# Customer-Led Network Revolution

DEVELOPING THE SMARTER GRID:

# The role of domestic and small and medium enterprise customers

LCN Fund
Low Carbon Networks

NORTHERN POWERGRID

British Gas
Looking after your world

Durham University

Newcastle University

ea technology

# Leading the way to a low carbon world

## The Customer-Led Network Revolution

The Customer-Led Network Revolution project, funded via the Low Carbon Networks Fund, was a smart grid project led by Northern Powergrid in partnership with British Gas, Durham University, Newcastle University and EA Technology.

It was designed to test a range of customer-side solutions (innovative tariffs and load control incentives) alone and in combination with network-side technology (including voltage control, real-time thermal rating and storage). The project was designed to deliver robust learning that would be applicable to a high percentage of GB networks and demographic groups.

More than 13,000 domestic, SME, industrial and commercial and merchant generator customers took part in the project, which involved trialling innovative smart grid solutions on the Northern Powergrid's electricity network and trialling novel commercial arrangements to encourage customer flexibility.

Learning from the project will help distribution network operators (DNOs) find cost-effective ways to manage the introduction of low carbon technologies 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. The project tested the flexibility in the ways customers generate and use electricity and how DNOs can find ways to reduce customers' energy costs and carbon footprint in the years to come.

The project was designed to predict future loading patterns as the country moves towards a low carbon future and to research novel network and commercial tools and techniques and to establish how they can be integrated to accommodate the growth of low carbon technologies in the most efficient manner. The project trialled new network monitoring techniques to measure power flow, voltage and harmonics, trialling alternative smarter solutions that employ active network management and customer engagement to increase network capacity and/or modify load patterns and it developed new planning and design decision support tools for engineers.

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# 1. EXECUTIVE SUMMARY

**The UK Government's three energy policy objectives (security of supply, affordability and addressing climate change) all impact on the electricity system. As electricity generation becomes lower carbon, the Government's energy scenarios suggest that more electricity will be generated from less flexible sources such as nuclear and renewable sources that are intermittent such as wind.**

The decarbonisation of transport could lead to an increase in the use of electric vehicles and reducing the use of fossil fuels for heating may well see an increase in the use of heat pumps in homes and businesses, both of which could result in load growth on electricity distribution networks. There will be an increasing number of distributed generators connected to the distribution network including at the domestic level. Customers will be encouraged to participate in demand side response (DSR) using their own demand, local storage and/or generation.

Learning from the project will help DNOs find cost-effective 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.

The project explored the flexibility in the ways customers use and generate electricity and how DNOs can find ways to reduce customers' energy costs and carbon footprint in the years to come. It therefore tested demand side response (DSR) through a range of customer-side innovations (innovative tariffs and load control incentives) alone and in combination with network-side technology (including voltage control, real-time thermal rating and energy storage). The project was designed to deliver robust learning that would be applicable to a high percentage of GB networks and demographic groups. More than 13,000 domestic, SME and industrial and commercial customers and merchant generators took part in the project.

The project was also designed to investigate future loading patterns as the country moves towards a low carbon future and to research novel network and commercial tools and techniques and to establish how they can be integrated to accommodate the growth of LCTs in the most efficient manner. The project trialled new network monitoring techniques to measure power flow, voltage and harmonics, trialling alternative smarter solutions that employ active network management and customer engagement to increase network capacity and/or modify load patterns and it developed new planning and design decision support tools for engineers.

This report presents the findings from the part of the project that explored the load and generation characteristics and flexibility of domestic and SME customers. Two other reports deal with larger customers[1] and the network-related elements of the project[2]. The project was designed to deliver a specific set of five learning outcomes, and this report addresses the first two.

**1. Understanding of current, emerging and possible future customer (load and generation) characteristics**

This part of the trial involved monitoring the electricity consumption and generation profiles of around 13,000 domestic and SME customers, both those with and those without LCTs (heat pumps, photovoltaics, micro-CHP, electric vehicles). For smaller selected sub-groups this also included enhanced monitoring of selected individual appliance usage at 10-minute intervals in addition to half hourly metering. This is the largest sample of customers' electricity usage to have been undertaken in the UK and Ireland to date. The size of the sample, when compared with previous projects monitoring customer electricity use, has generally ensured a statistically robust set of conclusions and greatly improved the rigour and breadth of our understanding.

In addition to quantitative monitoring of electricity usage, two methodologies were used to help understand the social dimensions of the CLNR trial, surveys and qualitative face-to-face research visits. These methods were used in conjunction with the analysis of energy consumption data to provide insights into how and why energy use takes particular patterns for groups and individuals.

The qualitative surveys and interviews supported the applicability of the CCRES model of energy use (conventions, capacities, rhythms, economies, structures), in which each element works together to shape how energy is used. This approach, with its emphasis on practices rather than energy behaviour, is still not widely understood by energy practitioners and policy makers, who continue to focus on energy use and thereby miss a crucial link in understanding domestic energy-using behaviour and how to influence it.

**2. To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?**

This part of the trial aimed to assess the effectiveness of different kinds of demand side intervention in encouraging those taking part to change the pattern of their electricity usage. These interventions included combinations of electricity tariffs, in home displays and automation. This type of time of use (ToU) tariff had not previously been trialled in the UK. The smart washing machine and smart heat pump trials were a first in the UK, as were the automatic and manual within-premises balancing of PV load. Despite the difficulties arising from the technology tested and the data collection, the smart technology trials have provided valuable case study findings and indicated areas for further research.

Information on each of the various test cells which comprise the customer trials are set out in the table to follow, including key findings and implications for networks and the wider energy industry and policymakers.

**Learning outcome 1: Understanding of current, emerging and possible future customer (load and generation) characteristics**

| Ref | Description | Summary findings |
|---|---|---|
| TC1a | Basic profiling of domestic smart meter customers without LCTs or interventions | • Around 9,000 domestic customers from a wide range of socio-demographic backgrounds took part in this baseline trial[3]<br><br>• DNOs need reliable information about domestic consumer load profiles for system planning. The current ACE49 standards are based on data which is over 30 years old. These findings have been used to propose possible revisions to ACE49[4]<br><br>• The link between electricity use and income merits further investigation, as does the link with domestic energy efficiency. It could have implications for network planning if it implied a need for a higher after diversity maximum demand (ADMD) in more prosperous geographical areas<br><br>• Since maximum peak demand is well correlated with annual consumption, applying network charges on a per unit basis (as at present) is a good proxy for the burden placed on the network by a domestic customer<br><br>• The research supports the need to concentrate on energy practices rather than attitudes or demographics and this should help DNOs frame the way they should invite customers to participate in demand side measures |
| TC2a<br><br>TC2a HW<br><br>TC2a HW + SH | Enhanced profiling of domestic smart meter customers | • We carried out monitoring of individual loads within the household at 10-minute intervals[5]<br><br>**Without LCTs (TC2a)**<br><br>• Of the appliances monitored, washing machines and dishwashers offer the greatest flexibility in terms of time of use and our surveys suggest customers are prepared to be flexible<br><br>• Few of the households studied had direct electrical heating and electrical water heating but these loads would merit further investigation into their potential for demand side response as would the half of electricity consumption that was unattributed. The findings suggest that other options worth exploring include efficiency of primary and secondary lighting, and upgrading gas boilers to reduce the need for direct electrical heating<br><br>• The conclusion from the social science research that energy practices are important in understanding energy behaviour emphasises the need to gain a good understanding of their use of particular appliances if customers' behaviour is to be influenced. This will need closer interactions between DNOs, suppliers and appliance manufacturers<br><br>**With electric hot water immersion heating (TC2aHW) or with electric hot water immersion heating and storage heating (TC2aHW+SH)**<br><br>• Customers were on either an Economy 7 or an Economy 10 tariff and the average power consumption profiles broadly matched the profile of an Economy 7 or Economy 10 tariff, consistent with customers on these tariffs responding to the price incentives they provide<br><br>• However, there were two exceptions. The average data for immersion heaters alone showed a peak at 8am both on weekdays and at weekends, which may reflect a customer routine or an appliance setting. Also, for households with both an immersion heater and storage heaters, there was some power usage immediately after the morning off-peak periods. It may be that this is the result of misconfigured appliances or meters<br><br>• Storage heater use on all days was confined to the off-peak periods, probably reflecting appliance and/or meter settings<br><br>• Storage heaters combined with Economy 7/10 tariffs continues to be an effective means of reducing demand at peak times |

