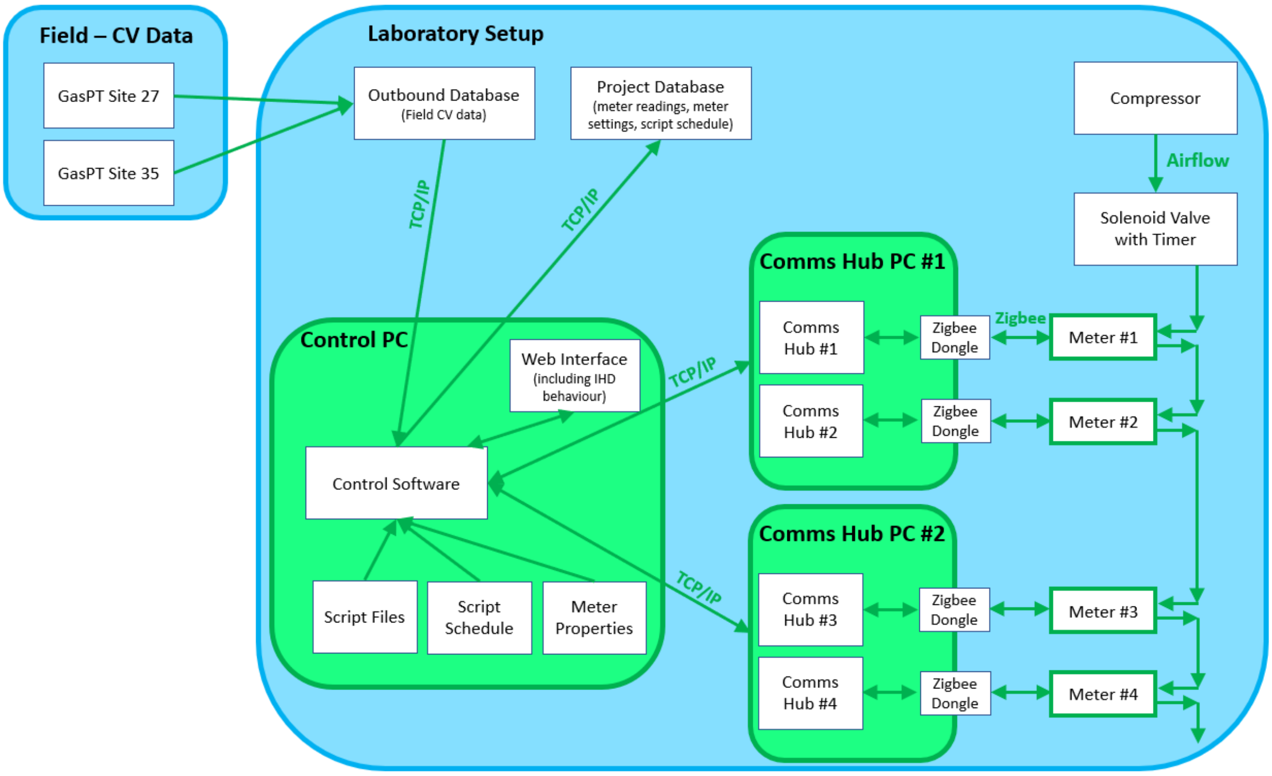


Figure 1: End to end system overview

4.2.1 Gathering CV data from the field and pushing it to the gas meters

Calorific value data is recorded in the field by two GasPT measurement devices and transmitted to the outbound cloud database. The GasPT was selected as a suitable and robust device for measuring calorific value in the gas network. The GasPT has a good track record and is approved by Ofgem for the measurement of calorific value at biomethane sites. Data from sites 27 (Barnard Avenue) and 35 (Louth Road) in the Hibaldstow (Lincolnshire) network were used for the smart metering trial, see Figure 2. The field trial also collected data from two GasPT sites in the Chittering (Cambridge) network, however due to unforeseen firmware issues with the PLCs (Programmable Logic Controller) at the Cambridge sites, data has been used from sites 27 and 35 only to ensure continuous data flow.

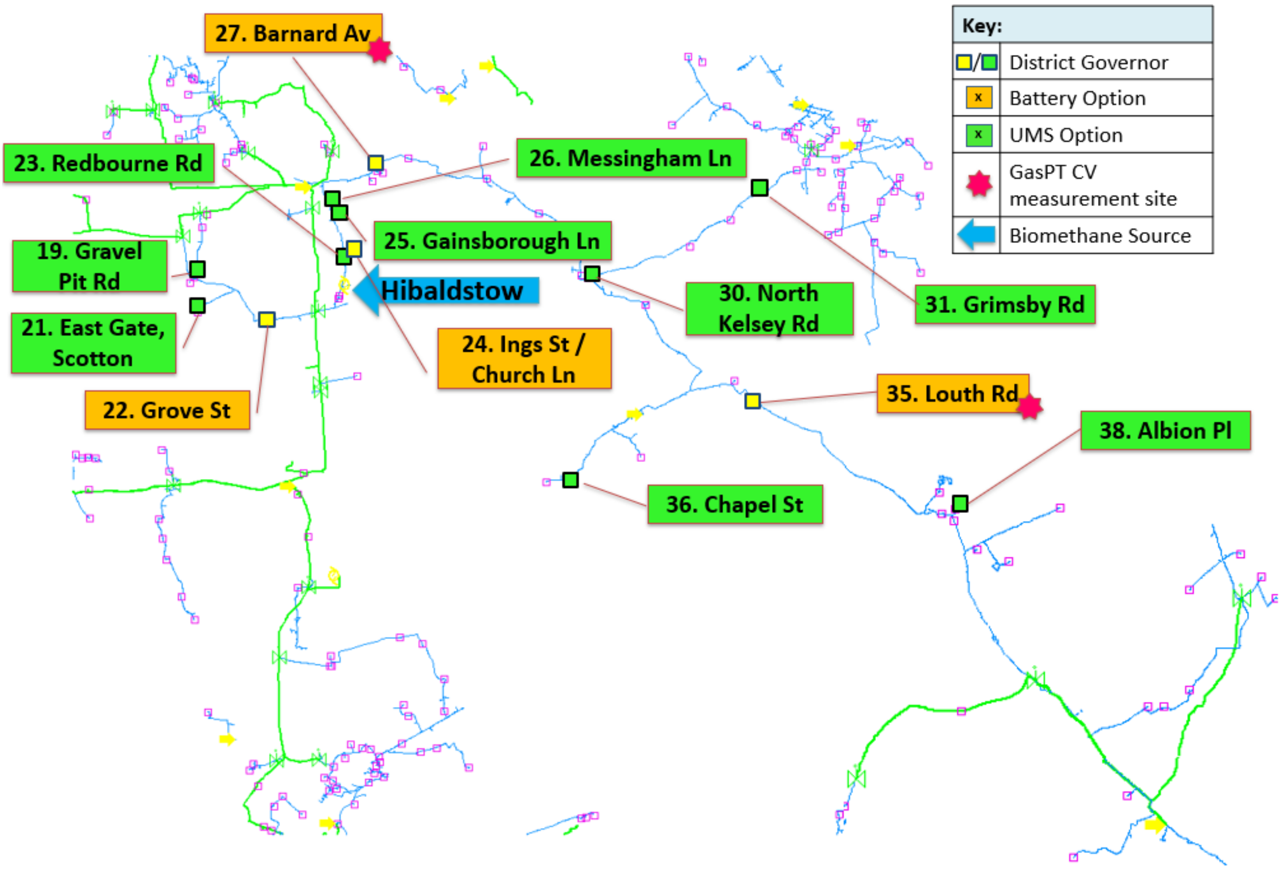


Figure 2: Field trial sites in Hibaldstow (East Midlands)

The control PC was set up to pull the average calorific values from the cloud database and push them to four SMETS2 gas smart meters via four (software-simulated) communications hubs, using a Zigbee tunnel between each pair. To ensure some redundancy during the trial, a parallel setup was adopted - whereby the system was configured to send data from one GasPT sensor to a corresponding pair of gas meters in the laboratory, twice over.

For the purposes of the trial, the calorific value data is being read every 6 hours, i.e. four times a day; however, this data was only being sent from the field once a day in order to maintain battery life at the relevant field installations. This effectively means the calorific value data was being updated once a day, with the most recent value being read, resulting in approximately one-hour and four-hour delays for the two sets of GasPT data.

This setup mimics the data flows that would occur if the system were to be implemented, with the control PC/comms hubs acting as the pseudo-DCC (Data Communications Company).

A compressor with valves was used to deliver airflow to the gas meters. Flows were adjusted manually and randomly by opening/closing the actuated valves.

4.2.2 Gathering data from the gas meters and sending it back to the cloud

The following readings are gathered and pulled back to the cloud:

- Cumulative Volume (sm^3) – every 30 minutes
- Calorific value (MJ/m^3) – every 6 hours

- Energy (kWh) – once a day
- Meter identification information

In order to extract all necessary data from the gas meters, the control software was set up to schedule and run a variety of GBCS[3] (Great Britain Companion Specifications) and non-GBCS scripts. These messages can broadly be split into two categories as follows:

- Primary test scripts – those needed to facilitate the main data requirements of the trial.
- Secondary test scripts – those which were required to support with the monitoring and stability of the trial.

See 'Overview of test scripts' in Appendix A for more details.

4.2.3 System setup

Prior to the commencement of the trial, all meters underwent a manual commissioning phase, which included:

- Setting the meter's clock, and ensuring it is marked as 'reliable'.
- Pairing the meter to the Comms Hub Gas Proxy Function (GPF), i.e. allowing this to be read in real-time.
- Setting the meter to credit mode.
- Setting the meter's tariff and price.

Each phase was setup using GBCS use cases, see Appendix B for further detail.

Additionally, internal testing was undertaken to ensure that the meters accepted the use cases delivered by all the test scripts, that the test script schedules were set up correctly and the scheduler and database connections were reliable.

4.2.4 Simulating an IHD using data published to the cloud database

Another objective for the trial was to present some of the trial data to an In-Home Display (IHD). However, due to complexities of the system requirements, an alternative solution was used whereby the IHD was simulated by building a web interface for the controller software.

A web interface was developed to provide a live data feed (i.e. for data that would ordinarily be retrieved by the IHD from the Communications Hub Gas Proxy Function (GPF) over the ZigBee Smart Energy network). Given the system design chosen, the data was recovered by the software Comms Hub Simulator anyway (via the primary/secondary scripts aforementioned) and (for clarity) is exactly the same data that would be sent to an IHD. An IHD does not communicate directly with a smart gas meter, so this alternative solution is a reliable approximation.

Smart Meter Equipment Specifications Version 2 (SMETS2)[4] requires that IHDs must be capable of displaying:

[1] Active tariff price
[2] Cumulative Consumption (day/week/month) in kWh and £ (see Figure 3)

---

[3] The GBCS describes the detailed requirements for communications between Smart Metering Devices in consumers' premises, and between Smart Metering Devices and the Smart DCC (Data Communications Company).

[4] SMETS2 defines the minimum physical, functional, interface, data, testing and certification requirements for Smart Meters deployed by electricity and gas suppliers in compliance with obligations defined in their respective supply license conditions.

