Customer-Led Network Revolution

Lessons Learnt Report

Customer Trial Equipment Installations

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1. Executive summary

The Customer-Led Network Revolution (CLNR) is a major collaborative project led by Northern Powergrid working with British Gas, Durham University, Newcastle University and EA Technology. Over a four-year period, the project trialled smart-grid solutions on the electricity distribution network.

The CLNR project was designed to better understand ways to manage the introduction of low carbon technologies (LCTs) like solar PV, heat pumps and electric vehicles and ensure customers continue to receive a safe, secure and affordable electricity supply now, and in a low-carbon future.

It aimed to achieve its outcomes through monitoring and interventions in different 'test cells'. Each test cell had a number of different variables based on low carbon technology installed, type of tariff, degree of monitoring, restricted/direct control of electricity using appliances and customer demographics. In particular the focus was on monitoring of electricity use in: homes and businesses, monitoring of low carbon technologies, and trialling of demand-side response (DSR) 1 technologies. The test cells for residential and Small and Medium-sized Enterprise (SME) trials are listed in **Figures 1 and 2**.

This review by Sustainability First focuses on the successes, challenges and lessons learned from the installation process during the CLNR residential and SME trials. It also considers implications for future smart meter rollout, smart grid development and the deployment of low carbon technologies. It is based on desk-based research and discussions with staff members from British Gas who had responsibility for project delivery, including installations, working with installation partners as needed.

Residential trials – successes and challenges of technical installations

Below are some general successes and challenges relating to the installation of equipment as part of the residential trials, looking at different stages along the customer journey:

- ***Technology development –*** CLNR sought to trial innovative technologies associated with the future growth of low-carbon technologies. In some cases ideal 'market ready' solutions were not available at the time of the trial, so it was necessary to develop 'future technologies' by combining existing equipment and systems to run trials.
- ***Trial recruitment –*** where ever possible existing British Gas smart meter customers were recruited for trials, and this led to a significant baseline dataset of around 9000 residential customers. However recruiting existing British Gas customers was not always

[1] DSR is changes in electricity usage by end-use customers from their normal consumption patterns, in response to changes in the price of electricity, or to incentive payments. In a distribution network context, DSR can be designed to reduce electricity use at peak.

possible. Low take-up of low carbon technologies made it challenging to find customers to fill certain trials. Sufficient participants were found in most cases by: working with third parties, installing subsidised low carbon technologies; and widening participation to non-British Gas customers, but this led to additional time required on the project, plus increased monitoring costs.

- ***Installation process –*** a significant number of installations were achieved with low dropout rates. Arranging times for installation was sometimes difficult if it involves people having to take time off work. It was not possible to do detailed pre-surveys of all trial customers, so installers sometimes found that the property was not suitable for the equipment required. Secondary metering for non-British Gas customers caused major challenges as it necessitated installing an isolation switch. This could only be arranged through the meter operator for the customer's supplier. There were frequently long delays in this process. Ensuring adequate space for the installation of possibly bulky equipment or appliances sometimes prevented the participation of a willing customer.
- ***Customer support –*** a dedicated customer support and data management system provided handholding for participants throughout the customer journey. But it was sometimes a challenge to get hold of customers during the working day to resolve any issues or make installation appointments.
- ***Data communications, collection and management –*** a large, statistically significant, data set was generated. The project also linked the distribution network operator, supplier and home appliances for first time. Smart appliances are still at an immature stage. There were issues of compatibility between devices and manufacturers. Various problems were encountered with data communications and connectivity, particularly links with the home hubs and the lack of broadband in some homes, but these issues were largely dealt with. Managing the data flows and getting it into a suitable state for analysis also proved challenging.
- ***Decommissioning –*** the process of removing equipment was smooth, benefiting from lessons learned through the trials, with only a small amount of remedial work required. Equipment was made available to be reused as part of two other LCNF projects.

Below are specific successes and challenges relating the equipment installed for the residential trials, split by monitoring of the home, monitoring of low carbon technologies and demand-side response.

Monitoring of home electricity usage

- ***Smart meters –*** or equivalent (non-fiscal) monitoring devices were used for trial customers in order to collect electricity use data, which recorded electricity consumption at 30-minute intervals. British Gas brought their experience of installing smart meters and managing the data, due to their early customer rollout. However smart meter penetration, ahead of the trial, was lower than expected, so a number of smart meters had to be installed. Unfortunately, British Gas's Phase 3 smart meter was not ready in time for the trial. Therefore, supplementary monitoring and communications equipment was used for some trials to get more detailed readings and for direct control devices.

- ***Secondary meters –*** enabled involvement of non-British Gas customers and customers where a smart meter could not be installed, to increase the level of trial participants. However, a mains isolation switch was needed to safely install the meter, which not all customers had. So in many cases isolation switches had to be installed first, which meant engaging with the customer's supplier and registered meter operator, causing additional project costs and delays.
- ***Polymeters –*** were used for disaggregated monitoring of different circuits in the home; and also in homes where it was not possible to install a smart meter or secondary meter. The Polymeters have provided a rich dataset covering electricity use for: cooking; space and water heating; cold and wet appliances; consumer electronics and home computing; and lighting. But this was an expensive option. There were also connectivity issues and a faulty part, but these were fixed without significant data loss.
- ***Smart plugs/in-line meters –*** were used to gather disaggregated electricity use data from different home appliances, such as storage heaters, electric hot water heating, kettles, washing machines, dishwashers, refrigerators, freezers and microwaves. This, together with the polymeter data, gave unprecedented insight into customer electricity use over a year. However, the placing of smart plugs was not always consistent – a maximum of 7 plugs per home, so not all appliances could be captured. Participation in the enhanced monitoring trial was limited to CLNR friendlies (i.e. partner organisations) due to the intrusive nature of the installation process and monitoring equipment, which impacted the sample demographics.
- ***In-home displays –*** were installed as standard with the British Gas smart meter. The Landys+ Gyr Eco Meter allowed customers to see the amount of energy they used and the cost of that energy, with a traffic light display to signal low/medium/high usage. Feedback on the displays was positive with 90% of customers finding them quite or very easy to understand[2].
- ***Electric heating monitoring –*** was undertaken to understand how customers respond to existing restricted hours tariffs such as Economy 7 and 10[3]. Detailed monitoring of electricity use and temperature monitors for the hot water tank, storage heaters and radiators, provided new insights into existing Time of Use tariffs.
- ***Home hubs –*** were required for most residential trials to communicate with the installed monitoring technology. These generally worked well when there was connectivity, but

[2] CLNR-L100: Domestic Survey Results and Analysis.

[3] These are differential electricity tariffs with on-peak and off-peak rates. Economy 7 has a cheaper seven-hour night rate. Economy 10 has a cheaper rate for seven-hours during the night and three-hours during the day.

many homes did not have broadband and there were issues, such as customers moving the hubs or changing broadband supplier, which impacted the collection of data.

Monitoring of low carbon technologies

- ***Air source heat pumps (ASHP) –*** This trial comprised 344 domestic customers with air source heat pumps. Recruiting customers to the trials was challenging. There was a scarcity of existing heat pumps, due to a delay in the Renewable Heat Incentive. Therefore, heat pumps had to be installed through the trial. Funding of £2.2m was secured from DECC to subsidise heat pumps to the price of a conventional boiler. However it was still difficult to find customers willing to accept technology due to cost, their size and the 'hassle factor'. The team worked with social housing providers who leveraged further EU match funding to install the heat pumps. The dominance of social housing impacted the sample demographics. There were barriers to participation, even for customers with heat pumps: including lack of broadband; insufficient space to install meter on heat pump, and safety issues associated with existing wiring in the home. Many of the heat pump customers were non-British Gas so required secondary metering. Customer feedback on heat pumps was mixed, with 76% satisfied/very satisfied and 15% dissatisfied/very dissatisfied[4].
- ***Micro-combined heat and power (micro-CHP) –*** the Baxi Ecogen micro-CHP unit was installed by British Gas Heating installations and monitored using an in-line micro-CHP monitor installed by PassivSystems. The cost of the micro-CHP units was subsidised by over 50%. Take-up was lower than hoped, only 11 units installed, due to the physical size of these units and operating noise levels, which drove the decision to pause recruitment for this trial.
- ***Solar photovoltaic (PV) panels –*** existing panels were monitored using in-line PV monitors, installed by PassivSystems, in 152 homes. It was difficult to find solar PV customers not on 'rent-a-roof' schemes or where the provider of the 'rent-a-roof' scheme agreed to householder participation. The team worked with housing associations to recruit participants, which impacted sample demographics. The monitoring equipment suffered from general connectivity issues.
- ***Electric vehicle –*** 159 EV-driving customers' household and electric vehicle charging demand were monitored as part of the CLNR project. For British Gas customers, charging was monitored using in-line monitors for EV charge points and installed by PassivSystems. From the existing British Gas customer base electric vehicle sales were much lower than had been anticipated at the time of the bid. Therefore, an alternative approach was undertaken through engagement with Charge your Car (North) Ltd to recruit EV users onto the trials, with a total of 143 EV customers successfully monitored. The trial monitored the existing EV charge point and whole-house consumption (via an

[4] CLNR-L104: Heat Pump Survey Report (July 2014)

EDMI Mk7C smart meters), which was installed as part of the CLNR project by G4S Utility Services. These participants were drawn from employees, or friends and family of employees, of Nissan in Sunderland, which impacted on sample demographics.

Demand-side response (DSR) technologies

The trial included technologies to promote changes in electricity usage by customers, in response to price signals or incentives, to reduce electricity use at peak and / or provide flexibility for cost effective balancing of the system.

- ***Smart washing machines –*** The original washing machine manufacturer planned for the trials decided not to enter the UK market at that time, which meant sourcing a new appliance and developing a new communications system. The Hotpoint AQUALTIS model smart washing machine was used to encourage customers to move usage away from peak times (i.e. 4pm - 8 pm), with two trials designed: 53 customers on restricted hours (Time of use Tariff to automatically schedule wash cycles); and 100 customers on direct control (automatic scheduling of wash cycles via an external signal from British Gas). Both trials had simple customer override of automatic scheduling. There were connectivity issues due to the distance between the washing machine and gateway. The remote signal was not always received by the appliance due to: broadband being down; equipment being unplugged; and teething problems with the technology platform.
- ***Smart heat pump with thermal store –*** The project involved the development of a new system that combined an air source heat pump and hot water storage tank, designed to enable direct control of the heat pump whilst maintaining comfort levels for customers. The 'Smart Grid Ready' NEURA NDA Nano thermal heat pump won the Micropower Council's innovation of the year award. The direct control signals worked effectively and there were no temperature impacts from the events. But the sample was small – 17 customers – as even with a subsidy, the proposition was a difficult sell to private homeowners. The system was too large for most homes due to the size of the thermal storage tank and the installation was non-standard. There were also some connection issues and a fault with the primary circuit board for some units. These issues were resolved. Temperature adjustments made by customers led to automatic override of direct control (to prevent excessive loss of temperature in the hot water cylinder) in some cases. This was addressed through lab testing.
- ***Solar PV manual in-home balancing –*** was designed to encourage customers to self-balance using an in-home display device to visually show them when they were generating/exporting and advise them to use this electricity in their home, rather than exporting to the grid. Customers found the IHDs helpful but the impact on in-home consumption was not conclusive.
- ***Solar PV automatic in-home balancing –*** was designed to provide automatic within-premises balancing using Coolpower's EMMA system to divert surplus power from on-site generation such as solar PV to immersion heaters whilst holding electricity export

close to zero. The system worked effectively, but required specialist installation from British Gas's installation partners on the project, Solar & Wind Applications.

SME trials – successes and challenges of technical installations

- ***Rich monitoring data –*** the monitoring trials provided important insights into the electricity use patterns of SMEs, with 1,514 customers taking part in basic monitoring of their half hourly electricity use and 40 British Gas customers in enhanced/disaggregated load monitoring. As every business has different equipment the enhanced monitoring set up was bespoke for each.
- ***Barriers to DSR –*** although there was positive initial interest in Time of Use and DSR trials, following the site survey, almost all SME customers dropped out because of concerns that the trials would interfere with business operations. SMEs felt they had a lack of flexibility in their daily operations. They had to meet customer expectations and regulatory requirements. The costs of participation seemed to outweigh the incentives.
- ***Insights from sight visits –*** through the process of undertaking detailed site visits, the project team gained additional insights into the way SME's operate and their electricity using practices. In particular, there were high levels of awareness of and interest in energy efficiency and renewable energy measures.