| Ref | Description | Summary findings |
| --- | --- | --- |
| TC3 | **Enhanced profiling of domestic customers with air source heat pumps[6] (ASHP)** | • Our research provides insights into the practical details of installation and use, and reveals the number of different actors and diverse interests that need to come together to make heat pumps work in the context of the complexity of relations between tenants, social housing landlords, suppliers, installers and electricity providers<br><br>• There is a clear need for user-side intermediaries–to bring together the social and the technical aspects, suggesting a role for different forms of intermediaries: whether to provide user-side support to recruit occupants to new practices, installer training on engaging with users, and chain of support from manufacturers<br><br>• Heat pump consumption profiles during the colder seasons showed distinct morning (6am – 9am) and evening (4pm – 8pm) peak demands. In addition to the morning and evening peak period, the heat pumps in this trial show a distinct peak in consumption around 3am due to default timer settings for hot water heating<br><br>• The 3am spike is clearly a product-specific occurrence with heat pumps programmed to come on at that time, but provides an important message for manufacturers, regulators and legislators that it would be better to build diversity into the appliances e.g. by randomising the defrost time between 2am and 4am<br><br>• As a heat pump load represents a near doubling of total household consumption, widespread rollout of the technology would present significant challenges to electricity systems. Technology solutions such as hybrid heat pumps or heat storage could reduce the impact, but future research is needed to understand technical feasibility, environmental performance and consumer acceptance. In the case of widespread heat pump deployment, steps may need to be taken to introduce diversity into heat pump operation, in particular the morning pick-up in demand |
| TC4 | **Enhanced profiling of domestic customers with micro-CHP[7]** | • The generation profile had a high morning peak, and a lower, but longer evening peak, with the summer peaks being lower than the winter ones. The micro-CHP also generated electricity for export in the winter mornings, as heat demand drives micro-CHP export before morning electricity demand starts to rise<br><br>• The main effect of the use of the micro-CHP units was to reduce the evening electricity demand peak by a few hundred watts in winter<br><br>• If micro-CHP plants become popular, the reduction in household load at peak could be significant for both network planning and electricity generation costs. The morning export peak could also impact on voltage levels. There would be benefit in a wider trial to establish more robust conclusions |
| TC5 | **Enhanced profiling of domestic customers with solar PV[8]** | • Households with PV have higher peak electricity demand and higher overall levels of annual total electricity consumption than those without PV. PV households also tend to use more electricity during daylight hours<br><br>• Householders with PV are more engaged in monitoring, assessing and manipulating their electricity consumption than those without PV. Despite the householders keenness to use their domestically generated electricity, substantial exports took place with a peak around midday with the potential to create voltage issues for networks<br><br>• Although PV generation does not appear to pose a risk to network capacity at the individual customer level as the peak export observed lies within the network design tolerance and is comparable to peak demand, widespread deployment of PV may pose challenges to the network in the future<br><br>• Our study on the diversity impact of PV concluded that the output of solar photovoltaic installations does diversify, because the panels point in different directions and therefore produce their peak output at different times of day. Because of this diversity, our new default planning assumption is to apply a 10% discount to the previous industry standard of assuming full output |

| Ref | Description | Summary findings |
| --- | --- | --- |
| TC6 | **Enhanced profiling of domestic customers with electric vehicles (EVs)[9]** | • Charging is very much concentrated in the evening, coinciding with the household peak. Weekend charging is lower than weekdays, correlating with the conventional weekday work pattern of the household and the predominant use the EV as a weekday car. These findings suggest that the EV drivers rarely change their daily/weekly commuting routines<br><br>• Average peak charger demand on a weekday was around 0.9 kW in January compared with less than 0.4 kW in June, probably reflecting the extra charging associated with car heating and lighting. Similarly, the average daily energy consumption for an EV was 7.9 kWh in the peak month of January 2014 and steadily reduced down to 5.2 kWh by June 2014<br><br>• At-home charging diversifies rapidly across households: i.e. the days and precise times at which participants charged their cars varied considerably, although this diversity could well be lower at particular times, e.g. pre-charging before bank holiday weekend<br><br>• From the peak demand perspective, the EVs present a fairly inflexible yet predictable load. All of the charging curves show evening peaks, which shows that people are probably coming in from work and putting the car on charge. Hence, the biggest issue we identified is the lack of diversity and flexibility in EV charging times<br><br>• Domestic charging of EVs has raised the level of domestic peak demand but is not yet a problem for network system design and operation. With greater concentration or if there were two EVs at a household, this would no longer be true<br><br>• EV users are already establishing habits to charge their car when it suits them and this may be difficult to break even with appropriate ToU tariffs. There is therefore a strong case for taking appropriate action to encourage off-peak charging behaviour at an early stage. Further work is needed to investigate ways of doing this<br><br>• Our work on domestic charging habits in rural and urban locations, and their different impacts on the distribution network, suggests that the impact on the network would be felt first in rural locations[10]<br><br>• Several factors seem to be the key to enable a large-scale adoption of the EV technology. One of the obvious factors is the initial investment people have to make when purchasing the car. Making the technology affordable and reliable and the development of a new battery technology such as replaceable batteries and/or charging infrastructure are the basic assumptions. The successful adoption of EV technology would also include the development of services associated with having and driving the electric car. Those include car insurance, maintenance, driving schools, and in general, training how to use and maintain the EV vehicle |
| TC1b | **Basic profiling of small and medium sized enterprise (SME) customers** | • SME consumption per customer 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<br><br>• The demand profiles of individual SMEs also vary to a much greater extent than households. They are heterogeneous in terms of their business activities, and hence also in terms of their overall demand for power and the timing of that demand during the day<br><br>• Because of the considerable variability in the SME community, the overall results themselves do not have implications for network planning or operation, but do provide an important baseline<br><br>• The fact that most SMEs do not contribute significantly to the evening peak is important. There could be value in targeting those that do have an evening peak<br><br>• Smaller businesses tend to consume a higher proportion of their total electricity in the early evening peak period and have limited consumption overnight, such as those in leisure, and hospitality industries. Larger businesses consume electricity more evenly across a 24-hour period, but may have larger total consumption and power demand per hour during the peak. This suggests that in terms of DSR, larger businesses may offer more potential to be flexible by shifting demand to other times of day/night whereas smaller businesses may have relatively fixed electricity demand in the peak period<br><br>• The proportion of total electricity consumption concentrated in the evening peak varies by sector with industrial businesses tending to consume a lower proportion of electricity in this period throughout the year while businesses in the agriculture, hunting and forestry, fishing sectors consume the most |

6 CLNR-L248: Developing the smarter grid: optimal solutions for smarter network businesses
7 CLNR-L086: Report on enhanced profiling of domestic customers with micro-CHP
8 CLNR-L090: Insight report-Domestic solar PV customers and CLNR-L244: High level summary of learning-Solar PV customers
9 CLNR-L092: Insight report - Electric vehicles and CLNR-L254: High level summary of learning - Electric vehicle users
10 CLNR-L038: Integrating smart meter and electric vehicle charging data to predict distribution network impacts

| Ref | Description | Summary findings |
|---|---|---|
| TC2b | **Enhanced profiling of small and medium sized enterprise (SME) customers[11]** | • Our findings about SMEs are important because this is an area which has been little studied in the past and where data is limited. The results provided valuable new information about detailed SME activities<br><br>• Some activities, such as lighting, are less susceptible to demand-side management, although lighting load could be reduced significantly through timers, motion sensors and energy efficient lighting such as LEDs. Other loads, such as chillers, have the capability of being moved from peak time if business priorities permit<br><br>• There is also scope for better energy management, for instance setting timers to begin operation after the peak period<br><br>• The potential for SMEs to provide valuable demand flexibility centres on both the scheduling and the interruptibility of practices; some processes are interruptible and others cannot be stopped once underway. Interruptible practices could respond at short or no notice to a network intervention whereas re-schedulable ones can be moved in time in advance and possibly on a regular basis if such interventions can be planned in advance |



**Learning outcome 2: To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?**

| Ref | Description | Summary findings |
|---|---|---|
| Domestic time of use tariff | | • The peak ToU rate was 99% higher, the day rate 4% lower and the off-peak rate 31% lower than British Gas' standard flat rate tariff at that time. The vast majority felt the tariff was quite or very easy to understand |
| TC9a | **Domestic smart meter customers on time of use tariffs[12] (ToU)** | • Compared to smart meter customers without the ToU tariff, the average peak power demand during the 4-8 pm period (i.e. the average across the year for each customer of the highest half-hour demand each day within this time period) was lower on average, by 96 W or 8% (from 1.219 kW to 1.123 kW). The difference in average peak power demand was statistically significant for the 2012/13 winter period in the trial<br><br>• The ToU tariff rewarded a reduction in consumption during the peak period throughout the year - and was effective in doing so - but did not reduce demand at the times of greatest system peak demand. Alternative ToU tariffs, such as Critical Peak Pricing, might be tried as a way of reducing demand during these times<br><br>• Compared to smart meter customers without the ToU tariff, annual energy consumption during the peak period was lower by 55 kWh or 6% (from 861.6 kWh to 806.6 kWh), with the difference focused on weekdays<br><br>• There was no statistically significant difference in total annual electricity consumption (on average, about 3,500 kWh) between the ToU customers and trial participants with a smart meter alone<br><br>• The majority of those on a ToU who were surveyed said they changed the timing of appliance use in response to the ToU tariff, and most considered that they used less energy overall while on the ToU tariff. Laundry was identified by most respondents as an activity that had been displaced to a different time, followed by washing dishes and cooking<br><br>• Participants in this trial were told that they were protected from an increase in electricity bills, which were capped at the level they would have been at under a flat-rate tariff. An enhanced level of response might be expected in a trial without a 'safety net'<br><br>• Identifying traditional socio-demographic groups for commercial propositions may not be appropriate. Instead, it may be most appropriate to focus on 'socio-technical' groups (e.g. customers with high income, large houses, and 2+ fridges) or different kinds of 'flexibility capital' (e.g. shift workers, those with dishwashers that can be programmed)<br><br>• The difference in peak demand seen in this trial is unlikely to be significant enough to be used only as a means of avoiding reinforcement of the network. However, static ToU could be used as part of a solution or could help if introduced imposed by energy suppliers such that different sources of value may be combined for customers |
| TC12 | **Domestic customers with air source heat pump on time of use tariffs** | • The electricity supply to the heat pump was automatically switched into a low output mode for periods of between 30-minutes and two hours in the peak hours during the trial period, in order to optimise the operation of the smart heat pump in line with the time of use tariff<br><br>• The heat pump was set to build up a store of heat for up to two hours prior to the peak period to ensure the customer always had a supply of hot water through the tariff's peak hours<br><br>• Should the customer want to override the low output mode of their heat pump, they could easily do this by using the control provided with the heat pump<br><br>• The proportion of electricity consumption during peak times was 21%, which is similar to that for customers with heat pumps and direct control. Compared to this other group, the elevated consumption in the evening peak was lower. We also observed a peak in demand at 4am peak in the same way that we observed a 3am peak in heat pump demand in test cell 3 was attributed to pre-set programming |