[3] Customer Identification Number
[4] Debt (aggregated in credit mode) including rate
[5] EC balance
[6] Historic consumption logs
[7] Low credit warning
[8] Meter balance (due balance since last billing reset in £) (see Figure 4)
[9] Payment mode

The simulated IHD uses the following to demonstrate feasibility.

- The active tariff price [1] was static for the trial – or in other words, a single tariff was applied to each meter. But the web interface was set up to display the details of the tariff.
- The customer number [3] was not set for the trial, but a random ID was generated in its place and displayed in the web interface.
- The pilot uses credit mode only, so display of emergency credit [5], low credit warning [7] and payment mode [9] were deemed to be redundant.
- There was no requirement to simulate debt recovery, so aggregated debt and recovery rate [4] were also deemed redundant.
- Historic consumption logs [6] are not typically displayed during normal IHD usage, but the IHD can display up to 13 months of cumulative usage and this was made available via the web interface.
- Cumulative consumption [2] was recovered and displayed via the web interface for the trial.
- Similarly, meter balance [8] (which shows cost of consumption in the current billing period) was also available for display on the web interface.

The aim for this trial was to publish calorific value data from GSME to the IHD, this is shown in Figure 3, meter make and manufacturer have been redacted. It is notable that one meter manufacturer displayed calorific value in J/m^3x10^7 rather than in the standard MJ/m^3 (e.g. 39.4 MJ/m^3) and the other meter manufacturer displayed the calorific value with an unknown conversion (e.g. 1094444), the manufacturer was not able to be contacted for comment; however, the accurate calorific value inputs were used to calculate the energy use in kWh, see section 5.1.1. In conclusion, it is proven possible for the CV to be shown on the IHD but may require some configuration by the manufacturer.

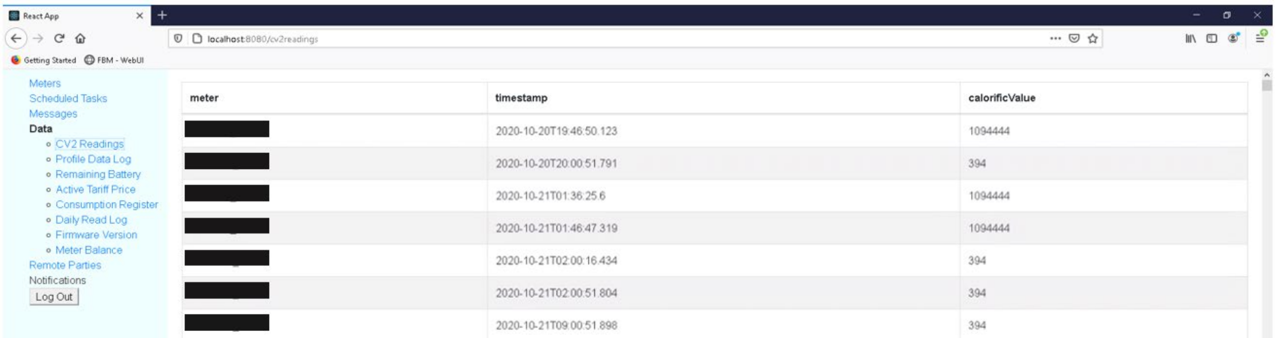


Figure 3: Screenshot from simulated IHD showing consumption register

Screenshots showing cumulative consumption and meter balance are shown in Figure 3 and Figure 4, meter make and manufacturer have been redacted. For all screenshots of the web interface used for the trial, including static data, please see Appendix C.

Cumulative consumption is being recovered and is displayed in Figure 3 with 'currentSummationDelivered' in kWh, the 'currentSummationDeliveredCalculated' in MWh. The field for unit of measure has been left blank and the multiplier and divisor fields detail the calculation for 'currentSummationDeliveredCalculated'.

The meter balance, see Figure 4, shows cost of consumption in £ for the current billing period, which will be reset to zero at the end of the billing period, e.g. every month.

The cost of the energy consumption is not shown by the web interface, however, can be calculated by multiplying by tariff price (see Appendix C). The IHD is then capable of showing the bill to date and credit remaining,

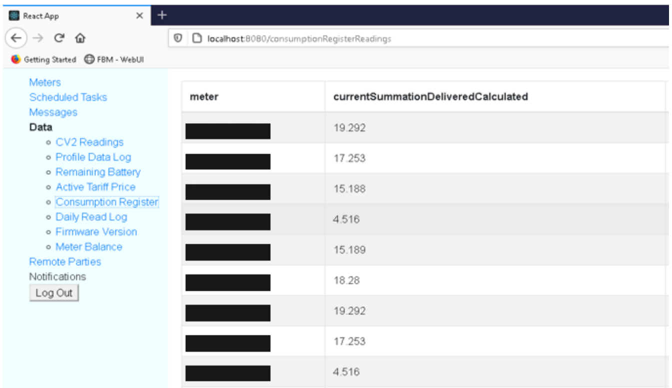


Figure 4: Screenshot from simulated IHD showing consumption register

4.2.5 Overview of system components and laboratory set-Up

The laboratory setup was originally designed to run at the DNV GL Technical Assurance Laboratory (DTAL) in Peterborough, however due to unforeseen company divestment this laboratory is no longer owned by DNV GL. DNV GL subsequently moved the trial to the testing facilities at the Loughborough laboratory. The trial system was made up of the following components, see Figure 5 for Loughborough laboratory setup:

- Clarke Silent Compressor, to provide supply of air to push through meters – simulated flow.
- Two solenoid valves with taps – to adjust flow randomly.
- Associated piping to channel the air supply through to the meters.
- Three networked Windows PCs:
  - One PC that hosts the controller software comprising:
    - Web interface to mock-up an IHD (see section above)
    - Scripts and schedules to pull/push data to/from meters/cloud
    - Meter properties
  - Two PCs that host the CyTAL CommsHub simulators and GSMEs:
  - Four CyTAL Comms-Hub Simulators with USB ZigBee dongles.
- Four SMETS2 GBCS Gas Smart Meters:

- Two Goldcard JGD4S-R Gas Diaphragm meters
- Two Flonidan Uniflo G4SZV-1 Gas Diaphragm meters

A range of meters were proposed for use, but the ones listed above were selected for their compatibility with the GBCS use cases.

- Two GasPT sites gathering data to push to the cloud. The gas quality measurement device GasPT2 uses correlative techniques to infer an equivalent five-component gas mixture (methane, ethane, propane, nitrogen and carbon dioxide) from which the gas properties, such as calorific value, are calculated using ISO 6976. The GasPT device is an Ofgem approved technology for measuring calorific value at biomethane network entry points. Figure 6 shows the installation at site 35, Louth Road (gas bottles are present for Site Acceptance Testing).

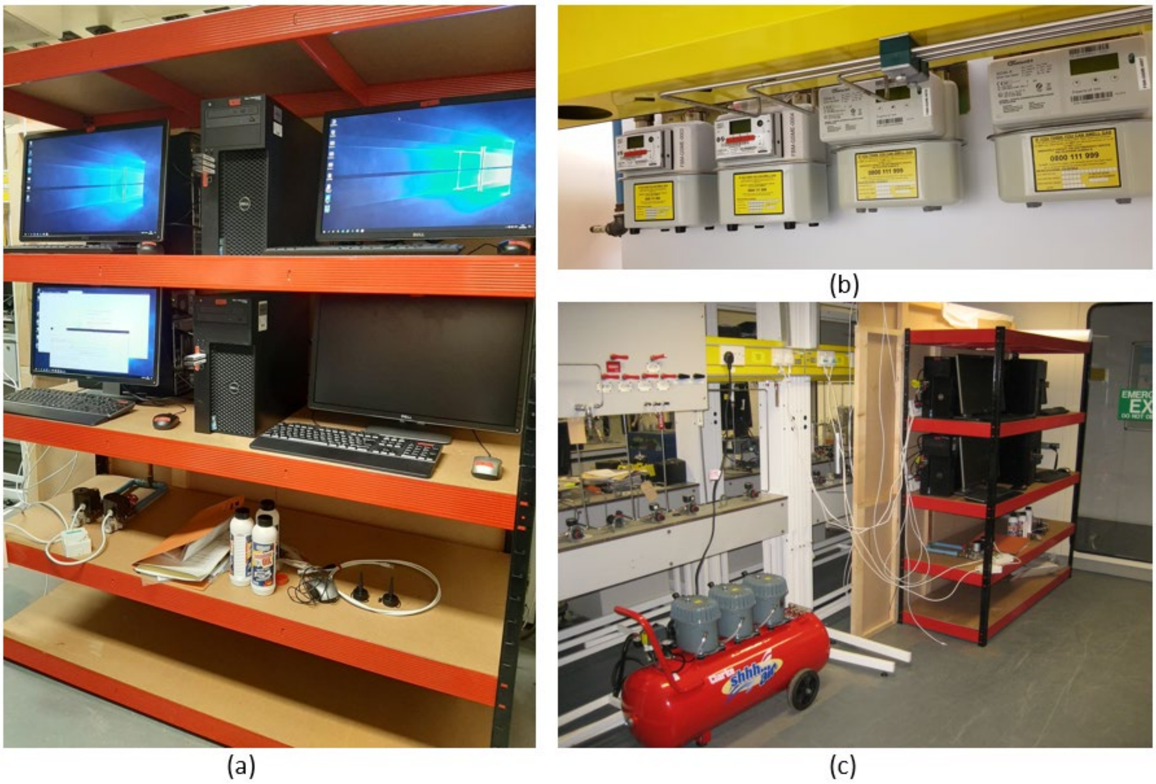


Figure 5: Loughborough laboratory setup (a) control, comms hub and spare PC; (b) meters; (c) overview setup with compressor and PCs shown

Figure 6: FBM installation at Site 35 during Site Acceptance Testing (GasPT site)

4.3 Trial Implementation

4.3.1 Duration

The trial duration was condensed to 4 weeks in the Loughborough laboratories, due to the closure of the Peterborough facility and field trial installation delays (refer to MS12 Final Report on Field Trial Progress /2/).

The reduction to a 4-week trial in the DNV GL Loughborough laboratories was mitigated by starting the trial once the chosen GasPT sites had been monitored and proven stable, with the addition of continual data monitoring, a daily summary email, script fail flags emailed directly to the project team and on-site management. With these mitigations in place, the trial constitutes a robust process to demonstrate the proof of concept that smart meters can be used to provide retail Gas Suppliers with converted data to generate accurate consumer bills.

4.3.2 Replicating the real-world smart metering system

The FBM trial system was designed to represent the real-world smart metering system as far as is reasonably practicable in the absence of any physical integrations to the DCC.

4.4 Assumptions

Trial assumptions are as follows:

- Satisfactory operation and transmission of data from the calorific value measurements installed in Hibaldstow.

- The satisfactory operation of the four SMETS2 GBCS Gas Smart Meters. The accuracy of these gas meters has not been assessed or validated beyond basic stability checks, as this has no impact on the trial objectives.

4.5 Exclusions

Trial exclusions are as follows:

- The provision of a final working solution design.
- Disclosure of any information that may compromise the security of smart meter data communications.
- Disclosure of sensitive data and costs related to stakeholders' internal processes and systems.
- No analysis of the implications for prepayment customers in detail.

5 RESULTS OF TRIAL

The objectives of the trial were to demonstrate the proof of concept that potentially links consumers' smart meters to the billing system; to detail the technical challenges/limitations for future implementation of the ideal scenario for the Future Billing Methodology project; and to discuss the potential costs of implementation of accurate billing using local calorific value measurement.