Lessons learned from the project

- ***Recruiting trial participants –*** targeting existing supplier smart meter customers to participate in trials was helpful, but this was not always possible, particularly for the technology test cells. Offering a suite of options for customers without a smart meter helped widen participation. Partnering with Third Parties such as Social Housing Landlords and Community Groups was critical to reaching customers with low carbon technologies. Some flexibility in trial design and recruitment targets is needed.
- ***Installing technologies in the home –*** pre-trialling of technologies enabled issues to be addressed before rollout into homes. Creating 'future technologies' from today's equipment had drawbacks, and some technologies are still not suitable for most customers' homes. It is important to make the most of the valuable time during installations with customers in their home and to provide advice on how to use the smart kit, so customers use it well and to reduce the risk of data loss. Alternative GSM options are needed for homes without broadband.
- ***Customer and technical support –*** it is critical to have a strong constant feedback loop between the customer support teams and the technical teams, so that any issues can be dealt with as quickly as possible. This should take into account the capacity of *equipment and installation partners.*
- ***Further research and data management –*** Further research is needed: on the role of storage in the context of smart energy; and to trial smart technologies, appliances and tariffs in combination. An overarching manager of end-to-end data flows is critical for

projects of this scale. The CLNR project has produced a rich source of data, which could be used for further research in future.

- ***SMEs –*** the sector is diverse, there is no 'one size fits all' approach to realising flexibility and there are many real and perceived barriers, which need to be carefully worked through with businesses. DSR should be wrapped into wider energy service offerings tailored to take into account the needs and constraints of particular types of business.

Implications for the future

- Need to train engineers of the future to deliver smart kit and advice.
- Smart kit must be designed for people and their properties – user-friendly, compact and cost-effective.
- It should be easy and attractive for customers to offer demand response services.
- Connectivity is critical.
- Technical coordination is needed between suppliers and appliance manufacturers to develop end-to-end solutions for smart communications.

2. Introduction

2.1. Aim of the review

This review by Sustainability First requested by Northern Powergrid and British Gas provides a brief account of the technologies deployed as part of the Customer-Led Network Revolution (CLNR) trial and the notable successes and challenges encountered by British Gas and their installation partners during the installation process. It sets out lessons learned through the project installation process and for future smart meter rollout, smart grid development and the deployment of low carbon technologies.

The paper focuses on residential and small and medium-sized enterprise (SME) customers, it does not look at industrial and commercial (I&C) customers.

2.2. Methodology

The review is predominantly based on desk-based research and a compilation of relevant information from relevant reports, including:

- CLNR project reports: closedown report; small customer level 2 report; six-monthly progress reports to Ofgem; change request document; social science reports;
- Sustainability First report on project lessons learned from trial recruitment;
- Installation information provided by British Gas including lessons learned from their installation partners PassivSystems; and
- Discussions with project team members in late 2014.

2.3. Structure of this paper

This report is split into 10 sections. **Section 2** introduces the CLNR project, partners and the trials. **Section 3** describes the equipment installed in the residential trials, the installation process, customer journey and customer retention/drop-out. The next sections look at successes and challenges experienced in relation to the installation process for the residential trials, with **Section 4** covering generic issues, **Section 5** monitoring of the home, **Section 6** monitoring of low carbon technologies and **Section 7** demand-side response technologies. **Section 8** looks at small and medium sized enterprises. **Section 9** sets out lessons learned through the installation process for the residential and SME trials. **Section 10** concludes with critical issues for the future.

2.4. Overview of the CLNR project

The Customer-Led Network Revolution is a collaborative project undertaken by Northern Powergrid, British Gas, Durham University, Newcastle University and EA Technology, funded via the Low Carbon Networks Fund.

Over a four-year period (2011 - 2014), the project team trialled smart-grid solutions on the electricity distribution network by installing and monitoring a range of customer facing low carbon technologies such as electric vehicle charge-points, air source heat pumps, micro-Combined Heat and Power and Solar Photovoltaic arrays as well as trialling innovative tariffs and direct control solutions such as smart washing machines.

The project involved around 13,000 residential, SME and larger industrial and commercial customers. As well as exploring the impact on electricity demand of customers using new technologies themselves, the project also explored the use of new network-operated technology on the electricity network and commercial arrangements between suppliers, distributors and customers.

Project Learning Outcomes were as follows, with Learning Outcomes 1 and 2 being relevant to this report:

1. What are current, emerging and possible future customer (load and generation) characteristics?
2. To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?
3. To what extent can networks be more flexible, and what is the cost of this flexibility?
4. What is the optimum solution to resolve network constraints driven by the transition to a low carbon economy?
5. What are the most effective means to deliver optimal solutions between customer, supplier and distribution network operator?

2.5. Partner roles and responsibilities

Northern Powergrid	Overall project lead. Responsible for project management to deliver Learning Outcomes 1, 2, 3, 4 and 5.
British Gas	Customer trials project delivery. Responsible for customer recruitment, engagement, equipment installations and de-commissioning associated with the residential and SME customers for Learning Outcomes 1 and 2.
Durham University **Newcastle University**	Test cell design, data analysis and detailed evaluation of trial outputs from Learning Outcomes 1 and 2 (customer facing trials) and Learning Outcomes 3 and 4 (network trials).
EA Technology	Technical consultant for delivery of the policy recommendations and national standards from Learning Outcomes 3, 4 and 5.

In terms of the installation process, British Gas had overall responsibility. They installed the smart meters, appliances and, where needed, low carbon technologies.

Their installation partners included: PassivSystems - who installed most of the monitoring and communications equipment, Solar & Wind Applications – who installed the solar power hot water system; and G4S – who installed the meters for SMEs.

The breakdown of the supplier roles and equipment installed in CLNR residential trials is identified in **Appendix A**.

2.6. Test cells – overview

The project aimed to achieve its outcomes through monitoring and interventions in different 'test cells'. Each test cell had a number of different variables based on low carbon technology installed, type of tariff, degree of monitoring, restricted/direct control of electricity using appliances and customer demographics. The test cells for residential and SME trials are listed in **Figures 1** and **2** respectively**.**

2.6.1. Residential test cells

CLNR Trial - Residential Test Cells		
Number	**Name**	**Composition**
1a	Smart meter data	Basic monitoring of domestic electricity use of regular smart meter customers.
2a	In-home monitoring	Enhanced monitoring of customers, incl. cooking, space & water heating, cold & wet appliances, consumer electronics, and lighting.
2a HW	Hot water monitoring	Enhanced monitoring smart meter customers with electrically heated hot water on a restricted hours tariff.
2a SH	Hot water and storage heaters monitoring	Monitoring of smart meter customers with electrically heated hot water and storage heaters on a restricted hours tariff.
3	Heat pump monitoring	Monitoring of air source heat pumps (ASHP) use and whole house consumption, via a flat-rate tariff.
4	Micro combined heat and power boiler monitoring	Monitoring of micro-CHP appliance electricity use and whole house consumption, via a flat-rate tariff.
5	Solar Panel monitoring	Monitoring of photovoltaic electricity performance and whole house consumption, via a flat- rate tariff.
6	Electric vehicle Monitoring	Monitoring of electric vehicle charging patterns.
9a	Time of Use Tariff	Half-hourly monitoring of domestic electricity use with a three-rate (time of use) tariff.
10a WWG	Smart washing machine and restricted hours	Monitoring of electricity consumption with a three-rate (time of use) restricted hours tariff plus direct external control of a smart washing machine.
11a WWG	Smart washing machine and direct control	Monitoring of electricity consumption with a general flat-rate tariff plus direct external control of a smart washing machine at peak.

12	Heat pump and Time of Use monitoring	Monitoring of air-source heat pump electricity use and whole house consumption, via a three-rate (time of use) tariff.
14	Heat pump and direct control	Monitoring of air-source heat pump electricity use and whole house consumption, via a general flat-rate tariff plus direct external control of heat pump.
20 IHD	Solar panel monitoring and manual in-premise balancing	Monitoring of customer photovoltaic electricity production and use, with in-home displays for manual in-premises balancing.
20 Auto	Solar panel monitoring and automatic balancing with hot water generation	Monitoring of customer photovoltaic electricity production and when excess power is being produced it is automatically diverted to heating a hot water tank (EMMA unit) and whole house consumption.

Figure 1: CLNR project residential test cells.

2.6.2. SME test cells

CLNR Trial - SME Test Cells		
Number	**Name**	**Composition**
1b	Smart meter data	Basic profiling of regular smart meter customers in SME sector
2b	Enhanced monitoring	Enhanced profiling of regular smart meter customers in SME sector
9b	Time of Use Tariff	Time of Use tariff, general load in SME sector
10b	Restricted hours	Restricted hours tariff, general load in SME sector

Figure 2: CLNR project SME test cells.

3. Technology installations for the residential trials

This section covers the residential trials – equipment installed, customer journey, installation figures and customer retention and drop out. The SME installations are covered in a separate SME section.

3.1. Equipment installed for residential trials

The equipment installed as part of the residential trials is summarised below, covering technologies for: monitoring the home; monitoring low carbon technologies; and enabling demand-side response (DSR).

3.1.1. Monitoring of the home

To understand consumer electricity use today, there was a project requirement to collect whole house electricity use data from all participants involved in the trials. Depending on the trial and the technology, building, communication or operational constraints, this was collected using either: a smart meter, secondary meter or polymeter. The monitoring equipment used in the trials is summarised below.

Smart meter	The smart meter collects half hourly consumption data in kWh, via British Gas' smart meter head end system. Installed by British Gas Smart Metering as part of their smart meter foundation programme.
Secondary meter	The non-fiscal secondary meter collects import/export data in kWh on either a 10-minute or 1-minute resolution, dependant on the trial via PassivSystem's zigbee enabled hub and communicated either via broadband or 3G modem. Installed by PassivSystems, where it was not possible to install a British Gas smart meter.
Polymeter	The non-fiscal MicroWatt Polymeter collects import/export data in kWh at a 1-minute resolution from up to 16 individual circuits in the home. Installed by PassivSystems, at the customer's consumer board. This was used when it was not possible to install a smart meter or secondary meter and for disaggregated monitoring of electric space & water heating, cold & wet appliances, consumer electronics & home computing, and lighting.
Smart plugs / in-line meters	These enable electricity consumption/generation data to be collected from an individual load, such as an appliance or low carbon technology. They collect import/export data in kWh on either a 10-minute or 1-minute resolution via PassivSystems' zigbee enabled hub and communicated back to Passiv's Head End System either via broadband or 3G modem.

In-home display	The Landys+ Gyr Eco Meter displays the customers electricity usage with Traffic Lights to make it easy for customers to see how much electricity they are using at any time - a green light means low usage, amber is average and red is high usage. The display also allows customers to view the cost of energy they are using over the last week, the last 28 days or the last year and their carbon emissions. This is installed as standard with the British Gas smart meter.
Electric heating system monitoring	In-line monitors were used to capture electrical load data for immersion heaters, storage heaters and some non-storage heaters. Temperature monitors captured hot water, room and radiator temperatures. All installed by PassivSystems.
Home area network hub	The PassivHub is a gateway router that receives data from various meters in the home using broadband.

The intention was to recruit existing British Gas smart meter customers to the CLNR trials. However this was not always possible. For British Gas customers involved in the trials, who did not have a smart meter, one was installed. In order to fill some of the test cells, particularly the low carbon technology test cells, it was necessary to recruit non-British Gas customers.

For non-British Gas customers, a secondary meter was installed where possible. In order to safely install a secondary meter an isolation switch was needed in the customer's home. Some customers did not have a mains isolation switch. In these cases, either an isolation switch was installed, or it was necessary to use the more expensive polymeter for monitoring.

The enhanced monitoring trial (TC2a) looked in detail at how people use electricity in their homes, including what appliances they use and when. This disaggregated electricity use data was collected using a combination of the polymeter and smart plugs. A subset of the enhanced monitoring trial also considered the use of electricity for hot water storage heating (TC2a HW and SH), focusing on customers on restricted hours tariffs – such as Economy 7 and Economy 10.