| Ref | Description | Summary findings |
|---|---|---|
| TC10a | **Domestic customers on the smart washing machine restricted hours trial** | • This combined the ToU tariff with an automated service that used smart-enabled, automatic interactive scheduling for smart washing machines with customers able to override this automated service when they wished<br><br>• The trial tested customers' willingness to accept a default time-based restriction on the use of a specific appliance, and the degree to which they exercised the over-ride facility<br><br>• For those who had engaged the 'energy control', the trial successfully reduced load during the peak period. The peak that occurred following the end of the peak period could be reduced by the manufacturers including a randomisation element<br><br>• The level of engagement was low. If energy control buttons on washing machines become more prevalent, finding ways to encourage engagement could prove valuable in reducing peak load |
| **Direct control[13]** | | • These trials tested customers' willingness to have the time of use of a specific appliance directly controlled by the customers' electricity supplier, in response to a distributor's need<br><br>• The terms of the trial allowed the operation of these appliances to be delayed or turned down through external dynamic signals. Limitations were placed on the frequency, timing and duration of interventions and customers could override without penalty<br><br>• These signals were initiated from Northern Powergrid's network control centre and passed to the smart device via British Gas' demand management platform |
| TC11a | **Domestic customers on the smart washing machine direct control trial** | • This trial is unique and ground-breaking. It has demonstrated the end-to-end process of a DNO successfully calling a response from a DSR supplier automatically using 'smart grid' systems and that direct control of appliances can reduce peak load<br><br>• The potential of direct control to reduce peak load is limited at present, partly due to the relative infrequency with which most households use a washing machine compared to other appliances such as heating<br><br>• The technology is new and will improve. The small reduction in peak means that this intervention is unlikely to have much impact on distribution network planning. However, if the technology becomes more widespread (and particularly if mandated by product standards), this intervention could be of use for national system balancing |
| TC14 | **Domestic customers with air source heat pumps on direct control trials** | • On receiving a signal the electricity supply to the trial participant's heat pump was automatically switched into a low output mode for 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 an interruption<br><br>• The existence of peak loads in the morning and early evening on non-intervention days and the peak immediately following an intervention suggests a particular characteristic of the type of air source heat pump (ASHP) with thermal storage used. This characteristic, together with the mixed attitude of customers and the additional space requirement for the thermal store, limits the potential benefit of this intervention at present<br><br>• Nevertheless, the trial has been ground-breaking, using innovative equipment, and clearly demonstrates the technical potential for this intervention. The size of the peak reduction makes it of interest to a DNO, but the use of the intervention will depend on what cost the DNO would have to bear, and whether the large payback spikes can be mitigated |
| **Within premises balancing** | | • Customers attempted a degree of balancing to avoid exporting surplus electricity. We trialled balancing by both manual and automatic means, with customers increasing electricity consumption within the premises in line with generation by, for example, heating water<br><br>• PV households have a strong tendency to shift chores such as washing and drying clothes or using dishwashers according to levels of PV generation. From our survey results, respondents reported small changes to timing of shower practices, but were more motivated to switch appliance use times than by hot water usage<br><br>• In-home display units are a welcome addition to PV households enabling even greater degrees of flexibility<br><br>• We find that such interventions are creating new ideas of what 'good' and 'valuable' forms of solar generation and use might involve. This provides a potentially valuable resource for network operators. Even though the effects on overall power demand are likely to be low, developing ways in which consumers come to use their own electricity could provide network benefits by reducing the risks of voltage imbalance and steady state voltage rise especially in areas where PV arrays are clustered on particular distribution networks |

| Ref | Description | Summary findings |
|---|---|---|
| TC20 IHD | **Domestic solar PV customers using in-home displays for manual in-premises balancing** | • This trial used an in-home display (IHD) to provide a visual cue that net exporting was occurring, so customers had an opportunity for load-balancing<br><br>• Average annual gross electricity consumption was 1,170 kWh higher (4,675 kWh as against 3,507 kWh) than for trial participants with a smart meter but without PV, and was significantly higher in nearly every month, but less so at weekends. A higher proportion of electricity consumption (30%) was between 10am and 4pm, compared to 27% for those without PV<br><br>• Average and maximum peak demand was higher (1.6kW and 4.9kW as against 1.2kW and 4.2kW, respectively) than for trial participants with a smart meter but without PV, with the difference focused more in the summer months<br><br>• Since we did not have demand data for customers before the balancing trial began, we cannot say how much they managed their demand, just how their demand compared to that of PV customers not participating in the balancing trial. We found no significant difference in any of these consumption and peak demand variables between trial participants with PV and manual in-premises balancing and those with PV alone<br><br>• In the survey and interviews, participants said that, through the use of the IHD's traffic light display, they had made shifts in laundry and dishwashing. However, on the basis of the monitoring data, manual in-premises balancing would be unlikely to make a significant contribution to DSR |
| TC20 Auto | **Domestic solar PV customers with automatic in-premises balancing for hot water charging** | • This trial used hot water heating engaged automatically, i.e. without user intervention, as a form of balancing<br><br>• From our survey results, respondents reported small changes to timing of shower practices, but were more motivated to switch appliance use times than by hot water usage<br><br>• Average annual gross electricity consumption was 5352 kWh (14.5% higher than in TC20IHD). Average annual PV generation in TC20Auto was 4.9% higher than in TC20IHD (2019kWh compared with 1925kWh for TC20IHD)<br><br>• Energy export in 20Auto was about half that of 20IHD (209kWh as against 413kWh). While this might suggest that the automatic balancing is more effective at managing export, it should be noted that the significantly higher average annual consumption in 20Auto could equally explain the reduction in energy export |
| **Interventions with SME customers; ToU, restricted hours and direct control** | | • We approached over 20,000 SMEs about participating in our ToU, restricted hours and direct control trials. We recruited customers and undertook time consuming technical site surveys with a significant number. Whilst we found a high level of interest in the concept of demand-side management, there were a number of factors with SME customers that severely limited the number of customers who ultimately took part in the trials |
| TC9b | **SME smart meter customers on time of use tariffs** | • Although few conclusions on the impact of ToU tariffs on SMEs can be drawn from this trial, there is clearly interest from SMEs in ToU tariffs and so further work would be useful. However, it demonstrates the need, because of the heterogeneity of the SME community, to conduct monitoring both with and without the ToU tariff for the same SME types |
| TC10b | **SME customers with restricted hours tariff and customer override** | • Survey results indicated that broadly the needs of the business meant that the uncertainty introduced by potential interruptions was unacceptable<br><br>• Despite this we conducted a trial of the restricted hours trial with one customer, demonstrating that the restricted hours DSR can be successful in reducing load during the peak window. This potentially is of use to both suppliers and DNOs. The difficulty remains in recruiting suitable SMEs and meeting their concerns about being able to continue operating their mainstream business despite the intervention |

[13] CLNR-L096: Insight report - Domestic direct control trials

## CONCLUSIONS

The basic and enhanced monitoring of customers with smart meters has provided valuable up-to-date information about domestic consumer load profiles and their make-up. Washing machines and dishwashers offer the greatest flexibility in terms of time of use and our surveys suggest customers are prepared to be flexible. However, there is limited use of these appliances during weekday peak times, and so customers without LCTs may have limited ability to move load out of the peak period.

- Enhanced monitoring of LCTs provided important new information that will assist system planning as increased numbers of LCTs are introduced

- Only domestic charging of EVs could have a major impact on the network, but this will depend on the speed and extent to which EVs are introduced

- Whilst this is not yet a problem for network system design and operation, there is a strong case for taking appropriate action to encourage off-peak charging behaviour from the outset

For a DNO, what is needed in terms of customer flexibility is a reduction in peak load at times of particular network stress, for example at network peak or after a power cut. All of the domestic interventions tested were successfully demonstrated, but, on the basis of our findings and with the tariffs and costs we used, none of them appear likely, in isolation, to be cost effective if they were to be used only as a means of meeting DNO needs to avoid reinforcement.

Diversity is a factor in network planning so understanding when a network is going from having a 'diverse' to a more uniform customer base might be important in terms of where different measures might be implemented. Examples include the emergence of clusters of electric vehicles or heat pumps on the network, or particular interventions in the urban environment

(e.g. a new major business with particular shift patterns), or an ageing population.

By reducing the amount of electricity consumed during the peak period, ToU tariffs could be of benefit to a supplier. Electricity suppliers have different needs in relation to demand side response from DNOs. They might be interested in reducing electricity consumption at times when generating costs are high and they can aggregate the responses achieved over a wide geographical area. By reducing the amount of electricity consumed during the peak period, the ToU trial has the potential to reduce generation costs. An enhanced level of response might be expected in a trial without a 'safety net'.