5.1 Proof of Concept

The Future Billing Methodology trial system was designed to represent the real-world smart metering system as far as is reasonably practicable in the absence of any physical integrations to the DCC. The trial successfully demonstrates the following four processes:

- The collection of calorific value data from sensors in the field, and the publishing of the data into a cloud database, averaging readings and hence showcasing the notion of leveraging locally derived calorific value data.
- The transfer of average calorific value data from a cloud database into Gas Smart Metering Equipment (GSME) via the GPF (simulated by a software comms hub simulator in the trial).
- The publishing of calorific value data from GSME to an IHD (simulated by taking data from the cloud and publishing it to a web interface in the trial).
- The transfer of calorific value and energy (kWh) data from a GSME via the GPF, back to the cloud, ready for processing, showcasing the potential for more accurate billing based on calorific value data.

5.1.1 Energy Calculation

The data inputs (calorific value and volume flow) were used to calculate the energy use in kWh and confirmed the GSME has the potential to provide accurate energy consumption data. The outputs of the GSME were named consumption register and consumption reading, see Figure 7.

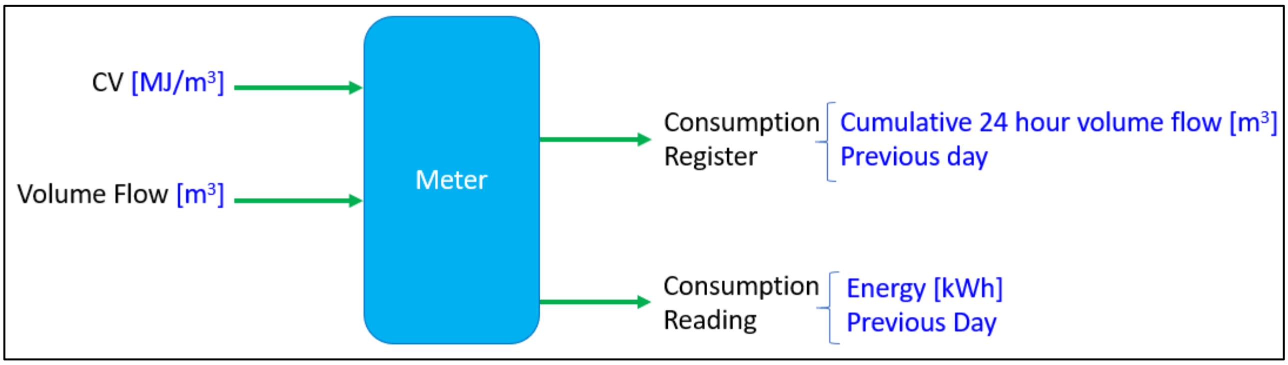


Figure 7: Meter Energy Calculation

The following formula is currently used to convert gas volume to energy.

$$\text{Energy (kWh)} = \frac{\text{Calorific Value (MJ/m}^3\text{) * conversion factor * gas consumption (m}^3\text{)}}{3.6}$$

The Gas (Calculation of Thermal Energy) Regulations 1996 define a standard conversion factor value of 1.02264 for domestic and small businesses consuming under 732 MWh per annum.

5.1.2 Success criteria

A set of technical success indicators has been evaluated, see Table 2.

Table 1: Success Criteria Evaluation

#	Success criteria	Notes	Met
1	All physical laboratory apparatus and test tool software components will be clearly documented (partly fulfilled by this document).	Detailed specifications and training were provided over the course of development and execution of the pilot.	Yes
2	Test laboratory staff will be competent, well-trained and familiar with the design of smart meters and the DCC services and systems.	Training was provided to DNV GL laboratory staff when the pilot was transferred to Loughborough.	Yes
3	The test laboratory will simulate a domestic Smart Meter System including gas meter and In-Home Display. An automatable air supply will be used to advance the GSME index. The test environment and meters will be monitored throughout the pilot to ensure optimal test conditions are maintained.	Physical IHDs were dropped from the pilot before commencement. Production SMETS2 compliant gas samples were used in the pilot. Monitoring was undertaken by DNV GL supported by a third-party contractor.	Partial - alternative solution developed to deliver outcome
4	Gas Supplier billing cycle activities will be emulated with respect to recovery of billing data and interval data logs. Additional data items will be regularly recovered from smart gas meter specimens to validate pilot operation. Test data may not accurately represent the actual data items recovered by individual gas suppliers.	Billing data was populated in the MS SQL project database.	Yes
5	A set of technical success indicators evaluated at the end of the pilot will assess the validity of metrology and operational data outputs, optimisation of calorific value inputs and data outputs, capabilities, and performance requirements of the DCC's systems, SMETS2 and GBCS requirement gaps and issues, and technical limitations of current smart gas meter designs.	Output data has been assessed and confirmed that the GSME is capable of calculating accurate energy consumption data. Performance requirements and technical limitations are discussed in section 5.2.	Yes
6	Physical smart gas meter specimens will be MID approved and calibrated to measure consumption accurately. All metrology data outputs from smart gas meters will be validated against MID approved G4 (U6) accuracy class 1.5 check meter monitored weekly (no requirement to be SMETS compliant).	Production SMETS2 compliant gas samples were used in the pilot.	Yes
7	Converted energy data recovered from smart gas meters will be validated using the associated CV and PTZ conversion factors. Each data record created in the project database will include an associated validity flag. Data consistency issues will be flagged to the project team. Where suspect data output patterns are detected, the pilot may be temporarily halted for further investigation. An exception report will be generated for the project team detailing reasons for the stoppage, the outcome of investigation analysis and the resolution.	The trial was subject to continual data monitoring, daily summary emails, script fail flags emailed directly to the project team and on-site management. Software failures were swiftly rectified with no impact on the results.	Yes
8	Pilot equipment and smart gas meter test specimens will be inspected for physical irregularities or anomalies at least daily. Smart gas meters will continue to operate without failure for the duration of the pilot. Failures or operational issues (e.g. error flags) identified during inspections will be exchanged in accordance with the [trial's] procedures.	The trial was subject to continual data monitoring, daily summary emails, script fail flags emailed directly to the project team and on-site management. No physical failures were encountered.	Yes

5.2 Technical Considerations

The trial system provides a reasonable physical representation of what would need to happen (for a real implementation) and further highlights some of the DCC/Xoserve responsibilities that would need to be developed in due course. This section details the technical challenges and limitations for future implementation of the ideal scenario for the future billing methodology project.

5.2.1 Data frequency

In order to replicate the smart meter infrastructure and data architecture, the calorific value data should be read at 30 minute intervals, however the current SMETS2 meters are limited.

In SMETS2 GBCS Smart Metering terms, the gas meter is a 'sleepy device' and therefore will only wake up and poll for messages every 30 minutes. For the Future Billing Methodology trial, in addition to writing the calorific value, a number of further reads of different data items was required from the meter per day. If we were to send calorific value data to the meter every 30 minutes then this would be all the meter could do every time it 'woke up' and polled for data, leaving no time to send other data/messages to the meter. Therefore, during this trial, we chose to write the calorific value data four times per day, i.e. every six hours.

5.2.2 Battery Life

The calorific value data in the field was recorded at six-minute intervals, however this data was only being sent from the field once a day in order reduce energy consumption. This effectively means the calorific value data was being updated once a day, with the most recent value being read, resulting in approximately one-hour and four-hour delays for the two sets of GasPT data.

Increasing the amount and frequency of data will have an impact on meter battery life. The frequency of data polls used for this trial is greater than meter manufacturers would normally reasonably expect, and consequently may likely impact the intended 10-year life lifespan of the battery in the gas meter. This would require gas suppliers to visit sites more often to change batteries, possibly close to the meter's natural end of life. Gas suppliers and manufacturers would need to consider these needs and costs.

Potential bandwidth/latency or energy consumption issues would be encountered if industry were, for example, to move towards domestic half-hourly settlement for gas using locally derived calorific value data.

5.2.3 GBCS use case for kWh retrieval

Currently, no GBCS use case exists to retrieve kWh from a GSME. This would require a change to the industry specifications and appropriate implementation/testing. For the trial, an appropriate script was created to enable this functionality, as we were able to configure a software comms hub simulator to do this.

5.2.4 DCC traffic load

Increased upstream data reading traffic load will put additional load on the DCC network. There is also a downstream load pushing calorific values (and potentially the conversion constant, see section 5.1.1) to meters.

The DCC has a complex monitoring and capacity planning strategies in place. Any proposed increase in capacity would be subject of a cost benefit analysis and weighed against the other ambitions in the DCC's business plan. Current innovations on the roadmap include half hourly settlement, next day switching, development of 4G CHs, SMETS1 enrolment and double band Communication Hubs (CH).

Increased interactions also mean increased transactional charges for gas suppliers.

5.2.5 Meter Reading

SMETS2 gas meters measure volume and convert volume data (m^3) to energy consumption (kWh) at the point the data is to be logged. SMETS2 defines several data logs that meters must record converted data to at different intervals (30 minutes, daily, weekly or monthly).

Current SMETS2 gas meters are capable of recording and storing the following cumulative data:

- Nine days of energy consumption comprising the current day and the prior eight days, in kWh and £
- Six weeks of energy consumption comprising the current week and the prior five Weeks, in kWh and £
- Fourteen months of energy consumption comprising the current month and the prior thirteen months, in kWh and £

GSME also records the cumulative energy consumption and cost of consumption in kWh and £ for the current day up to the current time to the Cumulative Current Day Value Store.

There are a number of different ways gas suppliers can retrieve billing data from smart gas meters, see Table 2. There is no set method and gas suppliers are likely to use different commands to recover data depending on the type of customer, tariff and any energy management services they provide.

Table 2: Meter Reading Services

Gas supplier activity	Target meter log	DCC User Interface Service command	Data Available in kWh?
Midnight reading	Daily Read	4.6.1 Retrieve Import Daily Read Log	No
Reading at the time of payment mode or tariff update	Billing Data	4.4.2 Retrieve CoM or Tariff Triggered Billing Data Log	No
Half hourly data	ProfileData	4.8.1 Read Active Import ProfileData	Yes
Consumption data	Consumption	4.17 Retrieve Daily Consumption Log	Yes
Meter reading data & prepayment data	Billing Data	4.4.3 Retrieve Billing Calendar Triggered Billing Data Log	No
Instantaneous read	-	4.1.1 Read Instantaneous Import Registers 4.1.2 Read Instantaneous Import TOU Matrices	Yes
Midnight	Prepayment Daily Read	4.14 Read Prepayment Daily Read Log	No
Prepayment data (instantaneous)	-	4.3 Read Instantaneous Prepay Values	No

Not all of the above services will bring back kWh data. In order to use the current gas meter calorific value functionality, gas suppliers may have to change the method they use. For instance, billing snap shots are created by the meter over a set billing period which are retrieved by the gas supplier at a later time within the billing window. The type of log retrieved does not contain converted kWh data, therefore the gas supplier would need to select another service or ask for the historic energy consumption log in addition to the billing log. The alternative is for the SMETS2 specifications to be modified to add additional services.

5.2.6 Change management

Issue Resolution Proposals (IRP) are issues with GBCS arising from developer R&D, testing and certification activities, and can be raised by any stakeholder. Change Resolution Proposals (CRP) are specific specification modification requests to change or add functionality.