British Gas installs an in-home display device as standard with their smart meters. Non-British Gas customers, involved in the trial, did not have in-home display devices, except for the solar PV manual in-home balancing trial (TC20 IHD), which included an IHD to show when electricity was being generated/exported. The majority of trials required the installation of home area network hubs to communicate with the installed monitoring technology.

3.1.2. Monitoring of low carbon technologies

To understand the generation and load patterns of emerging low carbon technologies (LCTs) in the residential trials, there was detailed monitoring of electricity import and where applicable export of:

- Air-source heat pumps (ASHP)
- Micro combined heat & power (micro-CHP)
- Solar photovoltaic (PV) panels
- Electric vehicles (EV)

This was done using in-line meters, which provided import and export data on either a 10-minute or 1-minute basis. For the microgeneration technologies there was additional monitoring of temperature and power quality.

The original intention was to focus on homes that already had these low carbon technologies. Unfortunately take-up of the technologies was lower than anticipated and it was therefore necessary to work with partners to find customers and/or subsidise installation of the technologies in some cases. For more on trial recruitment, see Sustainability First's recruitment paper[5].

3.1.3. Demand-side response

To understand the ability and appetite of householders to be flexible at times of system stress, the project trialled different demand-side interventions, including: Time of Use (ToU) tariffs; direct control of appliances; and onsite balancing.

The domestic ToU tariff was designed to encourage off-peak electricity use. The tariff had three rates: the peak rate (4pm-8pm) was 99% higher, the day rate (7am-4pm) was 4% lower and the off-peak rate (8pm-7am) was 31% lower than the flat rate tariff, with a 16p standing charge. The SME tariff differed from the domestic tariff in that it included an 'evening shoulder' period (8pm-midnight) priced the same as the day rate. Customers were told at the outset of the trial that if the ToU tariff would have cost them more, they would only be charged the standard rate. The ToU tariffs only required a smart meter and in-home display, no additional equipment.

The CLNR project trialled innovative approaches to demand-side response. This required the development of a communications system between the distribution network, supplier and households. Technologies installed to promote DSR are set out below.

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[5] CLNR-L036: Sustainability First (2013) CLNR: Project Lessons Learned from Trial Recruitment.

Smart washing machines	Hotpoint AQUALTIS model AQ113D 69 EH/A zigbee enabled smart washing machine installed by British Gas, collecting 10-minute resolution consumption data and appliance statistics via a Datamobile GRID BOX gateway device and sent back to British Gas' demand management system provided by GreenCom Networks. British Gas developed machine protocols to enable tariff based and/or remote automatic scheduling of wash cycles as well as display of custom text messages. This included a simple customer override of automatic scheduling.
Smart heat pumps with thermal store	'Smart Grid Ready' NEURA NDA Nano thermal heat pump installed with a highly insulated Gledhill 300 litre stratified thermal storage tank, collecting 10-minute resolution consumption data and appliance statistics via a Datamobile GRID BOX gateway device and sent back to British Gas' demand management system provided by GreenCom Networks. Detailed modelling and analysis determined that a 300 litre thermal store would permit approx. 0.5 kW load reduction during the 4 hours of the evening peak for a 3-bed semi in the North East. The thermal store also improves efficiency and increases economic benefits of the ASHP.
Solar panel in-home display	Passiv Controller. Trial participants on the Manual Within Premises Balancing Trial were provided with an IHD from British Gas' installation partner on the project, PassivSystems at point of installation of their monitoring equipment, The Passiv Controller visually shows when they are generating/exporting electricity via their solar PV system and hence encourages customers to use this in their home, rather than exporting to the grid.
Solar panel and hot water	Coolpower's EMMA system was installed by British Gas's installation partners on the project, Solar & Wind Applications. It diverts surplus power from on-site generation such as solar PV to immersion heaters whilst holding electricity export close to zero. The EMMA collects 10-minute resolution consumption, generation and export data via coolpower's data management system.

3.2. Installation process - customer journey

Figure 3 sets out the typical customer journey for customers involved in the CLNR trials. This report focuses on the installation process – and in particular the stages of the customer journey marked with a red diamond. Installations began May 2012 and decommissioning was completed by end July 2014.

The customer welcome pack also included a trial specific insert and relevant terms and conditions associated with the trial. Customers had a seven-day 'cooling-off' period before any technical or tariff structures were installed and or activated. Any technical or trial related issues were first dealt with over the phone and in a majority of cases any connectivity issues were restored, in cases where they were unresolved an engineer was sent to the trial participants premises.

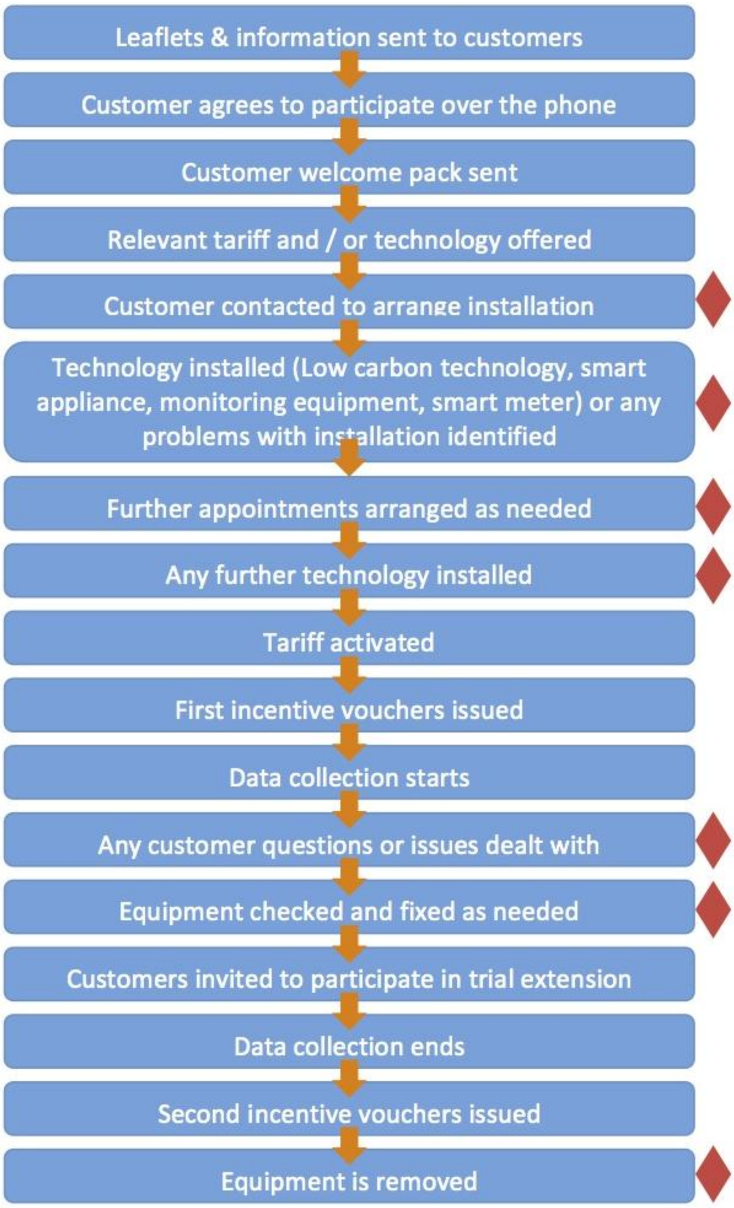


Figure 3: Typical customer journey for CLNR trials.

3.3. Installation figures

In total 3,446 items of equipment were installed through the residential trials, including 2956 items for monitoring and communications, 373 low carbon technologies, and 117 technologies / appliances for demand side response. For more detail on the number of technologies installed.

3.4. Customer retention and drop-out

There were a gross number of customers we aimed to recruit to each test cell on the assumption that there would be a third dropout rate during the trial. Accordingly, the net recruitment target was third lower than the gross target. In reality the dropout rate during the trials was very low. This is because customers were recruited into trials that were most appropriate to them and then given information on trial, the incentives and hand-held through the process with a bespoke customer service team.

However, it was not always possible for customers to participate in the trials that they wanted to, often for technical reasons. These customers were offered the opportunity to participate in a different trial. The circumstances for some customers changed over the trial period. The trials also had to be extended due to delays in the recruitment process, customers were asked by letter whether they were willing to extend participation.

Below are set out some of the main reasons for customer drop-outs, aborts and loss of data through the trials:

- British Gas not able to contact customer to arrange installation;
- Installers when arriving on site had to abort the installation due to either Health and Safety or wiring conformity issues;
- Property not suitable for a smart meter (as this was in the early phase of smart meter rollout, there were some customers not suitable for meters, these issues will be resolved in future and in the enduring phase of the smart metering roll-out programme);
- Property not suitable for low carbon technology (e.g. inadequate space to fit equipment);
- Missing relevant equipment, such as no existing ASHP for monitoring trial;
- No isolation switch for safe installation of secondary meter for non-British Gas customers;
- Additional equipment required for internet connectivity;
- Customers changing mind due to the amount of monitoring equipment required or size of technologies/appliances to be installed;
- Customers nervous about leaving the Hub on 24/7;
- Customer time constraints / other commitments in their diary;
- Customer change of tenancy;
- Customer change of supplier; and
- Customers not agreeing to the trial extension.

4. Generic factors impacting residential installations

This section discusses some generic factors impacting on the installation of technologies for the residential trials. It looks at successes and challenges through the project, under the following headings:

- Design and availability of technologies
- Finding and recruiting customers
- Installation process
- Customer communications
- Data communications and collection
- Equipment decommissioning

Issues for the SME trials are covered in the SME section.

4.1. Design and availability of technologies

4.1.1. Successes

Trialling innovative technologies	The project sought to trial technologies of the future, by trialling of new innovative technologies and combining existing technologies to offer functionalities that might be available in future.
Equipment for best customer experience	Care was taken to ensure equipment chosen for trials was minimally invasive, with as smooth a customer journey as possible. This was important in ensuring that the majority of trials had low drop-out rates.

4.1.2. Challenges

Technologies not available	Some technologies that were to be included in the trial such as British Gas' phase 3 smart meter and a new smart washing machine were not available in time for the trial so alternatives had to be found.
Developing 'future technologies' from existing equipment	The project team had to 'create' future technologies within project time-scales from products and materials available in the current market. 'Ideal' technical solutions were not necessarily available, and some products and equipment were larger / more cumbersome than a fully developed market-ready product. This process took longer than anticipated due to technical complexities and the need for extensive modelling, particularly of the thermal-storage capability for the heat pumps trialled.

4.2. Finding and recruiting customers

4.2.1. Successes

Recruiting existing British Gas smart meter customers	The trials benefited from the availability of existing half-hourly electricity consumption data from British Gas smart meter customers. Customer contract arrangements meant such data could be used for the trial, but British Gas additionally wrote to customers giving them the opportunity to 'opt-out'. This enabled baseline data to be gathered from around 9000 households.
Recruited sufficient customers	The project team filled most test cells and covered all key technology types in quite significant numbers, despite market conditions leading to the take-up of low carbon technologies being less than envisaged.
Partnering with third parties	Partnering with third parties helped in terms of reaching low carbon technology customers – such as social housing providers to install heat pumps and Charge your Car (North) to recruit scarce EV users.

4.2.2. Challenges

Difficult to find LCT customers	The original intention was to target existing British Gas customers who had already installed LCTs. However this proved difficult due to: low uptake of certain technologies; data protection meant lack of available data on which households had installed technologies; and lack of cooperation of some LCT providers, for example a large solar photovoltaic (PV) 'rent-a-roof' provider declined to permit monitoring equipment to be attached to their PV device. These issues were addressed by installing subsidised technologies and working with third parties to recruit customers.
Involving non-British Gas customers	Recruitment challenges meant that it was necessary to widen access to the trials beyond British Gas customers. This introduced additional costs, complexity and delay in particular to: amend the customer engagement plans and the data protection strategy; and, more significantly, to install isolation switches and additional metering equipment to collect the customer consumption data.
Delay to project timescales	The involvement of non-British Gas customers and challenges of technology development lead to delays in the project timescales. This meant an extension of the monitoring period, with agreement from customers and an overall delay of one year.

4.3. Installation process

4.3.1. Successes

Significant number of installations achieved	Over 3,446 items equipment were installed through the residential trials. The installation process followed strict guidelines, and quality checks. There were very few customer complaints, these were mostly minor and about the delay in receiving retail vouchers.