ToU tariffs could therefore be useful to DNOs as part of a solution or would help if introduced by another player such as an energy supplier[14]. Alternatively, more sophisticated tariffs might have a direct impact, but this would need further testing.

In seeking a pricing structure to optimise the desired response and attractiveness to customers, due consideration should be given to our findings that customers' behaviour is affected by much more than pricing, being influenced by a range of socio-technical factors. When considering customer recruitment and targeting for roll-out of similar initiatives, there is interest in knowing which customers might engage most readily, but those with most load capacity and potential flexibility tend to be those on highest incomes who might be 'hard to reach' through the usual mechanisms of information and incentives.

Smart washing machines are effective technically, but the level of engagement and the low amount of peak activity mean that the impact on the peak is low. Smart heat pumps can reduce peak load, but have relatively limited feasibility to fit into existing properties and problems of customer acceptability. The project has shown that some smart appliances clearly work from a technical

point of view and can deliver reductions in consumption at peak times. The technology will continue to improve. There remain problems with noise and space availability for smart ASHPs with thermal store.

In the future these smart devices may be more effective as part of a smart connected home, where multiple appliances run on a common platform, configured to respond to either a tariff or control signal. Refrigeration scrappage schemes could also help by improving the overall efficiency of home refrigeration. Without comparative data on customers demand before introducing in-house balancing, we do not have sufficient evidence to indicate whether PV with in-house balancing, whether manual or automatic, has the potential to make a significant contribution to demand management. Further studies could provide some insight on this point.

In summary, the acceptability and interest shown by domestic trial participants in smart meters is encouraging on the eve of the national mass roll-out programme. The industry needs to work together to introduce arrangements that enable the benefits to be captured while also establishing a platform for other forms of smart controllable loads that, while not identified here as being valuable right now, may then be added in the future as the technology matures.

> " Only domestic charging of EVs could have a major impact on the network, but this will depend on the speed and extent to which EVs are introduced. Whilst this is not yet a problem for network system design and operation, there is a strong case for taking appropriate action to encourage off-peak charging behaviour from the outset.

[14] Further insight into future commercial arrangements can be found in CLNR-L145: Commercial Arrangements Study – Phase 2

# 2. INTRODUCTION

## 2.1. Purpose and scope of this report

The purpose of this report is to disseminate the learning from the Customer-Led Network Revolution (CLNR) project with respect to domestic and SME customers, and specifically to the questions:

- What are the current, emerging and possible future customer load and generation characteristics?

- To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?

The CLNR project, funded via the Low Carbon Networks Fund, was a smart grid project led by Northern Powergrid in partnership with British Gas, Durham University, Newcastle University and EA Technology. This is one of three reports providing an overview of the project and its findings. The other two deal with larger customers[15] and network-related[16] aspects of the project.

## 2.2. Background information; the issues, legislation and initiatives

The UK Government has set some ambitious goals for reducing the amount of greenhouse gases that we as a country emit into the atmosphere. The achievement of these goals will require a dramatic change in how electricity is produced and used, which will have a profound effect on the way that electricity distribution networks are operated in the future.

In summary there are three broad UK government policy objectives[17] that will impact the electricity system:

- **Carbon reduction targets:** The achievement of 2020 and 2050 carbon reduction targets[18] is likely to require the almost complete decarbonisation of the electricity sector

- **Energy security:** There is a need to ensure secure and sustainable energy supplies as the power system decarbonises and electricity demand changes

- **Affordability:** This will have to be achieved while ensuring that networks continue to deliver long term value to existing and future customers

The impact of these policy objectives upon the electricity system will be:

- **Integration of inflexible and intermittent generation:** As the GB national generation infrastructure is renewed, more electricity will be generated from less flexible sources such as nuclear and renewable sources that are intermittent e.g. wind

- **Electrification of transport and heating:** The decarbonisation of transport will lead to an increase in the use of electric vehicles. Reducing the use of fossil fuels for heating will see an increase in the use of heat pumps in homes and businesses, both of which will result in load growth on the electricity distribution networks

- **Integration and optimisation of Distributed Energy Resources:** There will be an increasing number of distributed generators connected to the distribution network as opposed to the transmission network, including at the domestic level. In some cases this generation will be dispatchable by the transmission system operator whilst the remainder will be of a size that the customer will decide when they operate. Customers will be encouraged to participate in demand side response using their own demand, local storage and/or generation

Although a lot of these changes to the electricity system will be at the demand and generation ends, the network that connects these together will have to be strong yet flexible. Distribution networks will have to be operated to respond to power flows that are more complex and less predictable.

This will involve making effective and efficient decisions about how the network is designed and operated to minimise the impact on customers' bills while maintaining high levels of network reliability. This requires all distribution network operators (DNOs) to find the best deal for customers in the long term by seeking out and deploying novel solutions when economic, avoiding too much investment ahead of need but being ready for the accelerated uptake of these technologies when it happens in terms of investment and resource planning.

## 2.3. Structure of this paper

**Part 1 of this report covers delivery of the CLNR customer trials.**
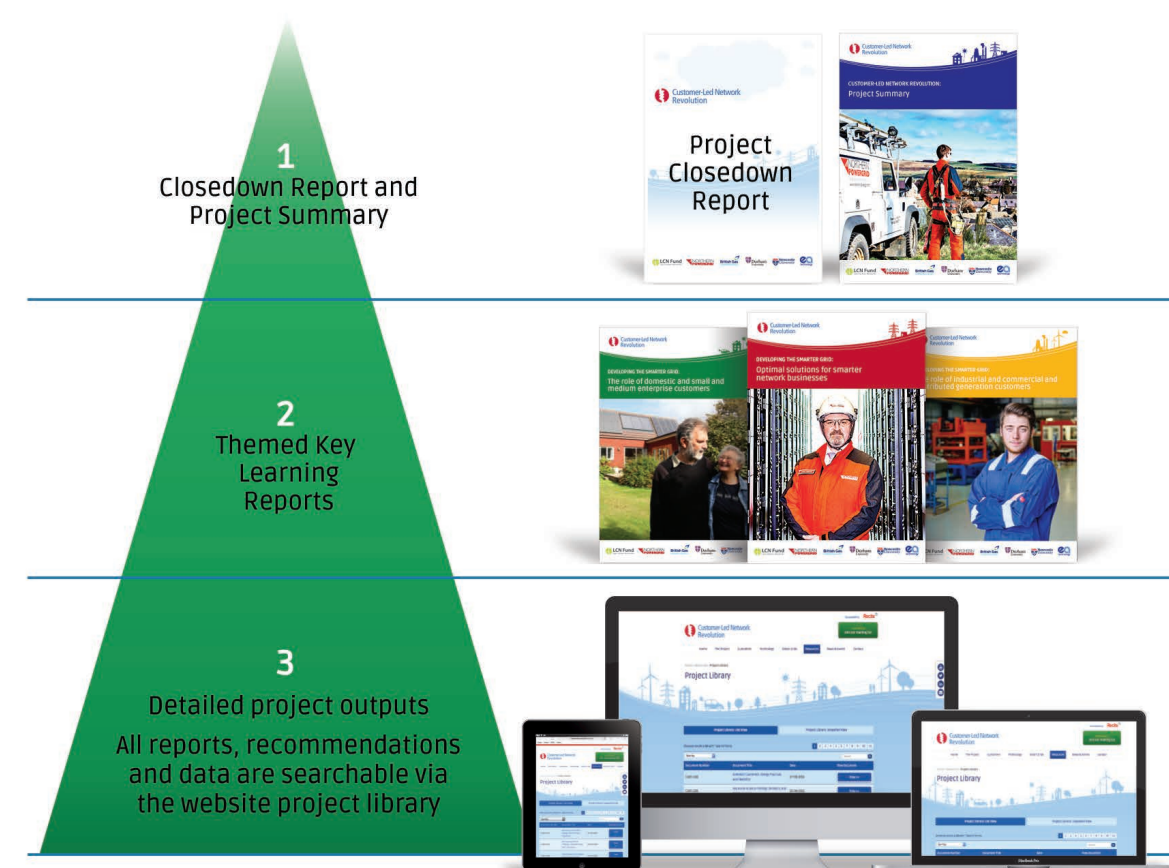
- Section 3 focuses on the trial design: gathering of baseline data, testing of different interventions, and issues relating to customer payment, consent and use of data

- Section 4 considers customer selection and recruitment: demographic modelling, methods of communication and engagement, customer response and types of intervention

**Part 2 looks at the findings from the trials.**

- Section 5 describes the findings from the on-line survey and interviews

- Section 6 explains what data was captured and the analysis that has been carried out

- Sections 7 and 8 set out the findings from the basic and enhanced profiling of domestic customers without demand side interventions. All of these had smart meters fitted and some had LCTs installed

- Section 9 describes the findings from demand side interventions on domestic customers

- Section 10 deals with SMEs

- Section 11 summarises the key findings and draws lessons for network companies, suppliers and future innovation projects

## 2.4 How this paper fits within the full CLNR output suite

The diagram below provides an overview of the structure of the CLNR project output documents. This report resides at Level 2, as shown in the diagram below.