The data and service requirements would need to be agreed at an industry level between all stakeholders using the above procedures. Relevant stakeholders involved in modification proposals include BEIS, the DCC, SECAS, Ofgem, manufacturers, suppliers, networks, MAPs, MAM, installers, trade bodies and consumer bodies amongst others. An overview of gas market roles is described in Appendix E. Changes would be drafted to the SMETS2, Communications Hub Technical Specifications (CHTS) and GBCS device specifications and the DCC's service specifications including the DCC User Interface Specification (DUIS) and Message Mapping Catalogue (MMC).

Agreed modifications are then rolled up into the next scheduled Smart Energy Code (SEC) release which includes the specifications as subsidiary documents. There are typically three SEC releases per year. Documentation releases are typically in February with system releases in June and November.

If modifications to SMETS2 and GBCS are required, the change cycle would take of the order 12-18 months to approve and implement in the SEC. Implementation in the DCC production environment may be outside this timeframe and manufacturer timelines would be commercially driven. The Secretary of State also has powers to force versions of SMETS2 to be rolled out by setting appropriate Technical Requirements Installation Validity Periods and Maintenance Validity Periods which are mechanisms to obligate energy suppliers to ensure they are installing and maintaining meters compliant with currently in force specifications.

The costs of these changes cannot be estimated without understanding the specific meter and system changes required which would be driven by gas suppliers.

5.2.7 Xoserve settlement changes

No changes to the Xoserve settlement process with gas shippers have been considered. Calculation of annual quantities is based on meter readings supplied by gas suppliers. These meter readings are currently supplied as volume readings in cubic metres or cubic feet and converted using the relevant calorific value. The data can be read daily for Class 3 consumers, but the data is rolled up and supplied into settlement less frequently. This process could continue in the Ideal Scenario and indeed would need to remain in place for Class 4 consumers which do not have, or want, smart meters. There are also considerations related to meter reading disputes and arbitrations.

For the smart metering legislative and regulatory framework, see Appendix C. For an overview of the gas market roles, see Appendix D.

6 CONCLUSIONS

6.1 Proof of Concept

The trial demonstrates that the existing smart metering system design can use calorific value data to deliver locally calculated kWh billing information into the gas billing process. The trial successfully demonstrates the following four processes:

- The collection of calorific value data from sensors in the field, and the publishing of the data into a cloud database, reading for averaging and hence demonstrating the concept of using locally-derived calorific value data.
- The transfer of average calorific value data from a cloud database into Gas Smart Metering Equipment (GSME) via the GPF (simulated by a software comms hub simulator in the trial).
- The publishing of calorific value data from GSME to an IHD (simulated by taking data from the cloud and publishing it to a web interface in the trial).
- The transfer of calorific value and energy (kWh) data from a GSME via the GPF, back to the cloud, ready for processing, showcasing the potential for more accurate billing based on calorific value data.

6.2 Technical Considerations

Technical challenges/limitations for future implementation of the ideal scenario for the Future Billing Methodology project include:

- **Frequency of data**

  In SMETS2 GBCS Smart Metering terms, the gas meter is a 'sleepy device', if we were to send calorific value data to the meter every 30 minutes then this would be all the meter could do every time it 'woke up' and polled for data, leaving no time to send other data/messages to the meter. Therefore, during this trial, we chose to write the calorific value data four times per day, i.e. every six hours.

- **Battery life**

  Increasing the amount and frequency of data will have an impact on meter battery life. The frequency of data polls used for this trial is greater than meter manufacturers would normally reasonably expect, and consequently may likely impact the intended 10-year life lifespan of the battery in the gas meter. This would require gas suppliers to visit sites more often to change batteries, possibly close to the meter's natural end of life. Gas suppliers and manufacturers would need to consider these needs and costs.

- **GBCS use case for kWh retrieval**

  Currently, no GBCS use case exists to retrieve kWh from a GSME. This would require a change to the industry specifications and appropriate implementation/testing. For the trial, an appropriate script was created to enable this functionality, as we were able to configure a software comms hub simulator to do this.

Potential costs of implementation of accurate billing using local calorific value are as follows:

- **DCC traffic load**

Increased upstream data reading traffic load will put additional load on the DCC network. Any proposed increase in capacity would be subject of a cost benefit analysis and weighed against the other ambitions in the DCC's business plan. Current innovations on the roadmap include half hourly settlement, next day switching, development of 4G CHs, SMETS1 enrolment and double band Communication Hubs (CH).

- **Meter reading**

  In order to use the current gas meter calorific value functionality, gas suppliers may have to change the method they use. The type of log retrieved for billing purposes does not contain converted kWh data, therefore the gas supplier would need to select another service or ask for the historic energy consumption log in addition to the billing log. The alternative is for the SMETS2 specifications to be modified to add additional services.

- **Change management**

  The necessary data and service requirements need to be agreed at an industry level between all stakeholders. If modifications to SMETS2 and GBCS are required, the change cycle would take of the order 12-18 months to approve and implement in the SEC. The costs of these changes cannot be estimated without understanding the specific meter and system changes required which would be driven by gas suppliers.

- **Xoserve settlement changes**

  Calculation of annual quantities is based on meter readings supplied by gas suppliers. These meter readings are currently supplied as volume readings in cubic metres or cubic feet and converted using the relevant calorific value. The data can be read daily for Class 3 consumers, but the data is rolled up and supplied into settlement less frequently. This process could continue in the Ideal Scenario and indeed would need to remain in place for Class 4 consumers which do not have or want smart meters. There are also considerations related to meter reading disputes and arbitrations.

The costs of these changes cannot be estimated without understanding the specific meter and system changes required which would be driven by gas suppliers.

6.3 Timeline

If modifications are required to meter designs, the effort, costs and risk associated with rollout of updated firmware to installed meters should be considered.

The meter market comprises of 55.2 million domestic and non-domestic meters which fall within the smart meter rollout of which 23.5 million are gas meters. There are another 900,000 gas meters in smaller commercial customers and microbusinesses. The domestic and small commercial meter market is expected to grow by 300-400,000 new connections per year from 2021 to a total of 56.8 million meters by 2024 (CAGR 0.71%) with non-domestic connection net grow growth c. 30,000 per annum. Gas meters are expected to roughly follow the national average with 44% of new builds receiving a gas supply. Energy suppliers have installed approximately 22.7 million smart meters to date of which 9.4 million are gas meters. This leaves approximately 14.6 million meters left to be installed.

The government has recently extended the rollout by 4 years to mid-2025 which presently includes an extension of 6 months to account for the impact of COVID-19. Assuming the Ideal Scenario is implemented towards the end of 2024 at earliest, gas suppliers will need to rollout firmware updates to

20+ million meters which would have a major impact on gas supplier transactional charges in addition to any scheduled updates.

6.4 Other Considerations

The UK Government announced its 10-point Green Industrial Revolution plan in November 2020 which includes limited details of the first package of commitments towards 5 GW of hydrogen production capability and development of town-scale hydrogen heating pilots by 2030. The introduction of hydrogen into the national gas network will impact the national gas meter portfolio, but the degree to which existing meters are affected and new meters are deployed is dependent on enduring policy. There is a growing body of research and roster of proof of concept trials in UK and around Europe including piloting hydrogen compatible SMETS2 meters.

The current position of town scale pilots by 2030 indicates a full deployment is not likely until the mid-2030s, however the next generation of SMETS2+ meters are likely to be hydrogen capable. This would not necessarily shift the paradigm for the Ideal Scenario but may impact the type of data and way that future meters record that data.

If gas networks are converted to 100% hydrogen in the longer term, the calorific value will vary much less than it does today for natural gas. However, since the metered volumes of hydrogen will be approximately three times greater, the impact of smaller changes in calorific value on overall customer bills will need to be investigated.

Consumer energy management services delivered at the point of consumption may be more beneficial in the long term. At the moment, consumers receive half hourly data from their IHDs (this data is not transferred to the energy supplier) and they can make the same data available to third party commercial service providers via a CAD which are becoming regularly available. It should be noted, the capability to retrieve and display calorific value corrected data is already available in IHDs, CADs and Prepayment Metering Interface Devices (PPMIDs).

6.5 Alternative Solution

Gas suppliers calculate consumer gas usage on a daily basis using the daily flow weighted average calorific value for the charging area which is one of 13 local distribution zones. With the introduction of smart meters, gas suppliers can recover actual daily meter readings. If a localised daily calorific value replaced the FWACV, the gas supplier would have the choice of converting daily volumes (m^3) in their billing systems or reading the daily converted energy consumption values (kWh).

It is not clear what benefits conversion at source would give over conversion at base if recovered on a daily basis. As mentioned above, there is also the possibility to acquire local calorific value corrected data via the CAD interface.

Current supply license obligations require gas suppliers to read the meter at least once a year, so suppliers would need to be incentivised to offer the service or Ofgem would need to change the licence conditions.

In the meantime, gas suppliers are free to trial retrieving the data discussed above from their meters with customer permission.

7 RECOMMENDATIONS

The Future Billing Methodology Project smart meter trial has demonstrated that the capability exists, in principle, to deliver locally-derived CV data to gas smart meters (GSME), and to convert this to a kWh value which could then be used for direct billing purposes. Such an arrangement could potentially provide a future platform to support a phased transition to full gas energy smart metering.

The trial study has further identified that to apply this in practice, GSME would need to be uprated to have active capability, rather than the existing "sleepy" default setting, with commensurate battery arrangements. However, more significantly, a GBCS use case would be required to enable retrieval of kWh data from GSME, which would require a change to the industry specifications, together with the appropriate pre-implementation testing, etc.

The above, together with increased DCC data traffic load, change management for the transition from the existing Xoserve settlement mechanism and impacts on supplier/retail billing systems would carry significant cost implications, which could not be estimated without understanding the specific meter and system changes required. This work would be outside the remit of gas transportation and driven principally by gas suppliers.

The FBM Project therefore recommends that in the light of the above, suppliers and the industry may consider whether it would be appropriate and generally advantageous to progress such changes in the future. These considerations should also include the implications of a future move to hydrogen transportation, which would involve the roll-out of hydrogen-specific GSME. If agreed, a separate industry engagement would be required to estimate the costs and timescales for implementing the necessary changes. This will be pointed to in the final cost benefit analysis for the Future Billing Methodology Project.