4.3.2. Challenges

Booking installation appointments	There were difficulties arranging installations as customers often had to take time off work. The bookings were sometimes made too far in advance, so customers forgot when the installer was arriving.
No pre-survey of household suitability	There was eligibility criteria for trial participation, but it was not possible in terms of cost and practicality to pre-survey all of households, this meant that in some instances, on arrival at the property, the installer could not install equipment due to lack of suitability for technology, health and safety or existing wiring issues.
Minor complaints dealt with	There were only four recorded complaints during installation relating to: a freezer turned off in error; a wooden cupboard having entry holes put in to allow monitoring equipment to be installed; a washing hose damaged; and a perceived issue with television interference due to hub being switched on. These were all dealt with by British Gas and their installation partners.

4.4. Customer communications

4.4.1. Successes

Dedicated customer support	A dedicated support line to manage calls from customers and installers on a daily basis proved successful. Continuity of the support team ensured the project ran effectively. A Project Manager ensured communications and escalations were dealt with in a timely manner.
Customer journey tracking	A new database was developed to manage customer communications and track the customer journey. This made it easier to track customer participation in the test cells which fluctuated during the process, as customers dropped-out or moved between test cells.

4.4.2. Challenges

Contacting customers to	It was sometimes difficult to contact customers by phone during the day to deal with issues, such as data communications.

resolve issues	

4.5. Data communications and collection

4.5.1. Successes

Large data set, statistically significant	A significant amount of data was collected through the trials on: electricity use in the home; appliance use; and efficiency of systems. Statistically significant data sets were captured from most test cells.
Linked network, supplier and home for first time	For first time in UK, these trials managed to link end-to-end Distribution Network Operator systems, supplier systems and customer's appliances.

4.5.2. Challenges

Communications within the home	The majority of residential trials required the installation of a home area network hub to communicate with the installed monitoring technology. This required broadband and a phone line. This also required homeowners not to move the hub once in place, which sometimes happened for household convenience or aesthetics.
Lack of customer broadband	Some properties did not have broadband or even a telephone line, which were required for data communications. In particular this was an issue for social housing customers in the PV and heat pump trials. Therefore, for some trials broadband had to be provided to the customer, free of charge for the duration of the trial. A new solution using a GSM[6] router was developed and installed in places where it was not possible to get broadband via a landline, which worked effectively.
Communications to the home and appliances	A suitable platform for the external interface with the in-home communications also had to be developed from scratch. In particular, it was necessary to develop a system that allowed load control of appliances remotely. This was a novel system that required repeated site visits to get it working effectively.
Managing the data sets	Inevitably, with such a large project, data issues arose - including failure of data communication in customers' premises, data compatibility issues between project partners and the significant effort needed to get the data into a suitable state for analysis.
Loss of data	During the project several factors caused data to be missing from individual homes. This data loss usually resulted from customer actions: switching the hub off; cancelling their internet / changing their

[6] GSM stands for Global System for Mobile Communications.

	internet provider without notification; placing objects in front of devices preventing signal; or removing smart plugs. These issues were dealt with through a phone call or visit.

4.6. Equipment decommissioning

4.6.1. Successes

Smooth process with few complaints	The process of removing equipment was smooth, taking into account lessons learned throughout project. There were few requests for remedial visits, customer complaints or claims for damages or compensation following the decommissioning activities.
Equipment reuse	The trial equipment was made available for use in two LCNF projects.

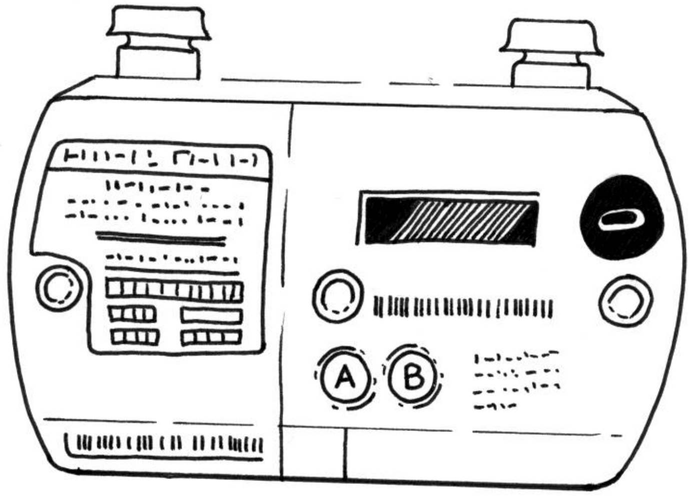
4.6.2. Challenges

Small amount of remedial work	There were two minor issues: a carpet frayed due to monitoring equipment being removed; and a small area of wall requiring decoration after the meter was removed. These issues were dealt with.

5. Monitoring of the Home

This section sets out some of the successes and challenges of installing each type of monitoring equipment in homes as part of the CLNR trials. See **Appendix A - Table 1** for a list of the equipment installed for each test cell.

5.1. Smart meter



The project sought to understand electricity usage patterns across the day, week, seasons and year and between different demographic groups. Smart meters were used to collect half hourly consumption data in kWh. All customers involved in the trials either had a smart meter or secondary metering equipment.

5.1.1. Successes

British Gas smart metering experience	British Gas went early on rollout of smart meters to customers across the UK. Therefore, they have experience of installing, managing and gathering data from smart meters
Recruiting existing 'smart' customers	Recruiting existing British Gas smart meter customers, where possible, reduced the need to install new smart meters.
Significant baseline smart meter dataset	Baseline data for the control group (TC1a) was gathered from existing British Gas customers. Customer contracts allowed British Gas to use the smart meter data for trials, but they also informed customers with a mail-out, giving them the ability to opt-out. Of the 9137 customers originally approached only 8% (695 customers) opted-out, which meant data was gathered from 8442 households.
Smart meter attracted participants	The prospect of a smart meter proved to be a strong incentive for Time of Use (ToU) test-cell recruitment (TC9a). Recruitment rates from 'smart eligible' customers were 11% higher than amongst those that already had a smart meter[7].

[7] CLNR-L036: Sustainability First (2013) CLNR: Project Lessons Learned from Trial Recruitment.

5.1.2. Challenges

Low smart meter penetration	Smart meter penetration was lower than forecast, reflecting the slower national rollout. This meant that for some test-cells it was necessary to install smart meters rather than use an existing one.
Smart meter capabilities	Some households had older smart meter models that did not have the capabilities required by the project for monitoring export.
Enhanced smart meter delayed	The intention was to use the British Gas' phase 3 smart meter for the trials as this would enable 10-minute monitoring and also perform the restricted hours / direct control functionality. However, deployment was delayed due to complexity of integrating these meters with British Gas' billing systems, which pushed the availability of this technology beyond the timescales of the CLNR project. Therefore Phase 2 smart meters were installed where needed, with additional secondary monitoring equipment to simulate the 'enhanced smart meter'.

5.2. Secondary meter

It was not always possible to install a smart meter in the homes of all trial participants, in particular for non-British Gas customers. However it was even difficult for some British Gas customers, in these cases, a non-fiscal secondary meter was installed by PassivSystems, which collected import and export data in kWh on 10-minute or 1-minute resolution depending on the trial.

5.2.1. Successes

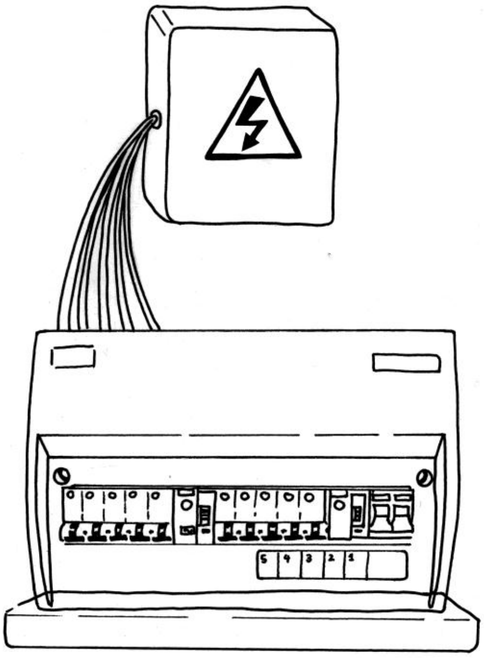
Participation of customers without a smart meter	The secondary meter enabled participation of customers where a smart meter could not be installed, including non-British Gas customers. The project was undertaken at the early stage of British Gas' smart meter rollout, and, hence, they did not have the capability to measure export (for PV, micro-CHP) or meter customers on Economy 7, prepayment or living in tall buildings (all of which they are now working on). In all these cases the research requirement to have whole house monitoring dictated that a secondary meter was required.

5.2.2. Challenges

Mains Isolation switch required for safe install of secondary meter	Secondary meters can only be safely installed if there is an isolation switch between the meter and customer unit. Many houses did not have such a switch. Only the supplier's registered meter operator can disconnect the power at the mains or install an isolation switch. Therefore, British Gas had to engage with other energy suppliers and their agents to fit the isolation switch in homes, which was time-

	consuming and costly. Where it was not possible to install an isolation switch, a more expensive MicroWatt Polymeter was used.

5.3. Polymeter



The MicroWatt Polymeter was used for disaggregated monitoring of electricity use in the home as part of the enhanced monitoring trial (TC2), and was also used in homes where it was not possible to install either a smart meter or a secondary meter. The MicroWatt Polymeter, installed by PassivSystems, monitored all circuits at the customer's consumer board, collecting import and export data in kWh at a 1-minute resolution from up to 16 individual circuits in the home.

5.3.1. Successes

Rich disaggregated dataset	The polymeter produced a rich dataset of disaggregated electricity use in homes focusing on: cooking; space and water heating; cold and wet appliances; consumer electronics and home computing; and lighting. 170 customers took part in the enhanced monitoring trial.
Participation of customers without a secondary meter	The polymeter also allowed the team to capture whole-house readings for homes that were not suitable for secondary metering. For example, it could be used in situations where there was no isolation switch as it could be installed without removing the cut-out fuse.

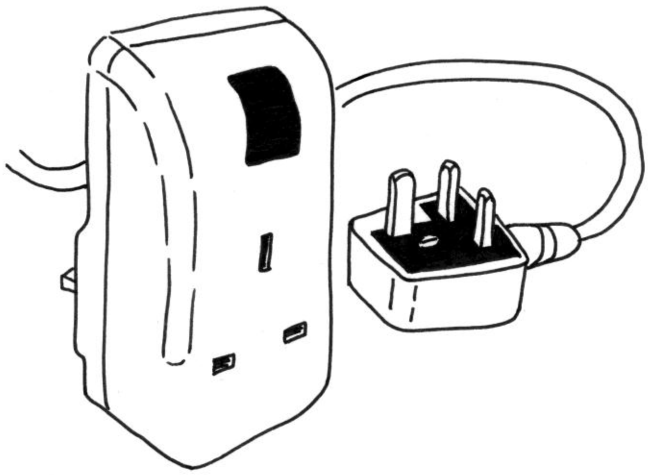
5.3.2. Challenges

Connectivity issues	The polymeter was not designed specifically for the purposes for which the project utilised it and was the only viable solution available at the time. Connectivity was unreliable as the system was built to be hard wired into the Internet rather than connected via Wi-Fi. Several remedial visits were required throughout the project due to connectivity issues and this lead to systems being replaced which added to costs.
Faulty parts	A batch of polymeters had a faulty part that prevented the system from communicating. The issue was fixed by replacing the motherboard. It resulted in a delay rather than a loss of data, as the data was backed up and was recovered in the majority of cases.
Technology support	The product was adapted from an existing commercial product for the specific requirements on this project. Therefore, it was not always

	possible for the manufacturer to provide the level of technical support called for by the project.

5.4. Smart plugs

The project sought insight into how people use electricity in their homes – what appliances they use and when. The enhanced monitoring trial (TC2a) focused on the collection of disaggregated electricity use data, by fitting smart plugs onto customers' appliances. The smart plugs, installed by PassivSystems, collected import/ export data in kWh on 10-minute / 1-minute resolution.



5.4.1. Successes

Data on home appliance use	Smart plugs captured data from key appliances such as storage heaters, electric hot-water heating, kettles, washing machines, dishwashers, refrigerators, freezers and microwaves. This is the most comprehensive data set to date covering 170 households for one year. It builds on and complements early work on the Household Electricity Survey by the Energy Saving Trust, DECC and Defra[8].