**1** Closedown Report and Project Summary

**2** Themed Key Learning Reports

**3** Detailed project outputs
All reports, recommendations and data are searchable via the website project library

**Figure 1:** Navigating the CLNR project outputs

[15] CLNR-L247: Developing the smarter grid: the role of industrial and commercial and distributed generation customers
[16] CLNR-L248: Developing the smarter grid: optimal solutions for smarter distribution systems
[17] ENSG 'A smart grid routemap' 2010
[18] Climate Change Act 2008 stipulates that the UK must reduce its CO2 emissions to 34% lower than the 1990 levels by 2020 and 80% lower by 2050

## PART 1
# Delivering the trials

# 3. TRIAL DESIGN

## 3.1. General approach

**3.1.1. Monitoring customers' existing load and generation patterns**

This part of the project involved monitoring the electricity consumption and generation profiles of around 13,000 domestic and SME customers, both with and without LCTs (heat pumps, solar photovoltaics, micro-CHP, electric vehicles). This is the largest sample of electricity customers' usage to have been undertaken in the UK and Ireland to date. The size of the sample, when compared with previous projects monitoring customer electricity use, has generally ensured a statistically robust set of conclusions and greatly improved the rigour and breadth of our understanding.

| Customer attribute | Customer type label |
|---|---|
| **Ages of the household members** | Dependant: household includes at least one child aged < 5 and/or adult aged ≥ 65years |
| | Non-dependant: all members ≥ 5 and/ < 65 years |
| **Household income** | Low income: ≤ £14,999yr |
| | Medium income: £15,000yr – £29,999yr |
| | High income: > £29,999yr |
| **House tenure** | Renter |
| | Non-renter |
| **Thermal performance of the building** | Low thermal efficiency |
| | Medium thermal efficiency |
| | High thermal efficiency |
| **Rurality** | Rural |
| | Rural off-gas grid |
| | Suburban |
| | Urban |

**Table 1:** Domestic customer group type

Almost 9,000 domestic trial participants from a wide range of socio-demographic backgrounds provided three important inputs to the project.

- The data created an overall picture of current domestic electrical energy consumption in the UK. This has been used to provide a key input to the proposed updating of ACE49, which provides guidance on the design of electricity distribution networks serving domestic areas and is currently based on data last gathered in the 1970s. More details are provided in the Optimal Network Systems report

- The data provided a baseline against which to measure the impact of the installation of LCTs and/or various types of customer intervention, which are described further on in this report

- Findings from customer surveys and in-depth interviews of trial participants within this cohort provided important understanding of customer behaviours and attitudes in relation to electricity use, electrical appliances, smart meters and customer interventions. This is of importance in relation to the development of effective customer interventions at the commercial scale by both DNOs and suppliers. It assists all parts of the industry and policy makers in gaining an understanding of the likely impact of changes in policy, marketing or regulation that impact directly on customers

For monitoring and analysis purposes, the trial participants were divided into a number of test cells. The base test cell excluded Economy 7 and other specific high electrical loading customers. These trial participants either already had smart meters installed or smart meters were installed prior to commencement of the trial start date. (Note that the purpose of the trial was to compare smart meter customers with LCTs and/or interventions against those with smart meters alone, rather than a comparison of before and after behaviour.) These smart meters were capable of recording electrical energy consumption to a 30-minute resolution. The trial participants were allocated to 144 different demographic customer groups, to provide a good statistical basis for assessing the typical electrical use of each of these groups.

The other test cells in this learning outcome involved customers with and without LCTs who had agreed to accept more detailed monitoring of the various appliances comprising the electricity usage within the premises. The original intention was to use only British Gas customers who had smart meters and/or low carbon technologies in their homes, of which a sufficient number seemed likely to be available. However, it became necessary to extend the means of recruitment. (See section 4.5 for changes that were necessary because of recruitment issues.)

### 3.1.2. Trialling customers' flexibility in load and generation

This part of the trial aimed to assess the effectiveness of different kinds of intervention in encouraging participants to change the pattern of their electricity usage. These interventions included combinations of electricity tariffs, in-home displays and automation:

- Time of use tariffs to test customers' ability and propensity to move their discretionary load to low-rate price periods

- Restricted hours tariffs, akin to Economy 7, to test customers' willingness to accept a default time-based restriction on the use of a specific appliance; and also the degree to which they exercised the over-ride that we provided

- Direct control of appliances to test 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)

- For domestic PV, studies of within-premises balancing (i.e. seeking to avoid the export of surplus electricity by increasing electricity consumption within the premises by, for example, heating water) where customers attempted a degree of balancing by manual or automatic means

In order to gain a deeper and broader understanding of demand side management as a whole and provide for independent expert challenge of our propositions and findings, we part-funded and contributed to Sustainability First's three-year GB Electricity Demand Project[20].

The interventions are described in more detail in section 3.2.

### 3.1.3. Installation of equipment

In order to gain a detailed understanding of customers' electricity usage, some trial participants had monitoring equipment installed on the premises in addition to the British Gas smart meter that recorded electricity consumption at 30-minute intervals, or for non-British Gas customers, in addition to their existing meter. The additional monitoring comprised of 'in-line' monitoring and/or smart plugs (which provided consumption data at 10-minute intervals) and (in the case of non-British Gas customers) a secondary meter for 'whole-house' monitoring. This was required for trial participants other than British Gas customers with plain single tariffs, i.e. for non-British Gas customers and for customers on a tariff such as prepayment or Economy 7.

In all instances where monitoring equipment was installed, trial participants were provided with details of this equipment installation (including an indicative timescale for it to remain in situ) before they consented to take part in the trial. Additional monitoring equipment was installed by the equipment supplier under contract with British Gas and, where appropriate and wherever possible, was combined with the installation of either a low carbon technology (where installed) and/or a British Gas smart meter to minimise disruption to the trial participant. The equipment was left installed in the customer's premises for the duration of the trial, after which the installer made arrangements with the trial participant for its decommissioning and removal.

A description of the monitoring equipment installed, including smart meters, secondary meters, smart plugs and LCTs is given in Appendix 1. A number of issues arose in relation to the installation of equipment, these are referred to in Section 11. A report from Sustainability First on lessons learned about installation of equipment for the CLNR trials is also available[21].

## 3.2. Tariffs and other interventions

### 3.2.1. Time of use tariffs

A set of tariff propositions was developed that aimed to maximise the relevant learning from the trials, given practical constraints faced in their implementation. A full report on our approach to the development of the commercial propositions has been published on the CLNR website project library[22].

The time of use and restricted hours propositions were both based on an underlying time of use tariff. For a time of use tariff to be commercially viable and valuable in 2020, it should reflect the costs of supplying electricity at each point in the day in 2020, and the likelihood that shifting demand in response to tariffs will change the profile of these costs. Time of use tariffs were developed for SME and domestic customers based on estimated future costs and demand patterns. For domestic customers, the peak ToU rate (from 4pm - 8pm) was 99% higher, the day rate (from 7am - 4pm) 4% lower and the off-peak rate (from 8pm - 7am) 31% lower than the flat rate tariff. In addition, there was a 16p standing charge. The tariffs were designed to ensure that overall the bills for an average customer remained similar. They were told at the outset that if they ended up paying more as a result of the ToU tariff, they would only be charged the flat tariff rate creating a safety net for customers taking part in this trial[23].

The domestic and SME tariffs differed in that the domestic tariff did not include an 'evening shoulder'. Instead it reverted back to the lower night rate directly after the peak evening period. Ideally an evening shoulder would have been included for the time of use tariffs; British Gas' systems were unable to accommodate this for domestic customers. Nevertheless, this domestic tariff provided new learning, as a tariff of this shape had not been included in recent major trials in the UK and Ireland. It allowed testing of the assumption that an evening shoulder is required to avoid a new peak occurring once the lower night rate commenced in mid-evening.

### 3.2.2. Restricted hours tariff

The restricted hours tariff aimed to test customers' behaviour with the above ToU tariff combined with an automated service that switched certain appliances (washing machines or heat pumps) off during the four hour peak period from 4pm to 8pm on weekdays, with technology provided to allow customers to override this automated service when they wished. By combining this automation with the same time of use tariff being used elsewhere in the CLNR, we could assess the incremental impact of the automation.

Participants in this trial received a smart washing machine, which they could set to turn off automatically as peak time began or turn on automatically at the most economical time. Alternatively they were able to chose the most convenient time themselves. If they opted for their machine to automatically select the cheapest time to do their washing, they needed to turn on the energy control mode before beginning their wash cycle. The machine would display the energy used by the appliance as well as the cost. The trial participant could chose to pause the cycle or disable the energy control mode at any time without penalty.

In order to optimise the operation of the smart heat pump in line with the time of use tariff, the electricity supply to the heat pump would be automatically switched into a low output mode for periods of between 30-minutes and two hours in the peak hours during the trial period.

The heat pump would be set to build up a store of heat for up to two hours prior to an interruption to ensure the customer always has a supply of hot water through the tariffs peak hours. Should the customer want to override the low output mode of their heat pump, they can easily do this by using the control provided with the heat pump.

### 3.2.3. Direct control

The aim of the direct control proposition was to test customers' behaviour in response to the occasional direct control of the load of specific appliances.

To calculate the value associated with moving customer demand, we used a methodology based on the Common Distribution Network Charging Methodology (CDCM). This suggested a value of £30/kW per year for occasional direct control of loads, assuming this intervention would be focused on the heavily-loaded parts of the network where the value of implementing it is at the higher end. For this cost saving to be realised by networks, customers would have to allow their load to be interrupted as many times as was required to defer HV network reinforcement. We estimated these interruptions would need to last for the four hours of peak, for around 10-15 consecutive working days, once every three years.