8 KEY DEFINITIONS

CAD	**Consumer Access Devices** A CAD is a device similar in capabilities to an IHD which facilitates access to information related to a consumer's energy consumption and tariffing. It provides a mechanism for third party non-SMETS2 devices to access consumer data, for example, integration with connected home devices, demand-side management equipment or cloud services.
CH	**Communications Hub** The CH routes data messages comprising of commands, responses and alerts between the SMWAN and the SMHAN. It is responsible for creating and managing smart meter device access to the SMHAN. It hosts two logical smart meter devices called the CHF and the GPF. The CH has a ZigBee low power radio for SMHAN communications using 2.4GHz frequency (single band) or a combination of 2.4GHz and sub-GHz (double band) frequencies. Single band CHs will be deployed in over 70% of properties. Double band CHs have better signal penetration and will be deployed where standard single band devices are unsuitable. CHs are owned by the Smart DCC and rented to energy suppliers.
CHF	**Communications Hub Function** The CHF is part of the Communications Hub responsible for managing the transport of GBCS commands, responses and alerts between SMHAN end devices and remote DCC User parties.
CSP	**Communications Service Provider** Two CSPs are contracted by the Smart DCC to provide the national SMWANs in three regions. Arqiva is responsible for a proprietary long-range mesh radio network for CSP North region covering the north of England and Scotland. Telefónica is using their existing 2G and 3G mobile network for CSP Central & South regions covering the most of England and Wales.
ESME	**Electricity Smart Metering Equipment** An ESME is an electricity meter which consists of gas metering functionality and additional smart capabilities via connectivity with the wider smart metering end-to-end system.
GBCS	**Great Britain Companion Specification** The GBCS describes the detailed requirements for communications between Smart Metering Devices in consumers' premises, and between Smart Metering Devices and the Smart DCC.
GCS28	**[Command] "GCS28"** GBCS commands sent to SMHAN devices are known as a 'use case'. GCS28 is a GBCS use case sent to the GSME by the gas supplier. GCS28 is a command to set the time of a gas meter. Practically, the command forces the gas meter to synchronise its internal clock to the Communications Hub's clock.

GPF	**Gas Proxy Function** The GPF is part of the Communications Hub and acts as a mirror for certain GSME data so that this data can be read in real-time even if the GSME is in a low power sleep state.
GSME	**Gas Smart Metering Equipment** A GSME is a gas meter which consists of gas metering functionality and additional smart capabilities via connectivity with the wider smart metering end-to-end system. The GSME is a battery powered 'sleepy device' which can be replaced during its lifetime by the gas supplier. It spends most of its time in a low power sleep state, waking up every 30 minutes to process commands or exchange data with the Communications Hub. Certain data is replicated (mirrored) between the GSME and the GPF residing in the Communications Hub which can be accessed by gas suppliers and consumers while the GSME is asleep. Commands sent by remote Smart DCC User parties to the GSME will be buffered by the Communications Hub until the GSME wakes from its low power state to process.
HCALCS	**HAN (Home Area Network) connected Auxiliary Load Control Switches** An HCALCS is a standalone SMHAN device which controls secondary electricity circuits connected to consumer loads including heating, water and electric vehicle chargers or controlling generation capacity. Auxiliary Load Control Switches may also be incorporated into an ESME.
IHD	**In Home Display** An IHD is a device which provides information related to a consumer's energy consumption and tariffing. It accesses electricity data directly from the ESME and gas data indirectly via the GPF. It is not capable of sending or receiving data messages to and from remote Smart DCC User parties.
PPMID	**Prepayment Metering Interface Devices** A PPMID is a type of IHD that is used by prepayment customers whose meters are installed in locations which are difficult to access. It supports critical prepayment services including vending, emergency credit activation and supply reconnection.
Smart DCC	**Smart Data Communications Company** The Smart DCC is responsible for providing communication services between smart meters and energy suppliers, network operators and other authorised DCC Users.
SEC	**Smart Energy Code** The Smart Energy Code (SEC) is a multi-Party agreement which defines the rights and obligations of energy suppliers, network operators and other relevant parties involved in the end to end management of smart metering in Great Britain.
SMETS1 /SMETS2	**Smart Meter Equipment Specifications version 1/2** SMETS2 defines the minimum physical, functional, interface, data, testing and certification requirements for Smart Meters deployed by electricity and gas suppliers in compliance with obligations defined in their respective supply license conditions.

SMHAN	**Smart Meter Home Area Network** The ZigBee short range low power network which created and managed within the consumer's premises by the Communications Hub for the purposes of secure data exchange between smart meter equipment including ESMEs, GSMEs, IHDs, HCALCSs, PPMIDs and CADs.
SMWAN	**Smart Meter Wide Area Network** The network infrastructure provided by the Smart DCC to enable sending and receiving information between the Smart DCC's systems and smart metering equipment in consumer's premises.

9 REFERENCES

/1/ DNV GL, MS06 – Smart Metering System Simulation Specification Final Report, July 2018.

/2/ DNV GL, MS12 Final Report on Field Trial Progress (SDRC 9.2), December 2020.

Appendix A Overview of the test scripts used in the trial schedules

The following tables provide further details about the primary/secondary test scripts that were developed and used for the trial; and where applicable, the GBCS use cases that they relate to.

A.1 Primary Test Scripts

Primary test scripts used	Details of relevant GBCS use case
FBM01_SetCV.groovy	GCS23, which sets the CV and conversion factor. Takes the most recent CV value for a specific tag in the cloud database and pushes it to the meter. Conversion value is fixed (as per GBCS) at 102264.
FBM02_ReadCV.groovy	GCS21a, reads the raw CV from the meter and writes to the database in raw format. Needs to be manipulated to get the true decimal value (could vary depending on meter type).
FBM07a_ReadAltConsumption_GPF.groovy	Not a GBCS use case but reads the alternative consumption (kWh) via the Gas Proxy Function. Used to obtain current day, previous day, current week, previous week, current month, previous month.
FBM07b_ReadAltConsumption_Meter.groovy	Not a GBCS use case but reads the alternative consumption (kWh) directly from the gas meter. Used to obtain current day, previous day, current week, previous week, current month, previous month.
FBM12_ReadConsumptionRegister.groovy	GCS13a, which delivers current summation delivered, unit of measure and a deviser/multiplier. Information is written to the database in raw and calculated format.

A.2 Secondary Test Scripts

Secondary test scripts used	Details of relevant GBCS use case
FBM03_ReadProfileDataLog.groovy	GCS17 to read the HH profile data log.
FBM04_ReadDailyReadLogs.groovy	GCS16a to read the daily read logs.
FBM05a_SetTariffPrice.groovy	GCS01a which sets the tariff and price table.
FBM05b_SetTariff.groovy	GCS01b which sets the price table.
FBM06_ReadActiveTarrifPrice.groovy	GCS21f which reads the active tariff/price.
FBM08a_ReadCostConsumption_GPF.groovy	Not a GBCS use case but reads cost consumption from Gas Proxy Function. Used to obtain current day, previous day, current week, previous week, current month, previous month.

Secondary test scripts used	Details of relevant GBCS use case
FBM08b_ReadCostConsumption_Meter.groovy	Not a GBCS use case but reads cost consumption directly from the gas meter. Used to obtain current day, previous day, current week, previous week, current month, previous month.
FBM09_ReadRemainingBatteryAndSupplyState.groovy	GCS33, reads the valve status (i.e. ON/ARMED/OFF) and the remaining battery capacity. Script throws an error if the supply status is not ON.
FBM10_ReadFirmwareVersion.groovy	GCS38 to read the firmware version.
FBM11_ReadMeterBalance.groovy	GCS60 to read the meter balance (credit remaining and bill to date delivered).

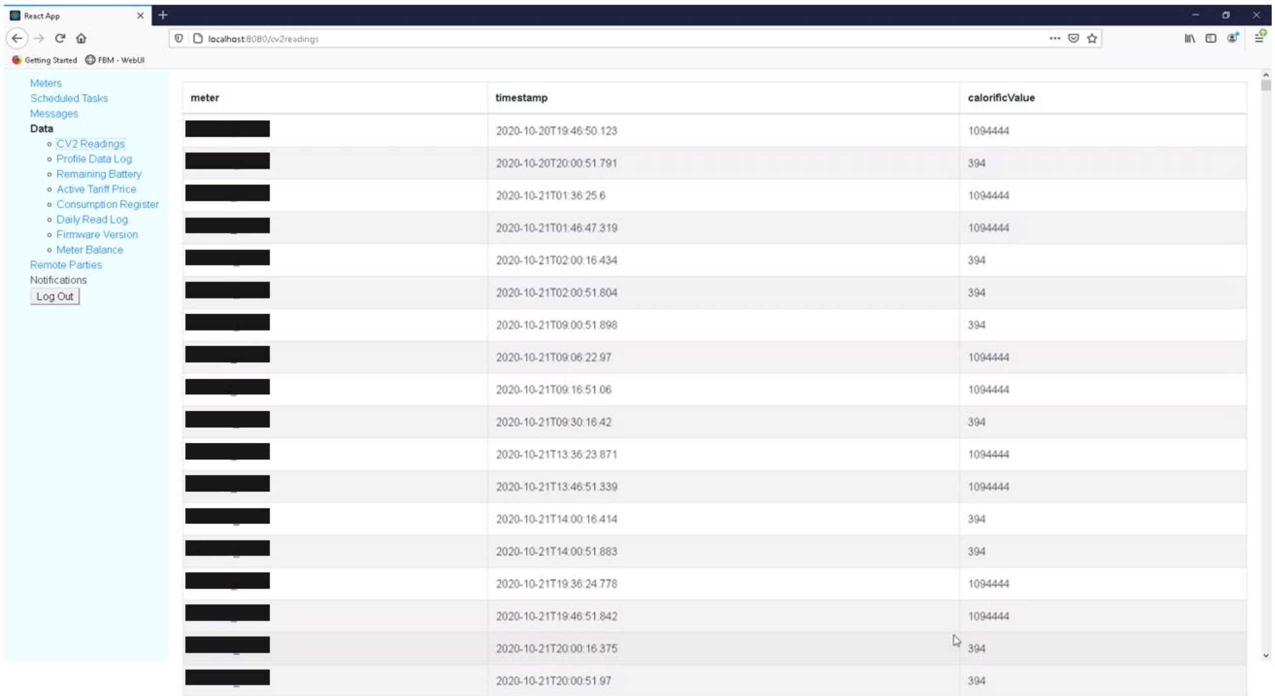
Appendix B Manual Commissioning Setup

Activity	GBCS Use Case(s)
Setting the meter’s clock, and ensuring it is marked as ‘reliable’	GCS28
Pairing the meter to the CommsHub GPF	CS03b
Setting the meter to credit mode	GCS02
Setting the meter’s tariff and price	GCS01a and GCS01b

Appendix C Simulated IHD Screenshots

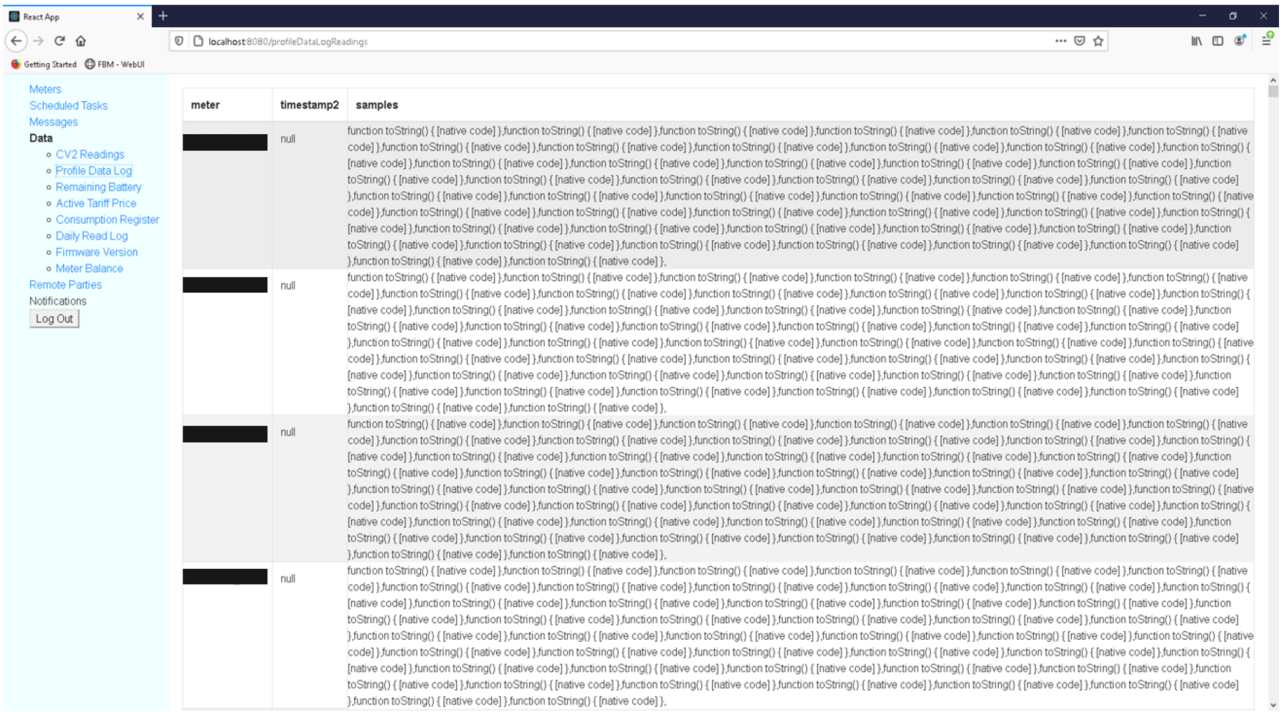
Meter name and manufacturer have been redacted.