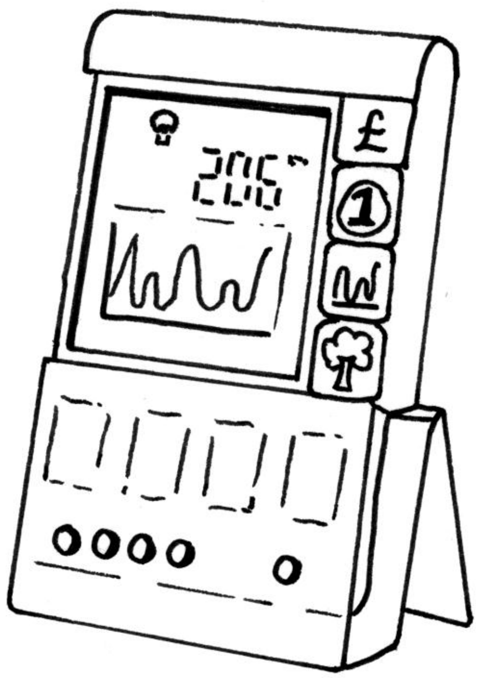
5.4.2. Challenges

Placement of smart plugs	With only a limited number of smart plugs it was not possible to cover every appliance in customer homes. Installers therefore had to decide on which appliances to connect to plugs on-site. This means that there is some variation in which specific appliances were monitored in each home. There may also be variations as a result of customers removing smart plugs / attaching different appliances to them without notifying the trial team.
Connectivity issues	In order for the data collected from the smart plugs to be relayed back to the PassivHub and then on to Passiv's head-end system, either broadband or 3G modem were required. There were some internet connectivity issues.

[8] Energy Saving Trust, DECC and Defra (July 2012) Powering the Nation – household electricity using habits.

Intrusive monitoring limits recruitment	Due to the intrusive and time consuming nature of the installation process and monitoring it was decided to only involve CLNR partner staff in the TC2a trial. This had implications for the demographic sample.

5.5. In-home display (IHD)



British Gas installs an in-home display as standard with their smart meter. The Landys+ Gyr Eco Meter allows customers to see the amount of energy they are using and the cost of that energy.

A ‘traffic light’ display told customers whether their real-time usage is high (red), medium (amber) or low (green).

5.5.1. Successes

Standard install	British Gas has experience of installing these as part of the business as usual smart meter rollout, so there were no particular issues.
‘Traffic light’ helps ToU customers	The traffic light display is designed to help customers to manage their energy use. Customers on the Time of Use trial (TC9a) could combine this visual display with their knowledge of peak and off-peak periods, to shift their usage to off-peak times.
User friendly	90% of customers found the IHDs quite or very easy to understand[9].

5.5.2. Challenges

No IHDs for some customers	Non-British Gas customers did not have IHDs. This may have implications for the way customers behaved in their homes and responded to signals about their electricity consumption.

[9] CLNR-L100: Domestic Survey Results and Analysis.

5.6. Electric heating system monitoring

The original intention was to recruit customers who use on-peak electricity for hot water heating, but it was difficult to find such customers. Therefore, it was decided instead to focus on electric heating customers on restricted hour tariffs – such as Economy 7 and Economy 10.

A new subset was created of TC2a covering customers with electric hot water (HW) and storage heating (SH), to monitor how rigidly customers' stuck within the tariff and how often they pressed the override button to boost hot water. This involved monitoring of the immersion heater, storage heaters, and some other non-storage heaters, as well as temperature monitors for the hot water tank, key rooms and radiators. All installed by PassivSystems.

This involved 80 Economy 7/10 customers with electric hot water and 75 Economy 7/10 customers with both electric hot water and storage heaters.

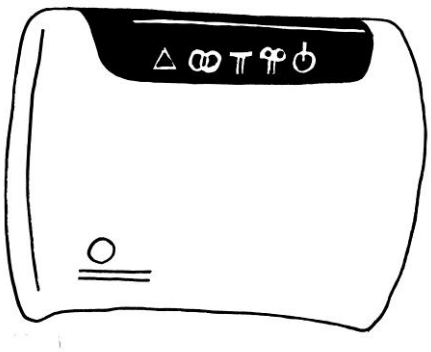
5.6.1. Successes

Insights into existing ToU tariff customers	Given the lack of industry data, these trials give a helpful insight into the consumption patterns of Economy 7 and 10 customers, how they respond to the ToU signal, and the degree to which they over-ride the controls.

5.6.2. Challenges

Difficult to find customers	It was difficult to identify sufficient Economy 7/10 customers from supplier records, so the team worked with social housing providers, which proved successful.
Storage heater ratings	A number of storage heaters were rated higher than the smart meters would safely allow and, therefore, those meters could not be used and an alternative monitoring approach was taken, using the polymeters.

5.7. Home area network hub



The majority of residential trials required the installation of home area network hubs to communicate with the installed monitoring technology. The PassivHub was installed by PassivSystems. Households that did not require hubs were the baseline smart meter customers (TC1a) and the Time of Use customers (TC9a).

5.7.1. Successes

Hubs worked effectively	The PassivHubs worked well when there was connectivity, but they required broadband and a phone line, which not all homes had.

5.7.2. Challenges

Lack of broadband	Many homes did not have broadband, so either this was provided for a year, free of charge, or a Bluebird GSM router was used.
Connectivity issues	The network hub needs to be in the range of signal of the router. There were communications issues between the home hub / router and the load controllable devices, which sometimes led to data loss. For example, due to: consumers moving the hub / switching it off; placing objects in front of devices preventing signal; changing their internet provider.
Software updates	Extended time taken to download 'new' software updates.

6. Low carbon technology monitoring

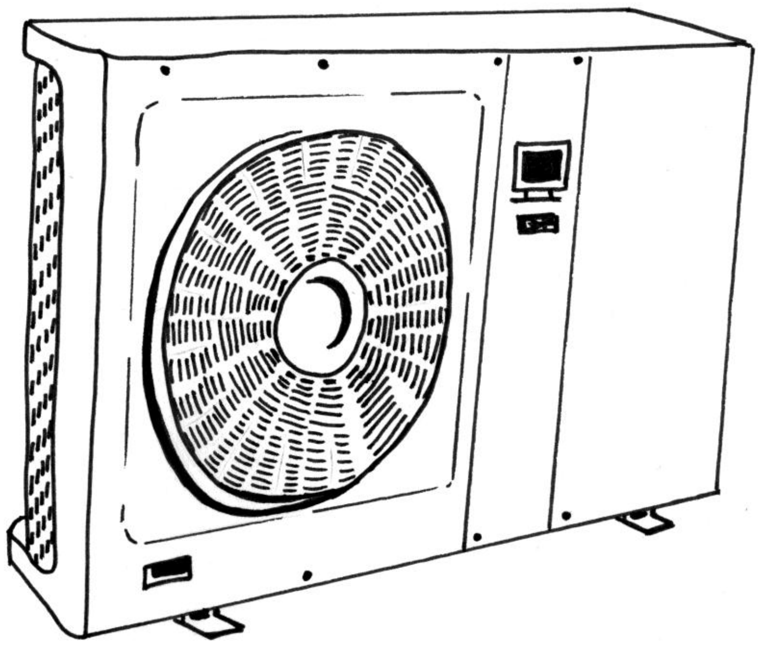
The project involved monitoring low carbon technologies. For all these trials, either a smart meter or secondary monitoring equipment was needed to monitor electricity use – with a home hub and in-line meters to monitor the technology. Some trials also required additional monitoring of temperature and power quality. See **Appendix A - Table 1** for a list equipment installed for each test cell.

This section looks at some of the successes and challenges of installing monitoring equipment for these technologies, and in some cases, installing the technologies themselves.

6.1. Air-source heat pumps (ASHP)

The trials included monitoring of electricity use patterns for Air-Source Heat Pump (ASHP) customers, using in-line monitors, installed by PassivSystems. The trial also looked at customers' attitudes to operation and performance of the technology and measured actual performance both thermally and electrically – collecting data on internal and external temperatures and coefficient of performance. A total of 344 customers took part in the heat pump monitoring trials.

Initially, the team experienced challenges recruiting customers for the heat pump trials, with a scarcity of existing heat pumps, due to a delay in the Renewable Heat Incentive (RHI). This meant that heat pumps had to be installed through the trial. This section focuses on installation challenges for the heat pump monitoring trials, the smart heat pump with thermal store (TC14) is covered under 'Demand-side response technologies.'



6.1.1. Successes

Subsidising heat pumps	The project secured £2.2m from DECC, in advance of the RHI, which made it possible to subsidise heat pumps to the price of a conventional boiler (average subsidy= £3,500, customer cost= £5-8,000). Social housing providers were able to use this funding to leverage further EU match funding to pay for the systems.
Social housing installations	Social housing providers installed heat pumps that were then monitored as part of the trial. This was critical to ensure sufficient trial participants, but it meant social housing dominated the sample, impacting on its demographic profile.
GSM network for homes without broadband	A home area network "hub", which used the GSM network to transmit data directly to British Gas's data management company, was developed and successfully deployed, in homes without broadband. This enabled a far greater number of heat pump installations to be technically ready for the installation of monitoring equipment with a marked increase in heat pump installation rates.

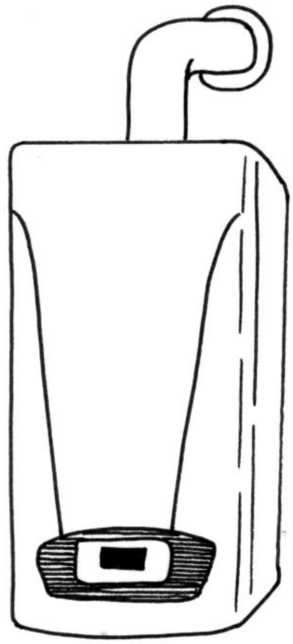
6.1.2. Challenges

Low take-up of heat pumps	Because of the delay in the launch of the Renewable Heat Incentive and the related uncertainty about the support to be provided to air source heat pumps, the number of customers with ASHP installations was much lower than anticipated at the start of the project. Even with the additional support from DECC it was difficult to find customers willing to accept the technology and pay a part of cost.
Barriers to take-up	Pumps were not as popular as expected with homeowners, due to cost, the 'hassle factor'of installation, space constraints, requirement for low temperature radiators / under-floor heating and due to low levels of insulation in rural off-grid properties. Some heat pump installations also required planning permission from the local authority, which caused delays.
Barriers to participation for customers with heat pumps	There were significant barriers to participation, even for customers with heat pumps, including: no broadband; insufficient space to install meter on heat pump, and safety issues associated with existing exposed wiring. The team had to provide 1-year free broadband to some customers, to enable their participation. Many of the heat pump customers were non-British Gas, which meant installing secondary meters and monitoring equipment in addition.
Mixed customer	Customer feedback on heat pumps was mixed, with 76% satisfied/very satisfied and 15% dissatisfied/very dissatisfied[10].

[10] CLNR-L104: Heat Pump Survey.

feedback	

6.2. Micro Combined Heat & Power (micro-CHP)



To understand micro-CHP electricity use patterns for TC4, the Baxi Ecogen micro-CHP unit was installed by British Gas Heating installations and monitored using an in-line micro-CHP monitor installed by PassivSystems. The Baxi Ecogen Stirling engine had a maximum heat output of 6kW, maximum electrical output 1kW, an overall efficiency of 90%.

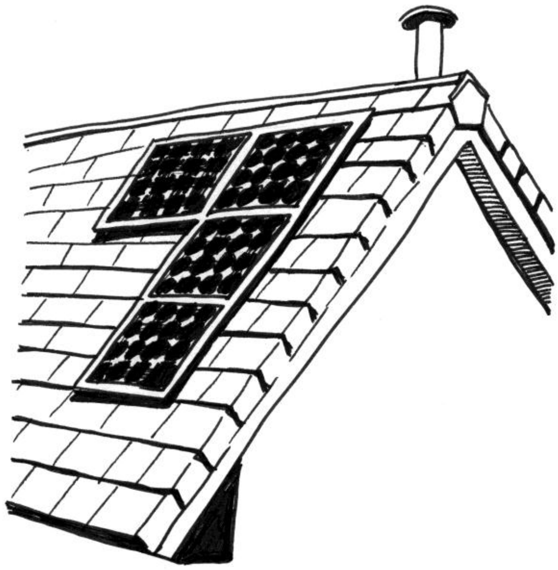
6.2.1. Successes

Subsidy for CHP helped take up	The project was able to subsidise the cost of micro-CHP units by over 50% of the cost (customer cost=£4-5000), to the price of a conventional boiler. This helped in delivering 11 units out of a target of 20 units.