The value to networks of a customer accepting a Direct Control proposition would depend on the size of load associated with the appliances that they had available for interruption. We analysed the value of interrupting various types of domestic load (see table 2). As cold appliances offered the lowest value we considered them unsuitable for this trial.

|  |  | Annual value of interrupting load at peak |
|---|---|---|
| **Cold appliances** | Fridge Fridge-freezer Freezer | <£0.20/year |
| **Wet appliances** | Washing machine Dishwasher Dryer | £2/year £2/year £4/year |
| **Hot water heating** |  | £15/year |
| **Heat pumps** |  | £10-15/year |

**Table 2:** Time of use tariffs - weekend

[20] www.sustainabilityfirst.org.uk/gbelec.html

[21] CLNR-L262: Lessons learned report - Customer trial equipment installations

[22] CLNR-L006: Domestic and SME tariff development for the Customer-Led Network Revolution

[23] As part of the Terms and Conditions of the trial, British Gas made a commitment to customers that if they paid more on the trial tariff than they would have paid on British Gas' Standard tariff over the period, then British Gas would refund the difference via a credit to their account. This was calculated on a customer by customer basis at the end of the trial by British Gas via a 'shadow billing' exercise

Trial participants in this part of the trial received either a washing machine or 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' demand management platform. Certain limitations were placed on the frequency and timing with which interventions could be called:

- A maximum of 15 interventions per year
- Only one intervention per day
- Interventions could occur on up to 10 consecutive days
- Each intervention could last up to four hours
- Interventions would be called in the peak periods of 4pm to 8pm only
- The trial participant could override without penalty
- Excludes weekends and public holidays

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 intervention, the trial participant always had a supply of hot water to see them through the peak intervention.

When enabled, the washing machine's energy control mode allowed the appliance to receive load control signals. These signals enabled the washing machine to automatically schedule a wash cycle to avoid the times specified for the load control, or if it was in use, it would send a message via SMS or the machine's display or in home display asking the customer to pause the cycle to be resumed after the load control event. Trial participants were encouraged to keep this mode enabled throughout the trial, but could operate an override at any time by disabling the energy control mode.

The technologies held by SME trial participants were much more diverse. British Gas developed a pragmatic approach to assessing the value of interrupting their loads. This was based on the assumption that interrupting the load of SME customers will allow a portion of their distribution network

costs associated with supplying electricity to them to be saved. Applying this methodology results in a discount of 2% in bills to Direct Control SME trial participants, who could allow 20% of their load to be interrupted. A proportionately smaller discount would be given where trial participants can reduce a smaller amount of load.

**3.2.4. Solar PV within-premises balancing**

The implementation of within premises balancing aimed to incentivise behaviour change through increasing energy consumption during periods of excess on-site generation from solar PV installed at the home. Trial participants were supplied with the Passiv Controller with a real-time solar meter display that showed when they were generating more electricity than they were using. They were encouraged to turn on their appliances manually at these times in order to reduce the amount of electricity they imported from the grid when they were not generating. Alternatively, we deployed Coolpower's EMMA system to automatically use any excess PV generation that would otherwise have been exported to heat hot water electrically in the home. This aimed to help trial participants use their solar panel generation in the most efficient way.

## 3.3. Payments to customers

We made payments in the form of £50 Marks and Spencer vouchers to all trial participants except those in the baseline monitoring test cell, for joining, project completion and project extension. We compensated some customers for allowing installations, such as electricity usage monitors, into their homes. These fees were also intended to provide an incentive to trial participants to sign up and to continue to participate for the duration of the trial, although anecdotal evidence indicates that trial participants often agreed to participate before being informed about the payments.

SMEs were given a £100 joining payment and a £100 completion payment, applied as an ex-VAT credit to the customer's account shortly after joining and on completion.

> **"**
>
> In the test cells where we needed to work with trial participants either to install additional monitoring equipment or ask them for more information on their energy use or production, the trial participants were recruited through an opt-in process.

## 3.4. Customer engagement and consent

Customer engagement was carried out in line with a customer engagement plan[24] agreed with Ofgem. We understood that to deliver a successful project we needed to build and maintain the trust of customers who agreed to take part in our trials. The management of engagement and consent played a key part in creating this positive relationship with trial participants.

The monitoring of trial participants in the base test cell required no explicit customer engagement since the data was already collected via the smart meter. Moreover, consent was effectively already in place for these trial participants. Where electricity consumption data could be obtained on a business-as-usual basis from British Gas' smart metering customers, the Privacy Notice (contained in customers' supply terms and conditions) allowed personal information held about trial participants to be used for, amongst other things, analysis and research purposes. Therefore, there was already a basis for using this customer data (including where such analysis is undertaken by third parties under contract with British Gas). Nevertheless, we still required and obtained consent to the use of smart customers' data via an opt-out letter. There was a less than 1% drop out rate.

In the test cells where we needed to work with trial participants either to install additional monitoring equipment or ask them for more information on their energy use or production, the trial participants were recruited through an opt-in process. Working through established supplier/customer interfaces, British Gas used its existing customer communication, sales, installation and support infrastructure to ensure the engagement of its customers in the trials.

Non-British Gas customers were also recruited to the trials in order to increase the number of trial participants; these trial participants were also recruited via an opt-in process. We only contacted non-British Gas customers who had given their consent via other routes - for example, if we approached an RSL about their tenants participating in the trial, the RSL managed and took responsibility or obtaining the tenants consent to take part.

Consequently, the project needed to seek additional consent to use customer data from trial participants in the following categories:

- Non-British Gas customers participating in any trial
- Trial participants providing additional qualitative information on their energy use or production
- Trial participants accommodating additional monitoring equipment; and
- Trial participants who enrolled in the CLNR intervention tariffs such as time of use, restricted hours, direct control time of use

Prior to formal enrolment in the trial, we provided trial participants with all relevant information about the project including its

background, objectives, timelines and an overview of the consortium members involved in its delivery. The need for generation and consumption data and a high-level overview of the analysis was explained. In enrolling in the project, trial participants gave consent for the use of their data in the ways detailed in that documentation.

## 3.5. Treatment of customer data

A data protection strategy was agreed with Ofgem to ensure customer privacy and to comply with the law. All customer data was anonymised during the project data management process.

The key information extracted from the British Gas system was electricity consumption data associated with a particular Meter Point Administration Number (MPAN). No name or address data was extracted. The MPAN was then removed and replaced with a randomly generated unique identifier created by British Gas, which was recorded against that trial participant and used for the duration of the project. All meter read data was also supplied against the unique identifier.

The process was broadly similar for non-British Gas customers. They were given a unique identifier number for throughout the duration of the trial. No name or address data was passed on to Durham University for the purposes of studying consumption (but this was clearly needed to invite customers on to the trial in the first instance, and was used by British Gas and Durham University for the purposes of running surveys and providing trial participants with support, and to arrange in-depth social interviews respectively).

In terms of linking this to the monitoring data (which comes from a different system but which all needs to be linked together), the same unique identifier was loaded in and associated with the corresponding trial participant. As such, whenever extracts of monitoring data were taken they linked through the common unique identifier. No sensitive customer data was ever shared and British Gas staff not involved in the project did not have access to consumption data from non-British Gas customers.

# 4. CUSTOMER SELECTION AND RECRUITMENT

## 4.1. Introduction

The CLNR project benefited hugely from the active participation of a major energy supplier. Indeed, much of the customer-facing aspects of the project would have been impossible without this. However, all those involved in the project were mindful of the need to avoid promoting or endorsing British Gas as an energy supplier.

## 4.2. Demographic modelling

The demographics of customers participating in the study were developed collectively between Durham University and British Gas. The project sought to achieve a broad representation of different customer demographics. The extent to which different customer groups actively participated in the study and changed their behaviours, and what factors influenced this were researched by Durham University and British Gas collectively. Durham University research included holding discussions with trial participants, including visits to their premises.

## 4.3. Non-British Gas customers

The vast majority of trial participants actively involved in the project were sourced from British Gas' customer base. Therefore the majority of engagement and interaction with trial participants for project purposes was carried out by British Gas. In a limited number of instances, it was necessary to engage directly with customers who were not those of British Gas. We developed a strong brand image for the project that was carried across all marketing and communications materials.

Interaction with these trial participants was the responsibility of British Gas on behalf of the project. Care was taken to avoid any appearance of attempting to recruit these trial participants to be supplied with electricity by British Gas, and no different tariff offerings were made to them. To protect against this, staff involved in non-British Gas customer recruitment were given training on the importance of recruiting trial participants to the project only and instructed not to enter into conversations about the individual's electricity supplier. The risk of this was considered low as the recruitment of non-British Gas supply customers was only required for certain test cells and there was no incentive or need to encourage them to switch to British Gas. Also, in the majority of cases, the staff involved in non-British Gas customer recruitment did not have access to the main British Gas account creation/management systems and channels.