9.1.1.1 CV2 reading



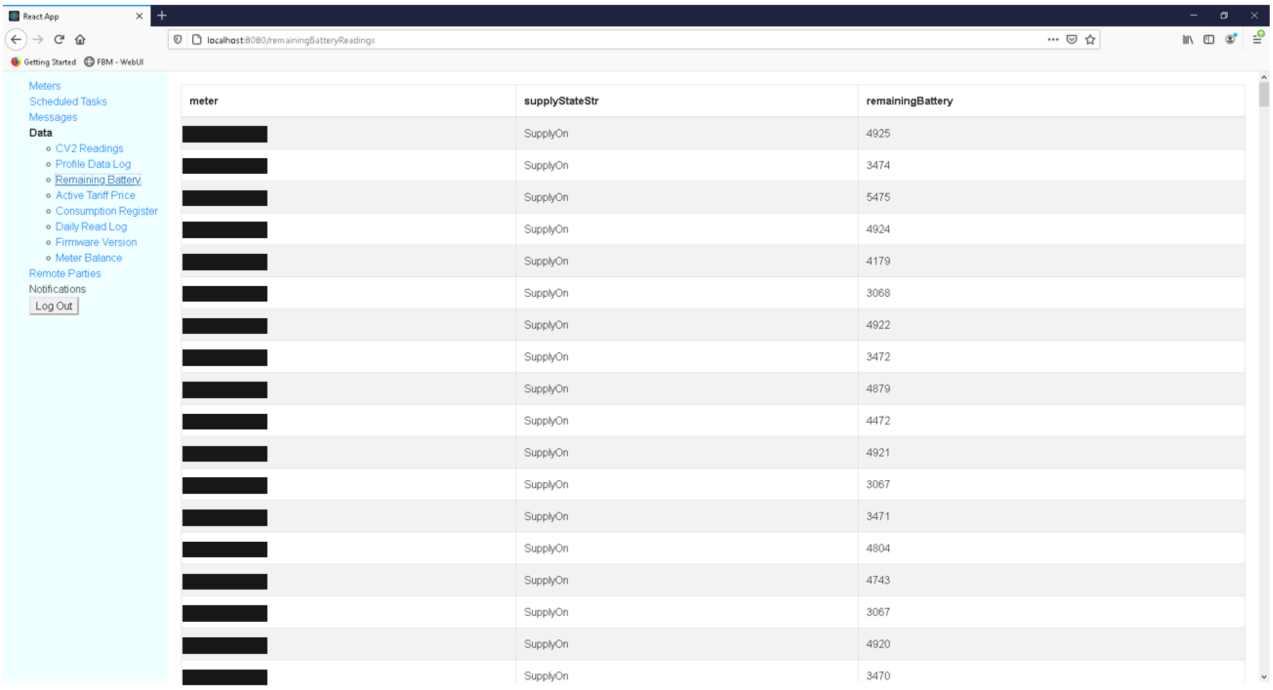
meter	timestamp	calorificValue
[redacted]	2020-10-20T19:46:50.123	1094444
[redacted]	2020-10-20T20:00:51.791	394
[redacted]	2020-10-21T01:36:25.6	1094444
[redacted]	2020-10-21T01:46:47.319	1094444
[redacted]	2020-10-21T02:00:16.434	394
[redacted]	2020-10-21T02:00:51.804	394
[redacted]	2020-10-21T09:00:51.898	394
[redacted]	2020-10-21T09:06:22.97	1094444
[redacted]	2020-10-21T09:16:51.06	1094444
[redacted]	2020-10-21T09:30:16.42	394
[redacted]	2020-10-21T13:36:23.871	1094444
[redacted]	2020-10-21T13:46:51.339	1094444
[redacted]	2020-10-21T14:00:16.414	394
[redacted]	2020-10-21T14:00:51.883	394
[redacted]	2020-10-21T19:36:24.778	1094444
[redacted]	2020-10-21T19:46:51.842	1094444
[redacted]	2020-10-21T20:00:16.375	394
[redacted]	2020-10-21T20:00:51.97	394

9.1.1.2 Profile data log



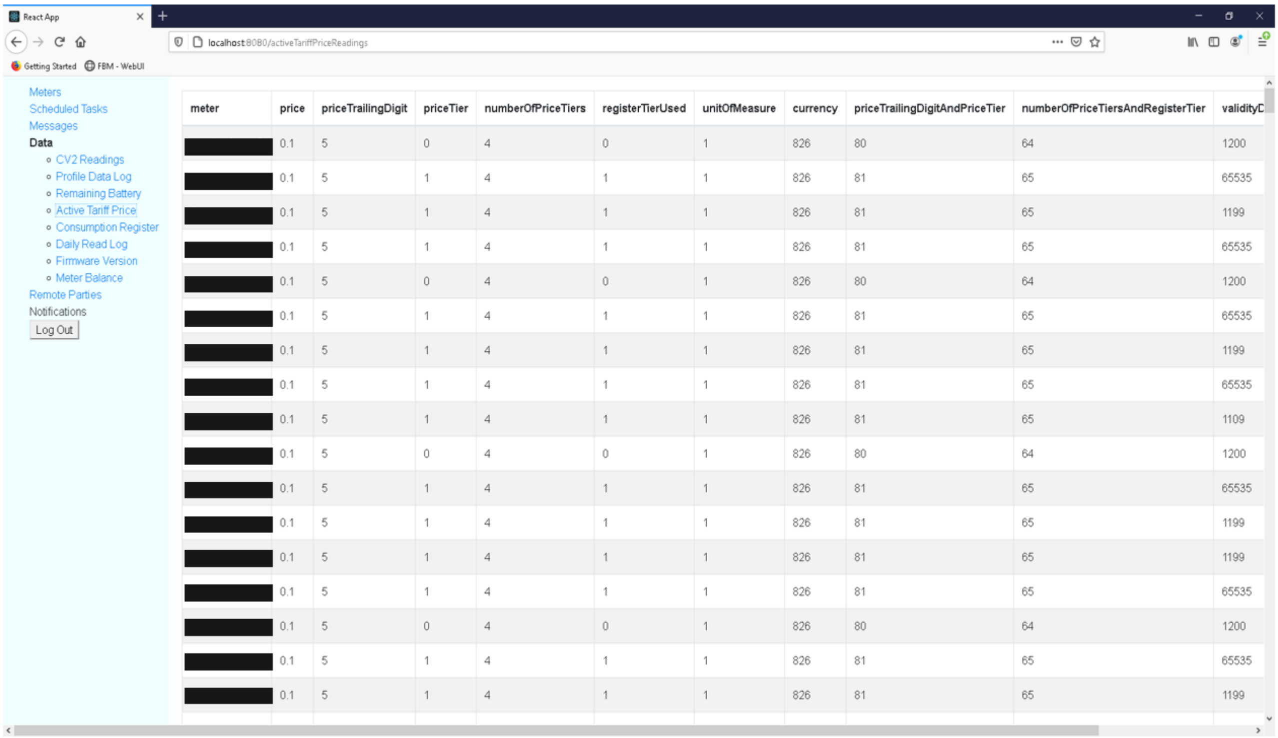
meter	timestamp2	samples
[redacted]	null	function toString() { [native code] },
[redacted]	null	function toString() { [native code] },
[redacted]	null	function toString() { [native code] },
[redacted]	null	function toString() { [native code] },

9.1.1.3 Remaining battery



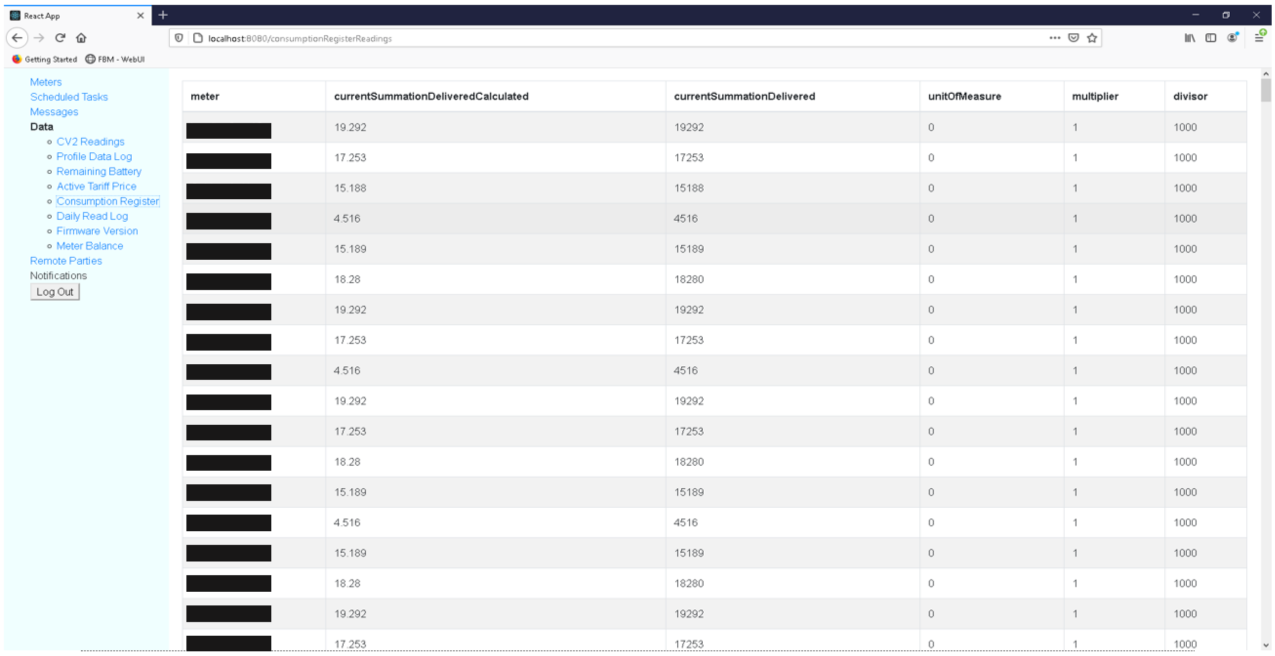
meter	supplyStateStr	remainingBattery
[redacted]	SupplyOn	4925
[redacted]	SupplyOn	3474
[redacted]	SupplyOn	5475
[redacted]	SupplyOn	4924
[redacted]	SupplyOn	4179
[redacted]	SupplyOn	3068
[redacted]	SupplyOn	4922
[redacted]	SupplyOn	3472
[redacted]	SupplyOn	4879
[redacted]	SupplyOn	4472
[redacted]	SupplyOn	4921
[redacted]	SupplyOn	3067
[redacted]	SupplyOn	3471
[redacted]	SupplyOn	4804
[redacted]	SupplyOn	4743
[redacted]	SupplyOn	3067
[redacted]	SupplyOn	4920
[redacted]	SupplyOn	3470