6.2.2. Challenges

Fuel cell micro-CHP not ready	The intention was to use a micro-CHP fuel cell unit, but it was not ready for deployment, so the BaxiEcogenStirling Engine unit was used.
Size of unit	Siting of the appliance was difficult due to its size (950 x 450 x 426mm) and weight (118kg), and meant retrofit was usually limited to properties with an integral garage.
Operating noise	There were some customer concerns about operating noise levels of the installed units.
Low take-up	Take-up was lower than hoped, and these technical issues drove the decision to pause recruitment and not fill TC4.

6.3. Solar photovoltaic (PV) panels



Existing solar photovoltaic (PV) panels were monitored using in-line PV monitors, installed by PassivSystems. 152 customers took part in the PV enhanced monitoring trial (TC5).

Trialling of solar-PV with an in-home display (TC20 IHD) and solar PV with hot water generation (TC20 auto) are covered under 'Demand-side response technologies.'

6.3.1. Successes

Recruited existing solar customers	Customers with existing solar panels were recruited so it was not necessary to install the solar PV panels.
Worked with housing associations	By working with housing associations it was possible to recruit sufficient participants for the trials. But this impacted the sample demographics.

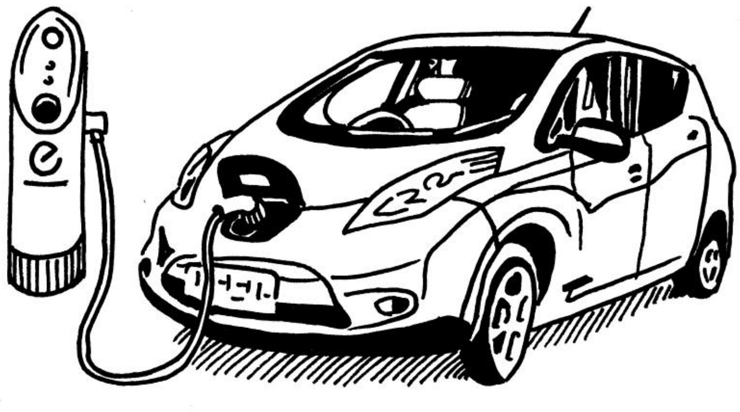
6.3.2. Challenges

Finding solar customers	Initially, it was difficult to find solar PV customers to involve in the trial. There is no register of customers with solar PV. Therefore British Gas customers were contacted. This generated a lot of interest, but many of the customers were with a 'rent-a-roof' PV provider who declined to permit monitoring equipment to be attached to their PV device.
Connectivity issues	The trials suffered from the same connectivity issues found generally with the PassivHub equipment.

6.4. Electric Vehicles (EV)

Electric vehicle charging was monitored through TC6 in order to develop a more accurate view of where, when and how network challenges will emerge due to EV uptake.

For British Gas customers, charging was monitored using in-line monitors for EV charge points and installed by PassivSystems.



Northern Powergrid also sought an alternative option working with Charge your Car (North) Ltd to recruit scarce EV users onto the trials. This involved monitoring of existing EV charge point and whole-house consumption (via an EDMI Mk7C smart meters), which was installed as part of the CLNR project by G4S Utility Services.

6.4.1. Successes

Successfully monitored EV customers	Northern Powergrid successfully monitored EV charging and whole-house consumption patterns for a total of 143 EV customers, through a combination of existing British Gas EV customers and the partnership with Charge your Car (North) Ltd.

6.4.2. Challenges

Sample demographics	Electric vehicle sales were much lower than had been anticipated at the time of the bid, making it difficult to recruit EV customers. Of those recruited through Charge your Car (North) Ltd., 108 participants were drawn from employees, or friends and family of employees, of Nissan in Sunderland, who drive a Nissan Leaf as part of a company car scheme, and were able to charge at work. This sample bias must be borne in mind.

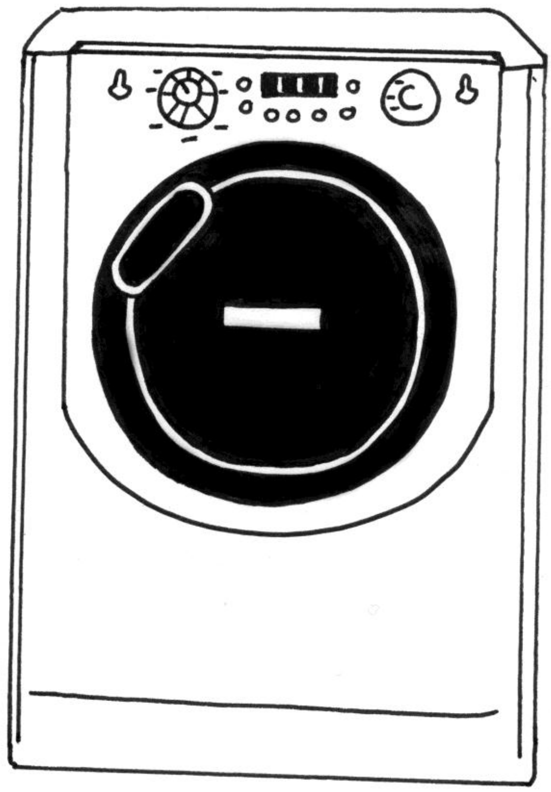
7. Demand-side response technologies

The project also tested customers' ability and willingness to change their electricity use in response to a signal. The focus of the trials was on:

Restricted hours trials	Tested customers' willingness to accept a default time-based restriction on the use of a specific appliance. The trials combined the Time of Use tariff with an automated service that turned down/reduced the load of certain appliances (smart washing machines or smart heat pumps) during the four-hour peak period (4pm-8pm), with the ability for customers to override this restriction should they wish to.
Direct control trials	Tested customers' willingness to have the time of use of a specific appliance directly controlled by the customer's electricity supplier (sometimes in response to distributor need). Customers participating in this part of the trial received either a smart washing machine or smart heat pump. The terms of the trial allowed the supply to these appliances to be occasionally interrupted through external dynamic signals, in this case from Northern Powergrid via British Gas's demand management platform. Certain limitations were placed on the frequency and timing that interruptions could be called: • A maximum of 15 interruptions per year • Only 1 interruption per day • Interruptions could occur on up to 10 consecutive days • Each interruption could last up to four hours • Interruptions would be called in the peak periods of 4pm to 8pm only • The trial participant could override without penalty • Excludes weekends and public holidays
In-home balancing trials	Tested customers' willingness for either automatic or manual balancing of electricity generation and use within the home. Various technology options were explored for these trials but none were considered viable within the timescales for the CLNR project. Therefore the focus was on PV only, with two trials: automatic charging of an immersion heater for hot water at times of high electricity generation; and manual balancing with the customer responding to an in-home display showing electricity generation/exportation.

7.1. Smart washing machines

Subsidised smart washing machines were used to encourage customers to move usage away from peak times (i.e. 4pm - 8 pm), with two trials: 53 customers on restricted hours; and 100 customers on direct control.



The Hotpoint AQUALTIS model AQ113D 69 EH/A zigbee-enabled smart washing machine was installed by British Gas, collecting 10-minute resolution consumption data and appliance statistics via a Datamobile GRID BOX gateway device and sent back to British Gas' demand management system provided by GreenCom Networks.

British Gas developed machine protocols to enable tariff based and/or remote automatic scheduling of wash cycles as well as display of custom text messages. Both British Gas and the appliance manufacturer Indesit felt it in the best interest of customers to have simple customer override of all automatic scheduling.

7.1.1. Successes

Customers liked the smart washing machined	Customers viewed the smart washing machines positively[11]. However it should be noted that the customers received the washing machine free of charge through the trials.
DSR signal successfully received	Successful DSR responses, both driven by the ToU tariff and via remote 'on-demand' signals from Northern Powergrid via British Gas.

7.1.2. Challenges

Smart appliance manufacturer decided not to enter UK	A significant setback was the decision by the smart appliance manufacturer, identified at bid stage, not to enter the UK market, requiring the sourcing of a new supplier, Indesit and development of a communications platform to enable direct control of the appliance.

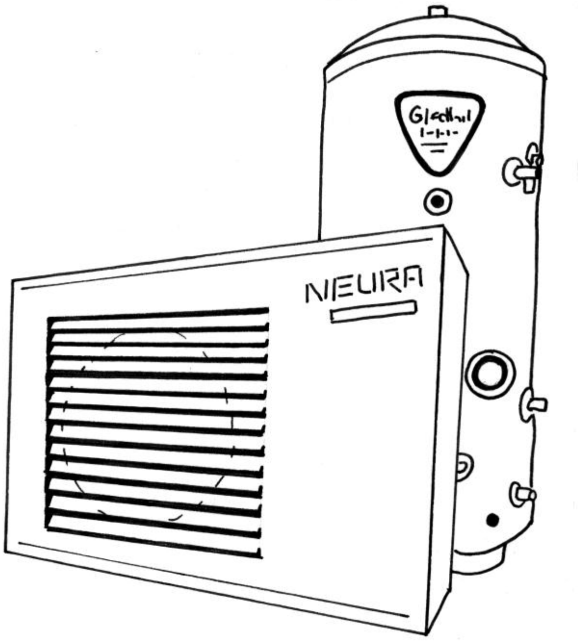
[11] CLNR-L097: Social science report on demand-side response.

	This led to delays and added cost.
Developing system for direct control events	It was hoped that the same system for direct control of the heat pump thermal store could be used for direct control events with the load-controllable wet white goods. However, the two could not be run through the same platform and the development costs of the latter (because it was working with a piece of technology which was entirely new to the platform developer) were higher than expected.
DSR signal not always received	The remote signal was not always received due to: broadband being down; equipment being unplugged; and teething problems with the technology platform. These issues were resolved via a phone call and, where appropriate, service visits.
Distance between gateway and appliance caused connectivity issues	In about one third of smart washing machine installations, the distance between the gateway and appliance caused communications problems. Initially repeater plugs were used to solve the problem, but there were compatibility problems between the repeater plug, smart appliances and the gateway. The cause of this was differences between the appliance and gateway in the way they handle fragmented messages. Therefore, repeater plugs were not used. 60 affected trial participants were revisited. Either the smart washing machine was placed in closer proximity to the communication gateway or power line communications (PLC) plugs were used.

7.2. Smart heat pumps with thermal store

The project included the development of an air-source heat pump (ASHP) with a thermal store (TC14) for direct control trials. The system was designed to enable remote turn down of heat pumps at peak times (i.e. 4pm - 8 pm), with a thermal store (hot water tank) to improve efficiency and ensure that consumers did not perceive a temperature change.

The 'Smart Grid Ready' NEURA NDA Nano thermal heat pump and highly insulated Gledhill 300 litre stratified thermal storage tank were installed by British Gas.



The secondary meter (for whole house load) was used in conjunction with a 'smart heat pump', to enable 10-minute monitoring of: heat pump consumption; room temperatures; and parameters enabling estimation of coefficient of performance. The smart heat pump has controls enabling tariff-based or external control of the load. Consumption data and appliance statistics were collected via a Datamobile GRID BOX gateway device and sent back to British Gas' demand management system provided by GreenCom Networks.

The initial intention was also to trial a restricted hours intervention with domestic heat pump customers (TC13) but this required participants to be BG customers as it was in conjunction with the ToU tariff. There were no eligible customers for this trial, so this test cell was cancelled.

7.2.1. Successes

Award winning innovative design	For the trial a smart heat pump was developed linked to a hot water tank – the Heat pump NEURA NDA Nanounit. This increased the efficiency of the system and enabled interruption to the heat pump operation with the water tank acting as a thermal store. This innovative future technology was designed by bringing together components available today. It won 'innovation of the year' from the Micropower Council.