## 4.4. Channels and approach

Customer engagement included all aspects of trial participants' involvement with the programme:

- Establishing which customers need to be engaged
- Planning customer selection and approach
- Developing and implementing initial engagement plans
- Bringing customers into the programme
- Keeping trial participants engaged in the programme
- Managing customer issues and questions; and
- Managing trial participants who are leaving the programme

A generic welcome pack was issued, with common themes to the approach to each customer group, with a specific trial insert and set of Terms and Conditions tailored to each trial. For each of the customer groups involved, British Gas provided trial participants with printed and electronic materials and access to agents from British Gas' customer contact centres. In addition, in more complex cases where the implications of the technology / tariff combination were likely to be greater (for example where a direct control tariff is being implemented) British Gas' field staff visited the trial participant if necessary in person to ensure the trial participant fully understood the situation and knew what to do if further support is required. Where trial participants were prepared to share their contact details, the project used email communications as a cost effective means of keeping them informed.

Communication with trial participants during the trial consisted mainly of proactive customer support, making outbound courtesy calls and arranging service visits. Trial participants could also access the project website and associated social media (Twitter, LinkedIn and YouTube) to find out more about the project, sign up for project updates by email or contact the project team.

## 4.5. Customer recruitment

For a variety of reasons explained, customer recruitment was more difficult and slower than anticipated at the outset of the project.

We considered that it was important to capture the learning from the experience of addressing these challenges and so, as part of the project Sustainability First was commissioned to report on the lessons learned during trial recruitment for use by future projects. This section summarises the findings. Appendix 2 of this paper gives a detailed breakdown by test cell of the numbers recruited and the reasons for any drop out.

The project bid assumed an ambitious timetable for recruitment of customers to the trial. Challenges (both foreseen and unforeseen) were found with the recruitment and installation into many of the customer groups. As a result, the recruitment timescale was revised in October 2011 and new recruitment targets set in October 2012 were considered to be more achievable, given the constraints encountered.

We had a gross target of a 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 target was a third lower than the gross target. In reality the dropout rate during the trials was very low (less than 3%).

Initial recruitment to domestic test cells (getting customers to initially agree over the telephone to be on the trial) was broadly successful. Recruitment proved most straight-forward into the 'simplest' household test cells (i.e. monitoring, enhanced monitoring, ToU tariff). The household test cells where recruitment fell short most against targets at the initial stage were those where it proved most challenging to find suitable customers with the right technologies, install new monitoring equipment, and/or to find customers willing to take on new low carbon technologies.

The vast majority of customers involved in the project fell within two smart-meter related groups.

In terms of customer volumes and the project timescales, recruitment into these two core groups was successful:

- For the baseline domestic customer group we had 8,909 trial participants, very close to the gross target of 9,000 customers). Although the demographic was representative of British Gas's smart-meter population at the time, it was not representative of the population as a whole

- The domestic time of use customer group exceeded the recruitment target of 600. This was a particular success as customers were required to opt-in and the trial was quickly oversubscribed

Recruitment to the other domestic monitoring test cells was strong enough for us to comfortably meet our gross targets for enhanced monitoring[26], for PV, for EV and to be close to our net targets for heat pumps (86% of target) and for CHP (70% of gross target).

For the flexibility trials, recruitment was strong for the PV balancing trials (77% of the net target), some with auto balancing and some with manual balancing. For the other domestic flexibility trials, numbers of trial participants was low due to the challenges mentioned above.

For the baseline monitoring of SME customers, we exceeded the net target. Whilst recruitment to the SME opt-in trials was initially successful (with over 560 initially recruited to take part in the enhanced monitoring and the three flexibility trials), once site technical surveys for installation were carried out almost all customers dropped out of the restricted hours or direct control trials, because of concerns about the possible impact on their business. Enhanced monitoring had the greatest rate of proceeding to full participation with 81% of the net target achieved. For the ToU trial, 44 customers (44% of the net target) proceeded to the trials.

> " The domestic time of use customer group exceeded the recruitment target of 600. This was a particular success as customers were required to opt-in and the trial was quickly oversubscribed.

**100+**

100+ of net target recruited for time of use trials

[26] Customers in all the '2a' test cells; i.e. domestic customers with no LCT, and customers with immersion hot water heating, or immersion hot water heating and storage

> **"**
> The project team took a flexible approach to sourcing and developing the technical and commercial solutions needed to trial technologies that were not already fully developed or market ready. This applied in the case of the demand response equipment itself, as well as for the monitoring and communications equipment.

## 4.6. Availability of low carbon technologies

The original intention at the time of the bid had been to contact British Gas customers who were installing LCTs, and to fit smart meters and other monitoring equipment at the time of the installation. Outside of the project, British Gas had been engaged in commercial sales of low carbon technologies, and it was intended to use this sales channel as a route to identify customers to participate in the CLNR project.

The commercial sales activities were not funded or subsidised by the project. However, for various reasons, recruitment was severely hampered by the lack of penetration of the various technologies:

- For the PV test cells, it was difficult to find sufficient properties where either the property owner or the 'rent a roof' provider was prepared to agree to the householder's participation. The principal provider of 'rent a roof' installations in the area was unwilling to take part in the project. This was solved by working with housing associations

- Because of delay in the launch of the Government's Renewable Heat Incentive and uncertainty about the support to be provided to air source heat pumps, the number of customers with air source heat pumps was much lower than anticipated. The CLNR team sourced additional funding from Department of Energy and Climate Change (DECC) for heat pump installations, including innovative heat pumps with thermal storage capability. There was very limited demand from the 'able to buy' market, so recruitment was largely via social housing providers

- Electric vehicle sales were much lower than had been anticipated at the time of the bid. The team worked with Charge your Car (North) to recruit scarce EV users

The project team took a flexible approach to sourcing and developing the technical and commercial solutions needed to trial technologies that were not already fully developed or market ready. This applied in the case of the demand response equipment itself, as well as for the monitoring and communications equipment.

The project included the development of an air-source heat pump linked to a hot water tank for the direct control trials. 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. British Gas worked with the supplier of the smart-enabled washing machine to develop a communications platform to enable direct control of the appliance.

For some trials, a secondary meter was installed to enable participation of customers where a smart meter could not be installed. These could only be safely installed if there is an isolation switch between the meter and the customer's unit. Many houses did not have such a switch. Only the supplier's registered meter operator can disconnect the meter 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. Where it was not possible to install an isolation switch, a MicroWatt Polymeter was used instead. Adapted from an existing commercial product for the specific requirements of CLNR, this product was also used in other CLNR trials to gather data on disaggregated electricity use, i.e. of specific appliances within the home.

The majority of residential trials required the installation of home area network hubs to communicate with the installed monitoring technology. This required broadband and a telephone line, which many homes did not have and therefore needed installing first. This also required homeowners not to move the hub once in place, which sometimes happened for household convenience or aesthetics. As the trial progressed, British Gas developed a GSM (mobile phone-based) solution as an alternative.

Some products and equipment were larger or more cumbersome than a fully developed market-ready product. Nevertheless, trial participants seemed relatively open to accepting trial equipment in their homes, despite some inconvenience.

# PART 2
# Findings

# 5. CUSTOMER ATTITUDES AND BEHAVIOUR

## 5.1. Method

The social science team at Durham University developed two methodologies to help understand the social dimensions of the CLNR trial; surveys (one for SMEs and one for domestic trial participants) and qualitative semi-structured face-to-face interviews and research visits.

These methods were used in conjunction with the analysis of energy consumption data to provide insights into how and why energy use takes particular patterns for groups and individuals within the population included in the CLNR trial. The social science team drew on the existing literature to design research instruments and a methodology which, as well as making a contribution to the existing academic knowledge base, could produce a sufficient dataset and deliver the learning outcomes required by project partners. A number of socio-technical reports have been published to provide detailed findings. Associated social science outputs can be found in Appendix 4.

The face-to-face interviews focused on building rapport with the participant while discussing their energy use in general terms. These conversations included gathering information about occupancy, major electrical loads, heating regimes, washing and cooking practices, thoughts and feelings about electricity use, seasonality and other temporal factors as well as experiences of and attitudes to new and existing tariffs and technologies.

During the tour of the premises led by the participant, they were prompted by the researcher to talk about all aspects of their electricity use using electrical equipment as a catalyst for conversation. Furthermore, multimedia data was collected by the researcher, with permission, to further enrich analysis. The participant-led approach was reflected in the instrument design which did not constrain the respondent or presuppose the factors which are most relevant to the participant. The third part of the visit enabled a discussion of the principal issues with which the project is concerned as they related to the participant's context and focused on the topics of flexibility, peak consumption, key practices with potential for demand side participation

and engagement. Some participants were involved in a follow-up visit, and in this case a fourth part of the research instrument was used to interview participants about their experience of the particular interventions they had engaged with through the CLNR project.

The online surveys were developed following consultation with several sources. National Energy Action's (NEA) experience of conducting different types of household surveys informed the initial set of questions, while feedback from the Durham Energy Institute's (DEI) external advisory group was instrumental for revising the attitudinal questions in the domestic survey. Reviewing examples of energy-focused surveys from different research projects helped in the preliminary selection of questions. The final set of questions for both the domestic and SME surveys was agreed in consultation with British Gas and Northern Powergrid.

The surveys were designed to produce quantitative data that directly addressed two of the overarching learning outcomes of the project. To that end, the questions included in the survey addressed issues of current and future energy use and flexibility of energy use in both domestic and SME contexts. There were a total of 152 responses to the SME survey and 1,285 responses to the domestic survey.

The survey and interviews included trial participants who had installed LCTs and trial participants subject to trial interventions, as well as trial participants that had only smart meters installed. The results are therefore summarised overleaf, with specific findings relevant to particular groups included within the appropriate groups in section 6.