9.1.1.4 Active tariff price



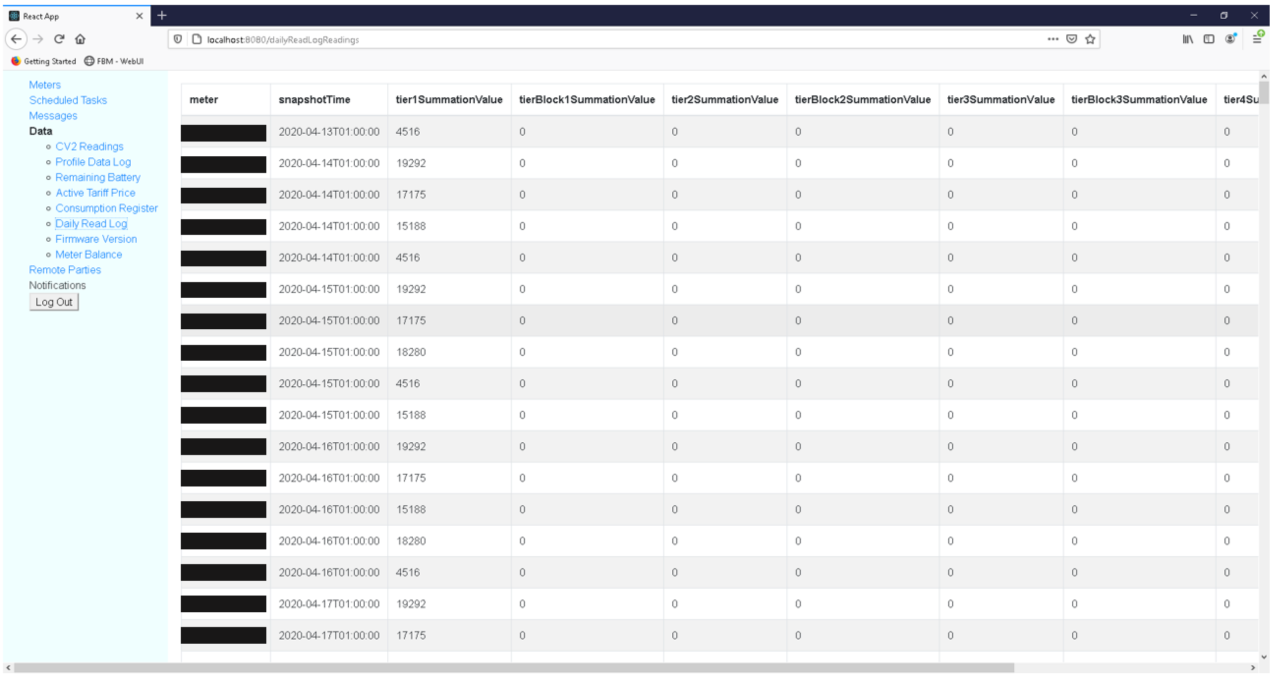
meter	price	priceTrailingDigit	priceTier	numberOfPriceTiers	registerTierUsed	unitOfMeasure	currency	priceTrailingDigitAndPriceTier	numberOfPriceTiersAndRegisterTier	validityD
[redacted]	0.1	5	0	4	0	1	826	80	64	1200
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	1	4	1	1	826	81	65	1199
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	0	4	0	1	826	80	64	1200
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	1	4	1	1	826	81	65	1199
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	1	4	1	1	826	81	65	1109
[redacted]	0.1	5	0	4	0	1	826	80	64	1200
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	1	4	1	1	826	81	65	1199
[redacted]	0.1	5	1	4	1	1	826	81	65	1199
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	0	4	0	1	826	80	64	1200
[redacted]	0.1	5	1	4	1	1	826	81	65	65535
[redacted]	0.1	5	1	4	1	1	826	81	65	1199

9.1.1.5 Consumption register



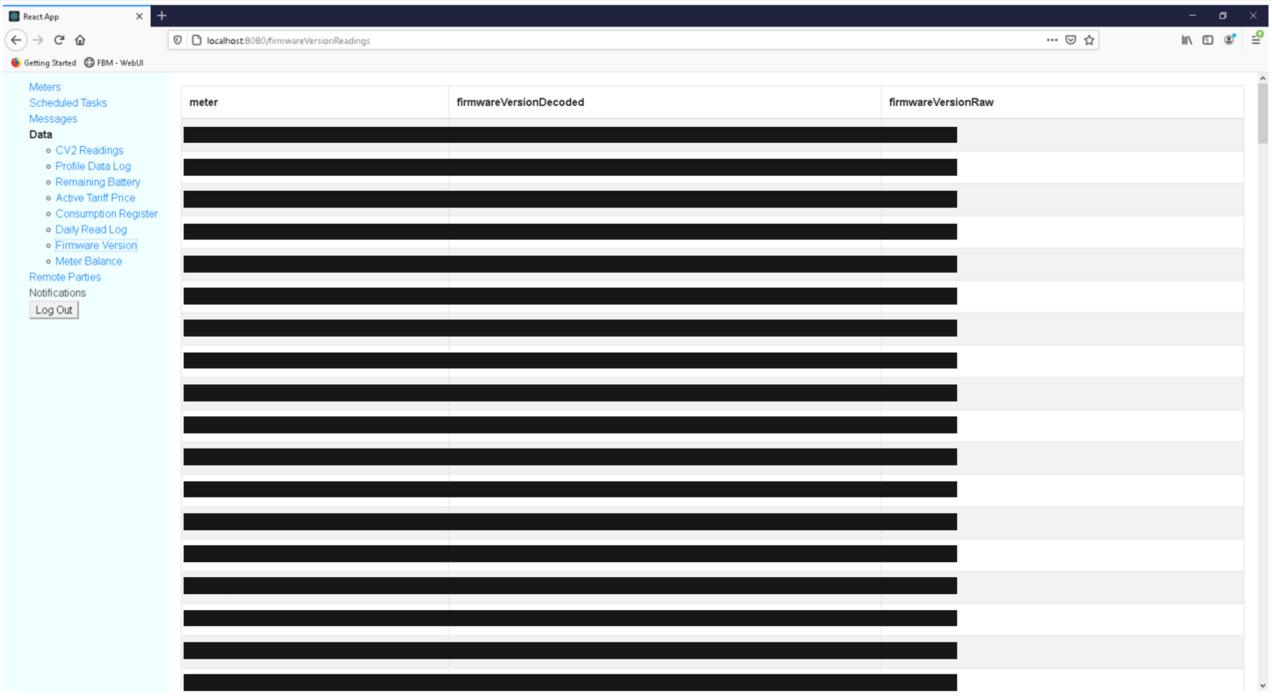
meter	currentSummationDeliveredCalculated	currentSummationDelivered	unitOfMeasure	multiplier	divisor
[redacted]	19.292	19292	0	1	1000
[redacted]	17.253	17253	0	1	1000
[redacted]	15.188	15188	0	1	1000
[redacted]	4.516	4516	0	1	1000
[redacted]	15.189	15189	0	1	1000
[redacted]	18.28	18280	0	1	1000
[redacted]	19.292	19292	0	1	1000
[redacted]	17.253	17253	0	1	1000
[redacted]	4.516	4516	0	1	1000
[redacted]	19.292	19292	0	1	1000
[redacted]	17.253	17253	0	1	1000
[redacted]	18.28	18280	0	1	1000
[redacted]	15.189	15189	0	1	1000
[redacted]	4.516	4516	0	1	1000
[redacted]	15.189	15189	0	1	1000
[redacted]	18.28	18280	0	1	1000
[redacted]	19.292	19292	0	1	1000
[redacted]	17.253	17253	0	1	1000

9.1.1.6 Daily read log



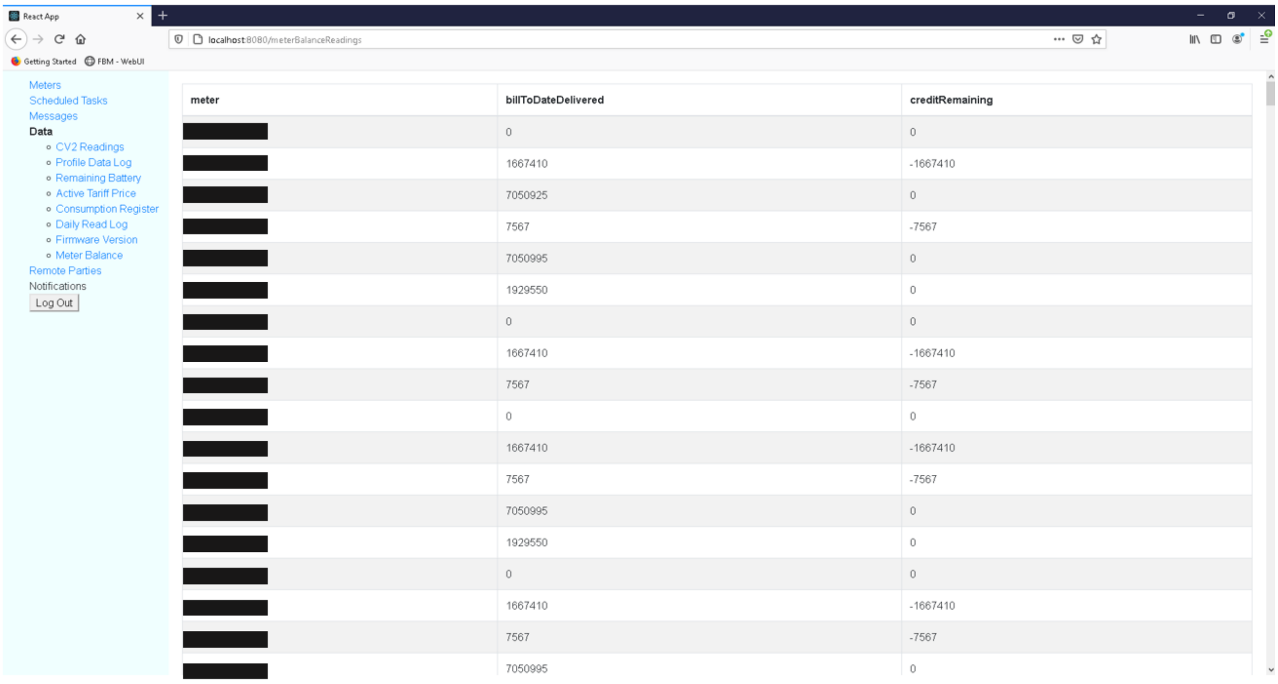
meter	snapshotTime	tier1SummationValue	tierBlock1SummationValue	tier2SummationValue	tierBlock2SummationValue	tier3SummationValue	tierBlock3SummationValue	tier4Su
[redacted]	2020-04-13T01:00:00	4516	0	0	0	0	0	0
[redacted]	2020-04-14T01:00:00	19292	0	0	0	0	0	0
[redacted]	2020-04-14T01:00:00	17175	0	0	0	0	0	0
[redacted]	2020-04-14T01:00:00	15188	0	0	0	0	0	0
[redacted]	2020-04-14T01:00:00	4516	0	0	0	0	0	0
[redacted]	2020-04-15T01:00:00	19292	0	0	0	0	0	0
[redacted]	2020-04-15T01:00:00	17175	0	0	0	0	0	0
[redacted]	2020-04-15T01:00:00	18280	0	0	0	0	0	0
[redacted]	2020-04-15T01:00:00	4516	0	0	0	0	0	0
[redacted]	2020-04-15T01:00:00	15188	0	0	0	0	0	0
[redacted]	2020-04-16T01:00:00	19292	0	0	0	0	0	0
[redacted]	2020-04-16T01:00:00	17175	0	0	0	0	0	0
[redacted]	2020-04-16T01:00:00	15188	0	0	0	0	0	0
[redacted]	2020-04-16T01:00:00	18280	0	0	0	0	0	0
[redacted]	2020-04-16T01:00:00	4516	0	0	0	0	0	0
[redacted]	2020-04-17T01:00:00	19292	0	0	0	0	0	0
[redacted]	2020-04-17T01:00:00	17175	0	0	0	0	0	0