Direct control was successful	Interruptions were successful the majority (67%) of the time. On receiving a signal from British Gas' demand management platform, the electricity supply to the trial participant's heat pump was automatically switched into a low output mode between 15 minutes and two hours. As the heat pump was set to build up a store of heat for up to two hours prior to an interruption, the trial participant always had a supply of hot water to see them through the peak interruption.
No temperature impacts	There were no customer complaints about temperature fluctuations or reports of inconvenience during the interruption events.
Helpful learning on how direct control events work	There were insufficient customer numbers for statistical robustness but the trials provided good quantitative and qualitative learning about the extent to which the innovative smart heat pumps with thermal store could accommodate direct control events and maintain comfortable / appropriate temperatures for the building and hot water.

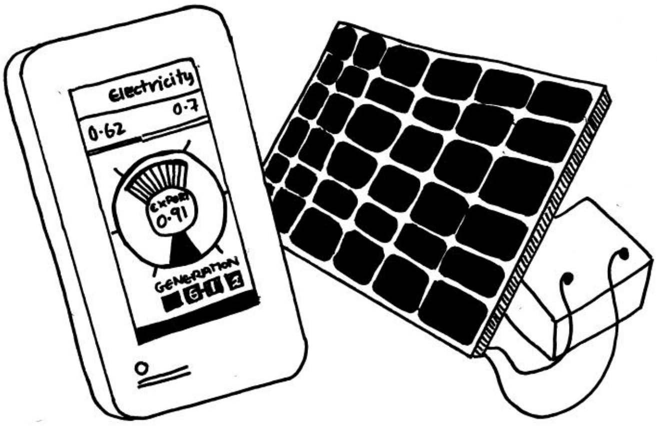
7.2.2. Challenges

Low take-up of heat pumps	Low numbers of existing heat pump customers (see heat pump section above). The proposition was a difficult sell to private homeowners, who are price conscious and averse to upheaval. Only 7 installations.
Heat pumps too big for most homes	Only houses with sufficient space could accommodate the heat pumps and thermal store due to their size and weight. The Neura NDA Nano smartair source heat pump measures 1040mm high x 1560mm wide x 560mm deep and weighs 236kg. The Gledhill300-litre thermal store is 1850mm x 710mm and weighs 170kg when empty / 470kg when filled. The installation was non-standard as it required rear access to the property and bespoke lifting equipment.
Heat pumps lack power for large homes	Larger properties often had such significant heat losses that even the larger heat pump systems were insufficient to meet a property's calculated peak demand.
Connection issues	The main connection-related issues encountered were; IP port restrictions/closed gates on customer routers preventing access from the Greencom Platform load-control messages; Firmware changes for the operating system for the heat pump; Customer internet connection stability; and changing IP addresses.
Faulty part	There was a systemic fault with the Primary Circuit Board in some units, which required a parts upgrade.
Temperature adjustments overrode direct	Minor adjustments made to the unit's temperature settings by the customer caused an automatic override of direct control (to prevent excessive loss of temperature in the hot water cylinder). This design

control	problem was addressed following trials at the test centre.

7.3. Solar PV with in-home display

The solar PV in-home manual balancing trial (TC20 IHD) was designed to encourage customers to self-balance their electricity use and their onsite electricity generation – by turning on their appliances manually when they were generating, in order to reduce the amount of electricity which they would later import from the grid when they were not generating.



In-home displays – Passiv Controller IHD – were used to show customers visually when they were generating/exporting – and to advise them to use this electricity in their home, rather than export to the grid. Whole house load was monitored using a secondary meter, with additional monitoring of the individual PV device including load/generation and import/export.

See the PV monitoring section for general successes/challenges, additional points for TC20 IHD are outlined below.

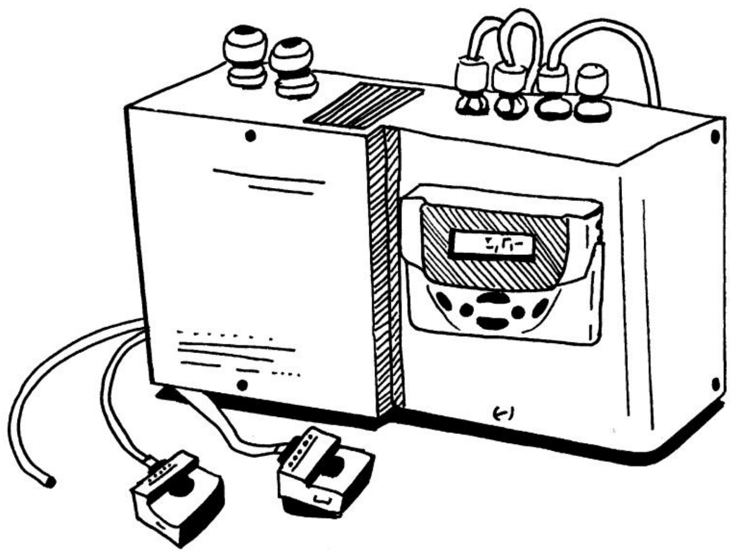
7.3.1. Successes

Good recruitment	This was a relatively straightforward intervention, which was targeted at existing PV users so it was possible to recruit 152 customers for the trial.

7.3.2. Challenges

Impact inconclusive	Results as to whether these had any influence on consumption are inconclusive.

7.4. Solar PV with hot water generation



The solar PV in-home automatic balancing trial (TC20 auto) was designed to provide automatic within-premises balancing. Coolpower's EMMA system diverted surplus power from on-site PV generation to immersion heaters whilst holding electricity export close to zero. The unit incorporated monitoring of: whole house import current; PV generation current; supply voltage; and some min/max data at 10-minute resolution.

See the PV monitoring section for general successes/challenges, additional points for TC20 auto are outlined below.

7.4.1. Successes

Good recruitment	Customers were attracted to the idea of maximising the efficiency of their solar PV using the EMMA system. Therefore, it was possible to recruit 99 customers.
EMMA system worked	This was a market ready product, which worked effectively, with no installation issues or customer complaints.

7.4.2. Challenges

Specialist installation	The EMMA system required specialist installation from British Gas's installation partners on the project, Solar & Wind Applications.
Data issues	Durham University found some issues with the data.

8. Small and medium-sized enterprises (SMEs)

The consumption per customer of SMEs tends to be an order of magnitude higher than domestic consumption, making these energy users of particular importance for understanding both current and future demand.

The project initially intended to conduct five different trials with SME customers: basic monitoring (TC1b), enhanced monitoring (TC2b) and 3 types of intervention: Time of Use (TC9b), restricted hours (TC10b) and direct control (TC11b).

1,514 SME customers took part in basic monitoring (TC1b) for one year (1 September 2011 to 30 August 2012) on an opt-out basis and 40 British Gas SME customers in enhanced monitoring (TC2b)[12] on an opt-in basis.

The intervention trials were more challenging to fill. 44 SMEs trialled the 3-rate Time of Use tariff (TC9b). Over 20,000 SMEs were contacted and 350 indicated an initial willingness to participate in the restricted hours trial (TC10b), but in practice, by the start of the trial only two SME customers went ahead. In the end no customers participated in the direct control trials.

Any customers who decided not to go ahead with the DSR trials, and who were suitable, were offered the opportunity to take part in the enhanced monitoring trial (TC2b).

8.1. Equipment installed for SME trials

For the basic monitoring trials (TC1b) all participants already had a smart meter installed or were scheduled to do so. For the enhanced monitoring trials (TC2b) additional monitoring equipment was installed to collect data and technical information at 1-minute intervals for total meter load and disaggregated loads – including volts, total harmonic voltage distortion, real power, reactive power, power factor, and energy. Different circuits on the premises were measured. A CT (Current Transformer) measurement device was used. This had its own Wi-Fi sim-card and was programmed to automatically dial up the modem and transfer data.

8.2. Installation process

Installations for the SME trials broadly followed the generic customer journey set out previously in **Figure 3**. The British Gas installer would also have a detailed checklist of issues to discuss with the business representative when visiting the premises. This checklist is included for reference in **Appendix B**.

[12] CLNR-L099 Insight Report: Small and Medium Enterprises (SMEs)

8.3. Successes, challenges and insights from SME installations

8.3.1. Successes

Rich monitoring data	A significant number of SMEs participated in baseline and enhanced monitoring. The findings from this are important because SME usage has been little studied in the past and data was poor.
Interest in DSR	There was an initial good level of interest from SMEs in the concept of DSR.
Site visit	The CLNR team recognised the importance of time onsite with business customers. They developed a detailed checklist of issues for installers to cover with customers. In some cases researchers from Durham University would also join for the site visit so that the technical and social science aspects of the project could be discussed with the customer during the same visit.

8.3.2. Challenges

Finding the 'right' person to talk to	It was sometimes difficult to find the 'right' or the same person to talk to within an SME – e.g. due to staff turnover, companies going out of business or changing ownership, or tenancy arrangements. When a person had left the business, this resulted in no one on site having knowledge of the project, installation dates and payments for enrolling in the project. There were also issues of MPAN numbers not matching and different named persons from those on the account because someone had left or due to meter changes.
Barriers to DSR participation	Unfortunately, at the site technical survey stage, almost all of the SMEs who had initially expressed an interest in DSR dropped out of the process. Most sites were found to be either unsuitable in terms of site configuration and/or that the loads which could be monitored or controlled were essential to businesses operations. SMEs were concerned about the impact of direct electrical interruption on daily running of their business. Other reasons for not taking part included: did not like the idea of equipment being installed; concerned about the size/impact of the monitoring/interrupting equipment; did not want to overlap with existing energy saving project; and no decision-making power on the matter (e.g. landlord/serviced properties, part of larger organisation, or dealing with electricity through broker). In some cases it was not possible to install equipment due to safety issues, such as presence of asbestos and existing wiring arrangements.
Lack of flexibility of activities	The SME market place is service driven, which determines business hours and production needs. SMEs felt a lack of flexibility in their daily business activities – there could be little movement of timeframes, they had to meet the expectations of their customers and compete for

	passing trade, and there were regulatory barriers – such as environmental, animal welfare, food standards, health and safety requirements – which meant that they could not interrupt certain electricity using practices. Key electricity using practices in SMEs were lighting, heating and cooling, refrigeration and ICT. Some companies had machinery, which took time to shut-down/start-up. Very few SMEs had backup generation. Installers reported that those who did, such as farms, often had diesel and were concerned about the cost and environmental implications for their products of using it (as supermarkets now require carbon footprint information).
Costs of DSR proposal outweigh financial incentive	SMEs were offered incentives to participate in the trials – including £100 payment and a cheaper retail tariff. In discussion with installers, businesses suggested that for the intervention trials, the benefits of participation would be outweighed by the potential costs and impacts on their core business of disruption.
Reconfiguring / installing meters	In order to provide the cheaper retail tariff, the existing meter had to be reconfigured or a new fiscal meter had to be installed by G4S. This process sometimes caused delay.
Capturing energy profile data	Every business is different which meant tailoring what was monitored for each customer based on an in depth survey. For example, the types of businesses monitored included farms, retailers, pubs and restaurants, hotels and manufacturers. Maintaining and servicing such a bespoke set up of monitoring equipment throughout the trial was challenging and it was found that some monitoring units had been switched off at the site because it was deemed to be unimportant or a new supply was needed for equipment, resulting in loss of data.
Providing information and support to SMEs	Initial information provided on the trials, such as the terms and conditions, was perceived by SMEs to be complex, and so there appeared to be an initial lack of clarity on exact nature of DSR offer and what was expected of businesses. For future, is critical that clear information is provided to SMEs on the project goals and implications for businesses. The diversity of businesses interests means that specialist support and advice is needed. For project, the same support team was used for both the residential and SME trials, but it might be better for future to have a dedicated team.

8.3.3. Other insights from site visits

Knowledge of energy efficiency	One of the main anecdotal findings from installers visiting SME premises was the high level of existing knowledge about energy conservation. Examples of energy efficiency measures seen during

	visits include: curtains on fridges/freezers; low energy lighting; occupancy sensors for lighting; and high efficiency rated appliances. There was strong customer appetite to understand more about energy efficiency, but concerns about: the lack of readily available information and advice; high cost of energy efficiency equipment; and lack of available funding
Interest in low carbon technologies	There was also significant appetite amongst some SMEs for onsite renewables. This was not part of the CLNR trials for SMEs. It was also not possible for British Gas installers to discuss any commercial micro-generation offers during the site visit. But this interest in low carbon technologies may be something to consider in the design of future trials. SMEs expressed some concerns about barriers to onsite generation including: the need for planning permission; how to cover upfront costs; payback levels and the feed-in tariff digression; and challenges of connecting to the grid – particularly in remote areas.

9. Lessons learned from technical installations

9.1. Residential trials

Targeting existing smart customers	The focus on existing smart meter and smart ready customers was extremely successful, particularly for gathering baseline data. However it was not possible to limit the trials to existing smart customers, the recruitment had to be widened, particularly to fill the low carbon technology trials.
Offering a suite of options for customers without smart	A major challenge for the project widening recruitment beyond British Gas smart meter customers to non-British Gas customers and to customers who could not have smart meters at the early stages of rollout for technical reasons. Ultimately the trial was able to include these customers by developing a suite of options for secondary monitoring of their electricity use. In the long-term, this should not be a problem, as smart meters are rolled out to all customers, but issues still need to be worked through to install smart meters in certain properties, e.g. for pre-pay and economy 7 customers.
Partnering with Third Parties	The project team struggled to find customers to fill all of the trial test cells, particularly, for low carbon technologies. Working with third parties gave them access to customers and another delivery route.
Need for flexibility in trial design	In the early stages of the project, a lot of time and effort was put into reaching the recruitment targets set in the original project proposal. Having some flexibility at the early stage of the project to reshape the targets based on technology trials and initial recruitment would be a

	helpful step.
Creating 'future technologies' from today's equipment	The project sought to trial technologies of the future with today's equipment. This meant that the technologies installed were not ideal. For example, for heat pumps with thermal storage, the size, weight, access restrictions, installation disruption and costs proved to be significant barriers to uptake. If this technology is to be acceptable to customers in the future, significant innovation is needed to make the system compact, user friendly and attractive.
Pre-trialling of technologies	In order to trial innovative technologies in people's homes, the team undertook lab tests for each technology, small pilot studies with householders, then worked out the end-to-end process before actually rolling out the trial technologies. This meant that they were able to anticipate and deal with some issues before the technologies were installed in homes. However, it is not possible to foresee all the challenges of the installation process, so issues had to be dealt with flexibly.
Home visit	Although there were pre-qualification criteria for customers to join the trials, it was often only during the installation visit that it became clear whether or not a customer's premises was suitable. A pre-survey of homeowner eligibility is helpful, ideally this would be in the home, but this is not always practical or affordable. Time in the customers' home is valuable, and in future trials it would be useful to capitalise on this by combining, for example, the installation process, an introduction to the project, customer advice and a customer survey in one visit.
Advice to customers on smart kit	Many of the connectivity issues experienced through the project were as a result of customers moving the trial appliances, putting objects in front of the home hub, switching off their broadband etc. Giving customers advice on how to use the smart kit at the outset – what to do and what not to do – would save time in the long run and reduce the chances of data loss.
Need for broadband	At the outset of the project it was intended that having broadband would be a pre-requisite for participation in the trials, but this was not always possible, particularly when working with social housing customers. Therefore, it was important to have alternative communication systems available for those homes without broadband.
End-to-end data management	Managing the vast amounts of electricity use data was challenging – including ensuring consistency, data access for different project partners, maintaining security/confidentiality and processing the data for analysis. We recommend having an overarching project data manager, whose role it is to ensure the end-to-end integrity and compatibility of data flows.
Thermal storage	The project gained interesting insights into both the behaviour of Economy 7 customers and the opportunity for future thermal storage

	with ASHP and PV. Further work is needed to understand the future opportunities for thermal storage, particularly in the context of a decline in hot water tanks in favour of combi-boilers and what smart technologies could offer existing economy 7/10 customers.
Smart technologies and interventions in combination	The monitoring trials looked at discrete technologies and the DSR trials focused on either: a static Time of Use/restricted hours tariff; direct control when needed for distribution system operation; or customer response to a dynamic real-time display. A next step would be to trial these options in combination: to understand how customers respond to static and dynamic signals; develop more sophisticated tariffs to combine both; expand the amount of smart appliances and services; and developing home automation/energy services from the retailer and customer perspective rather than starting from the network/technical perspective.
Customer and technical support	When managing a project as large as this, it is critical to have a strong constant feedback loop between the customer support teams and the technical teams, so that any issues can be dealt with as quickly as possible. A challenge for this project was that some technologies were being used for purposes they were not designed for, so issues had to be dealt with as they emerged.
Industry regulation on isolation switches	Further consideration is needed on industry regulations for installing isolation switches and whether the process can be made simpler. For example, there is no central register of whether homes have these switches, so engineers could not know whether they could fit equipment until they were in the home. This should not be a big issue as smart meters are rolled out to more homes, but isolation switches are still needed for the installation of some LCTs. Recommendation that any regulated meter operator being authorized to fit isolation switches regardless of suppler.

9.2. SME trials

Diversity of SME sector	It is important to recognise the differences between SME and domestic and the business impacts of interruptions to supply. The SME sector is diverse in terms of the scale and types of businesses. The CLNR projects has provided valuable insights into the sector and collected data in unprecedented detail. But there is still more to do understand the patterns of electricity use in different types of businesses and what this means for DSR potential.
Finding out what works for different SMEs	For SMEs there is no 'one size fits all' approach to realising flexibility and there are many real and perceived barriers, which need to be carefully worked through. In future, it might be helpful to start with interviews/focus groups/workshops to understand what different SME

	customers want, what constraints they have and where they might have flexibility. DSR offerings can then be tailored for different types of SME, taking into account their particular needs and business critical activities.
Developing a holistic package	As SME's expressed significant interest in energy efficiency measures and low carbon technologies, it might be helpful to develop more holistic packages or a suite of options for SMEs, which wrap DSR in with wider energy service offerings.
Providing information and advice	There was significant appetite amongst SMEs for clear, accessible information and advice on energy efficiency, low carbon technologies and DSR. For example, from the detailed monitoring trials it would be of great value to customers, to get a report back on their disaggregated electricity use, along with advice on where they could reduce or shift load.

10. Conclusions – critical issues for a smart future

Need to train engineers of the future	It will be critical to ensure that engineers are trained with the right skills to deploy smart technologies. For example: smart meter engineers might need to give advice on smart appliances and connect them to a Consumer Access Device (CAD); electrical engineers & appliance installers would need to be able to carry out the end-to-end appliance/connectivity installation.
Smart kit must be designed for people and their properties	In order to achieve wide take-up of LCT and smart kit, the technologies will need to be attractive to customers and suitable for their properties. Some current technologies, such as some models of heat pump and micro-CHP, are difficult to retrofit in homes and need further innovation to make them more user-friendly and compact.
Design easy and attractive offers for demand response	It is a hassle for householders and businesses to shift long-established electricity using practices off-peak. Therefore, it needs to be as simple as possible to make the changes, potentially with new smarter kit, and with incentives that outweigh the costs. Demand-response could be bundled with other energy services, which empower customers to manage their energy use and generation more effectively.
Connectivity is critical	Connectivity is a crucial consideration for the future rollout of smart appliances in customers' homes. However not all homes have broadband. This needs to be taken into account in the design of low carbon and smart technologies, making sure that alternative GSM solutions are ready to deploy for customers without broadband.
Technical coordination is needed to develop end-to-end solutions	In future, it will be possible to develop end-to-end solutions rather than having to 'bolt together' appliances, repeaters, hubs, communications etc. This will require greater technical coordination between suppliers and appliance manufacturers on tariffs/smart meters/Consumer Access Devices and smart/connected home technology.

Appendix A – installation figures

Table 1: Equipment installed in CLNR residential trial

		Home Hub	**ICM 300**	**Smart meter & in home-display**	**Secondary meter** *For non-BG customers*	**Mains isolation switch**	**MicroWatt polymeter** *For TC2a / when no isolation switch*	**Smart plug(s)**	**In-line monitor on:**	**Temp sensor for:**	**Low carbon technology / appliance**
Test Cell	*Installed by:*	*Passiv-Systems*	*Passiv-Systems*	*British Gas*	*Passiv-Systems*	*Supplier/meter operator*	*PassivSystems*	*Passiv-Systems*	*PassivSystems*	*PassivSystems*	*British Gas unless stated*
1a	Baseline monitoring smart meter customers	✕		✓							
2a	Enhanced monitoring smart meter customers	✓					✓	✓			
2a HW	Enhanced monitoring smart meter customers with electrically heated hot water on a restricted hours tariff	✓	✓		✓	✓	✓		- Immersion heater - Boost facility - Radiator	- Hot water	
2a SH	Enhanced profiling of domestic smart meter customers (electrically heated hot water and storage heaters on a restricted hours tariff)	✓	✓		✓	✓	✓		- Immersion heater - Boost facility - Radiator	- Hot water - Room temp - Radiator temp	
3	Enhanced profiling of domestic customers with air source heat pumps (ASHP)	✓	✓	✓	✓	✓	✓		- ASHP	- Room temp	- ASHP (social housing provider install)
4	Enhanced profiling of domestic customers with micro-combined heat and power (micro-CHP)	✓	✓		✓	✓	✓		- micro-CHP		- Baxi Ecogen micro-CHP unit
5	Enhanced profiling of domestic customers with solar photovoltaic (PV)	✓	✓		✓	✓	✓		- PV		
6	Enhanced profiling of domestic customers with electric vehicles (EV)	✓	✓		✓	✓	✓		- EV charge point		
9a	Domestic smart meter customers on time of use tariffs	✕		✓							
10a	Domestic customers on the smart washing machine restricted hours trial	✓	✓	✓				✓		✓	- Hotpoint AQUALTIS Smart Washing Machine
11a	Domestic customers on the smart washing machine direct control trial	✓	✓	✓				✓		✓	
12	Domestic customers with air source heat pumps on time of use tariffs	✓	✓	✓					- ASHP		- ASHP
14	Domestic customers with air source heat pumps on direct control trials	✓	✓		✓	✓	✓		- ASHP	- Hot water - Room temp	- Smart ASHP with thermal store
20 IHD	Domestic solar PV customers using in-home displays for manual in-premises balancing	✓	✓		✓	✓	✓		- PV		- In-home display of use/export
20 Auto	Domestic solar PV customers with automatic in-premises balancing for hot water charging	✓	✓								- Cool Power 'EMMA' system (install. by Solar & Wind Applications)

Appendix B – SME site visit checklist

Stage 1: Introductions, following questions

- Has the welcome pack been received
- The reason for the project and its aims and goals
- Has Smart meter been installed
- Ask for an overview of site processes and description of business
- Opening hours
- Number of staff
- How at present they use their electrical equipment and what energy conservation measures they take at present
- Check H&S documentation i.e. Asbestos register, NICEIC certificates for electrical installations, areas of dust pollution, chemicals held on site, ear defender areas, HV equipment, clean rooms, restricted access
- Any areas of a sensitive nature, such as server rooms, livestock, if hotel any rooms occupied
- Explain test cell type that the client has signed up to
- Cell 2 purely monitoring no disruption even at install stage
- Cell 10/11 explain how interruption is initiated and time scale i.e. 4 hours between 16.00 to 20.00, if this is not acceptable ask what time/length would be acceptable to the business
- If no movement offer Cell 2

Stage 2: Survey

- Check meter and record meter ID and Mpan (photograph)
- Check Local Authority supply cut outs clamp test tails and record (photograph)
- Check equipotential bonding is in place and adequate
- Ask to be taken to Distribution Boards (DB) and photograph
- Identify circuits to be monitored i.e. Air Conditioning, plant equipment, process equipment, water heaters ring mains, lighting
- Record DB identification, manufacturer and location
- Identify circuits to be monitored, type of equipment as above, Circuit identification, single or three phase, size of mcb rating and type and clamp test circuit for load current, record on survey sheet
- Ascertain state of installation during survey
- Note any areas of chemical storage, environment i.e. dust, noise not mentioned on the initial introduction
- If farm note animal pens and feed water supplies
- Check for and record spare ways in DB's mcb type if three or single phase spare way

Stage 3: Concluding conversation

- Confirm if client is in Cell 10 or 11 that there is no movement of timescale for interruption due to process type of business
- Discuss churning into Cell 2, if needs be, and discuss fully needs and requirements of Cell 2
- Get representative to sign survey form to accept change of Cell type
- Thank Client for his time and explain he will be contacted regarding Cell change and informed if possible
- Leave site and e-mail all documentation and photographs to project team

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