9.1.1.7 Firmware version



meter	firmwareVersionDecoded	firmwareVersionRaw
[redacted]	[redacted]	[redacted]

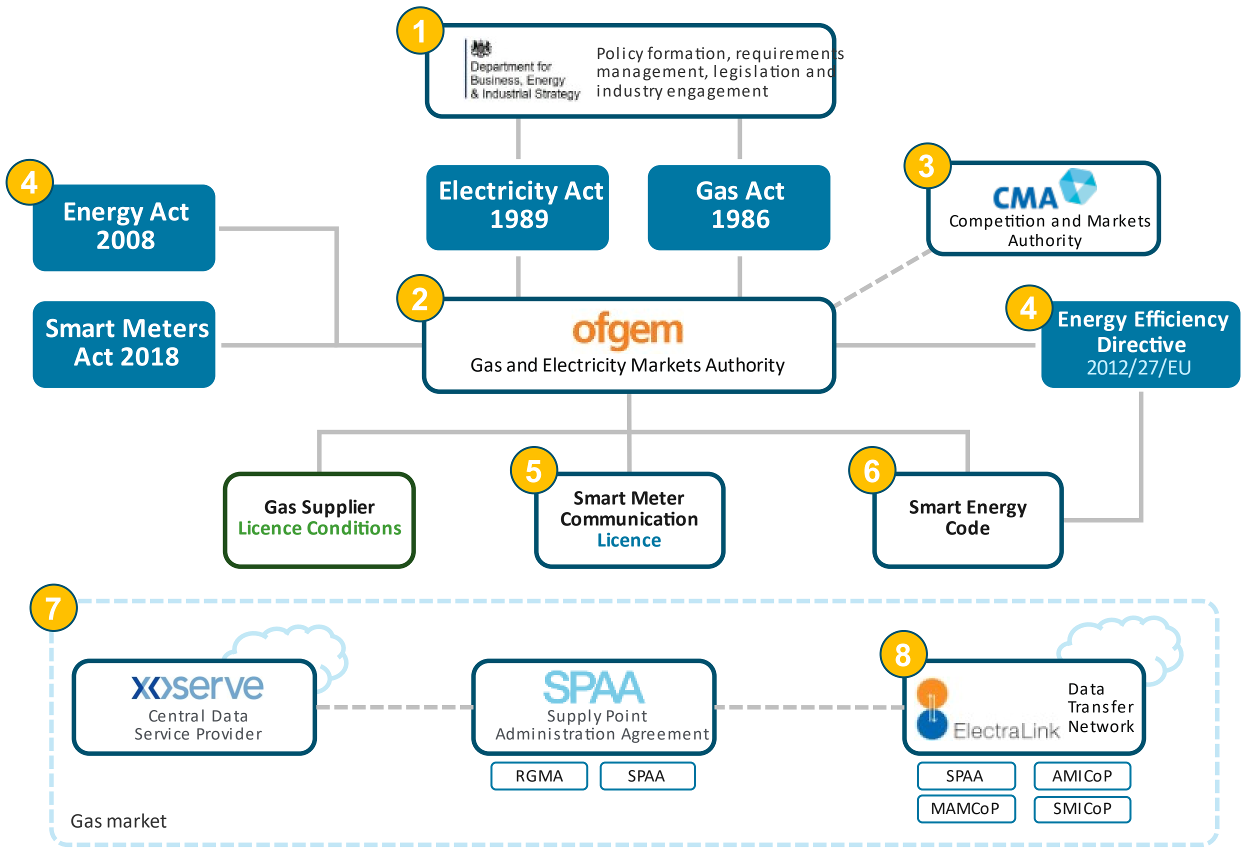
9.1.1.8 Meter balance



meter	billToDateDelivered	creditRemaining
[redacted]	0	0
[redacted]	1667410	-1667410
[redacted]	7050925	0
[redacted]	7567	-7567
[redacted]	7050995	0
[redacted]	1929550	0
[redacted]	0	0
[redacted]	1667410	-1667410
[redacted]	7567	-7567
[redacted]	0	0
[redacted]	1667410	-1667410
[redacted]	7567	-7567
[redacted]	7050995	0
[redacted]	1929550	0
[redacted]	0	0
[redacted]	1667410	-1667410
[redacted]	7567	-7567
[redacted]	7050995	0

Appendix D Smart Metering Legislative and Regulatory Framework

The key legislation for gas metrology is the Gas Act 1986, the Gas (Meters) Regulations 1983 and the Gas (Calculation of Thermal Energy) Regulations 1996. The core legislative framework for smart gas metering is shown below.



1. The Department for Business, Energy and Industrial Strategy (BIES) is committed to ensuring every home and small business will be offered a smart meter as part of its climate change targets.

2. The metering market is regulated by the Gas Act 1986 which describe the regulated activities energy suppliers undertake including metering arrangements. The Gas Act is enacted through energy retailers' standard supply license conditions and various industry codes. The market is regulated by Ofgem.

3. The Competition and Markets Authority is referred by Ofgem to review competitive market provisions or investigate anti-competitive practices including decisions related to the Smart Energy Code. The CMA has been engaged several times since the start of the SMIP most recently to protect prepayment customers in 2019.

4. New supply license conditions were introduced to ensure consumer access to data to meet the Energy Efficiency Directive in 2014. The Smart Meters Act 2018 extends BEIS's powers related to smart metering and to enact a special provision to safeguard defaulting of the Smart DCC.

5. The Smart DCC was awarded a licence to operate the national smart data communications network in 2013.

6. The gas market arrangements are defined in the Supply Point Administration Agreement (SPAA) between gas suppliers and transporters. his administered by Electralink. A number of codes of practices regulate metering services provision including the Meter Asset Manager Code of Practice (MAMCoP) and the Approved Meter Installer Code of Practice (AMICoP).

7. The Retail Gas Metering Arrangements (RGMA) defines standard industry data flows and data attributes for transferring information regarding installation, exchange and removal of meters transferred over the Data Transfer Network. RGMA also defines the information processes for change of gas supplier and change of MAM agent. MAMs must be SPAA registered parties.

8. Electralink runs the Data Transfer Network that underpins the energy industry. Electricity industry data flows are defined in the MRA Data Transfer Catalogue. Electralink also provides governance of a number of industry codes for the gas and electricity industry including the Smart Meter Installation Code of Practice that defines minimum standards for customer facing smart meter installers and the Distribution Connection and Use of System Agreement (DCUSA) defining terms for connection and use of electricity distribution networks.

9. The Smart Energy Code (SEC) lays out the roles, rules and obligations for all smart metering parties and sets out relevant governance arrangements.

Appendix E Gas Market Roles

The electricity market is based on the energy supplier hub principle where retailers are the customer's sole interface to the energy system. Electricity suppliers are responsible procuring electricity on the wholesale market, appointing various electricity and gas agents, installing and managing meters, and retrieving meter data via the Smart DCC. They recover wholesale, distribution and operational costs (including metering) via customer billing and pass payments back up through the value chain.

However, in the gas market, gas shippers are responsible for wholesale procurement and transportation. They contract directly with the gas transporter to transport gas to consumers and work with Xoserve to balance the NTS. Gas suppliers contract directly with customers to supply gas and pay gas shippers conveyance charges. The Big 5 and other large independent suppliers hold licences for both gas supply and gas shipping whereas most smaller suppliers will contract an independent gas shipper.

Gas transporters, also known as distribution networks, are responsible for transporting gas from the gas producer terminals to customers through the National Transmission System (NTS) operated by National Grid.

E.1 Uniform Network Code

The Uniform Network Code (UNC) sets out common gas transportation arrangements and the legal and contractual framework for supply of gas. The UNC governs transportation processes such as balancing of the gas system (supply versus demand), network planning, and the allocation of network capacity. All gas transporters and gas shippers are required to be UNC parties, but gas suppliers are not. The code is administered by the Joint Office for Gas Transporters.

E.2 Xoserve

Xoserve is the Central Data Service Provider for the gas market which holds information related to Britain's 24 million gas supplied premises. It acts as the interface between gas shippers and gas transporters (distribution networks). It is responsible for providing register data to gas shippers and provides information about gas flows across the entire network and manages the allocation. On behalf of gas shippers, it provides these transactional services for calculation of transportation volumes for billing, balancing settlement, demand estimation and supply point administration. It is also responsible for operation of the UK Link system for settlement which was overhauled in 2017. These services are governed by a multilateral agreement between Xoserve, transporters and shippers called the Data Services Contract. Xoserve is jointly owned by the networks and National Grid.

E.3 Project Nexus

Xoserve implemented a major update of the UK link system which went live in 2017 to improve handling and capacity of gas data. The introduction of smart and advanced metering required a substantial capability upgrade to receive and store millions of meter readings.

Prior to Nexus, gas consumer metered annual consumption, known as the Annual Quantity (AQ), was calculated by Xoserve before the end of the current gas year in October. After Nexus, Xoserve is capable of providing a more accurate rolling AQ basic on monthly meter readings dependent on the Settlement Class. Additionally, the meter's maximum daily usage, known as the Supply Offtake Quantity (SOQ), is also updated on a rolling monthly basis. Rolling AQ and SOQ is used for the purchase of gas by the gas supplier.

Accurate rolling AQs allowed Xoserve to invoice and reconcile all gas suppliers against actual data returned for domestic and small commercial smart metered sites, known as Small Supply Points (SSP), improving gas supplier cost allocation and promoting competitiveness. It is the responsibility of gas suppliers to supply meter reads acquired from consumers into Xoserve’s reconciliation process.

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.