## 5.2. The CCRES model

The surveys and interviews confirmed the benefit of the socio-technical approach to understanding the provision and use of energy services adopted by DEI, in which energy systems involve the continual interaction of social and technical factors, and where demand for energy is driven by the workings of different practices in homes and businesses.

This is known as the CCRES model of energy use, in which each element is a cog or gear which work together in different ways in different contexts to shape how energy is used. This approach, with its emphasis on practices rather than energy behaviour, while gathering momentum in academic circles, is not widely understood by energy practitioners and policy makers, who still focus on energy use being shaped by attitudes and socio-demographic attributes that condition people's consumption choices, and thereby miss a crucial link in understanding domestic energy-using behaviour and how to influence it.

Energy use as shaped through the interaction of five different core elements, which determine energy-related social practices and the ways they are organised:
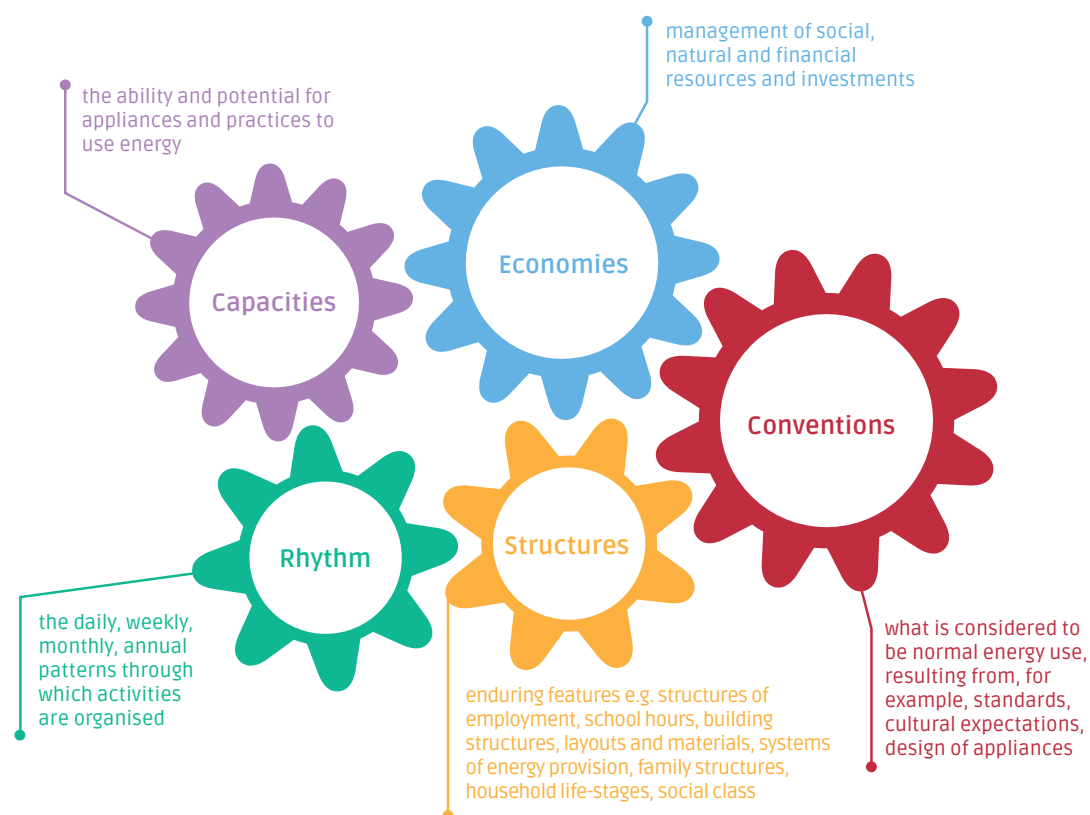
the ability and potential for appliances and practices to use energy

management of social, natural and financial resources and investments

**Capacities**

**Economies**

**Conventions**

**Rhythm**

**Structures**

the daily, weekly, monthly, annual patterns through which activities are organised

enduring features e.g. structures of employment, school hours, building structures, layouts and materials, systems of energy provision, family structures, household life-stages, social class

what is considered to be normal energy use, resulting from, for example, standards, cultural expectations, design of appliances

**Figure 2:** The CCRES model of energy use

## 5.3. Survey results

### Domestic results

CLNR customer surveys were as follows:

**Paying energy bills**

- 51% of respondents said they did not have problems affording their energy bills but 10% said they did. 43% said they never or rarely went without to pay their energy bills but 17% occasionally or often did

**Appliances and energy behaviours**

- Popular energy saving practices included switching off unused lights, waiting for a full load before doing laundry, and reducing the heat in some rooms

- Those in newer houses tended to be more engaged with energy efficiency and with LCT ownership

- Households with more occupants owned more appliances. Technology ownership increased with age until middle age when it began to fall

**In home display (IHD) devices**

- 54% of respondents agreed or strongly agreed that IHDs had caused them to change the time they use some electrical appliances

- IHDs are felt to have led to a small decrease in energy use

- 90% found IHDs quite or very easy to understand

**Social trends**

- Mobile and internet devices appeared to be growing in importance. We discovered a significant move from fixed line broadband to mobile internet use, particularly in the fuel poor. This will have implications for the widespread use of 'smart' homes

- Households were frequently changing their composition with a greater fragmentation of living styles, and often several generations in the same household

- The wish to manage energy use to reduce costs was growing

**Customer engagement**

- Customers had relevant knowledge and skill sets: energy is a key resource in the household economy

- Customers wanted to play their part in 'keeping the lights on'/maintaining the grid

- Little evidence was indicated of concerns about security and privacy. (Survey did not cover safety issues, such as use of appliances when house is empty or at night)

- The installation of technologies (by who, how, and what they replaced) was critical to customer experience

- Limitations: our understanding of customer experience over time/at the end of the trial

**Implications**

- Customers had varying levels of ability to be flexible, but this was shaped by practices and the 'gearing' of their everyday life, rather than by socio-demographic type

- The household practices that contributed most significantly to electricity use in the evening peak period were those which had the biggest load and which were most commonly undertaken at this time, in particular laundry and dish washing

- Electronic entertainment and cooking, although often undertaken in the evening peak period either had low electrical intensity (entertainment), and/or were perceived by respondents to be less flexible

### SME results

The key results from the survey of SMEs were:

- 72% agreed that they needed to reduce the amount of energy

- Majority of the SMEs had no environmental policy in place

- Electricity use was related to within-day (e.g. opening hours), weekly (e.g. shift schedules) or seasonal patterns of activities in pursuit of business goals

- Connectedness was seen as a vital service that energy use provides

- Servers and mobile devices were often reported as being among the most critical appliances to business continuity

- Energy was a lifeline; making changes would put business at risk

**90%**

of respondents found IHDs quite or very easy to understand

# 6. ELECTRICITY CONSUMPTION

## 6.1. Datasets used

For the purposes of understanding a customer's electricity consumption patterns, there are two key variables that can be measured. The first is the amount of electricity consumed in a particular period, measured in kilowatt hours (kWh). The second is the rate of use (or generation) of electricity at a particular time, called load and measured in kilowatts (kW).

During the CLNR project, smart meters were used to provide half-hourly consumption readings. From these readings, we could calculate electricity consumed over various periods and the average load for any half-hour. For the avoidance of doubt, where we refer to peak power demand in this report, we mean the average peak power in the half-hour with the highest overall consumption (measured in kW and numerically equal to twice the consumption measured in kWh in that half-hour).

The total span of the data capture period for the whole range of trials was from 1 May 2011 to 30 June 2014. Over that period customer numbers fluctuated due to circumstances such as customers dropping out of trials over time. Certain test cells started earlier than others, dependant on the complexity of recruitment and installation. The test cells monitored also finished in four distinct tranches: end of December 2013, end of March 2014, end of May 2014 and end of June 2014. In order to align the data for research purposes and to maintain statistical robustness we selected for each test cell the data that provides the optimum mix of customer numbers and trial duration.

For the majority of the trials, monitoring comprised whole house half-hourly meter reads of net consumption throughout 24 hours, every day. For the enhanced profiling trials, 10-minute whole house meter reads were taken throughout 24 hours, every day. In addition, 10-minute meter reads throughout 24 hours every day of the consumption/output of the specific LCT or smart appliance were taken.

## 6.2. Statistical analysis carried out

To generate results from the raw meter data, a small number of variables were used, which measure various characteristics that are relevant to network operators and generators:

- Absolute energy consumption: how much energy has been consumed over a given period of time (measured in kWh)

- Peak power demand: the maximum power that was demanded by a customer or group of customers within a specified time frame (measured in kW and reported with the period and time this peak occurred)

Note that this figure is derived from half-hourly or 10-minute meter readings and so is not the instantaneous peak power demand. Rather it relates to the half-hour/10-minute period within the specified time frame when consumption/output is highest and constitutes an average of the power demand over that half-hour/10-minute period)

- Variation in energy consumption: this measures the variability of customers' consumption patterns between the different socio-demographic subgroups and within the same subgroup. The results describe how homogenous a group is in terms of its energy consumption

- Variation in peak power demand: this measures how varied the peak demand is from a group of customers (and how much diversity or correlation there is between the timing or amount of peak demand from a group of customers). This supports network planning purposes in order to compute the overall peak demand from a set of customers and therefore how much network capacity is required

These measurements were made for various demographics and against varying time frames, namely annual consumption, monthly demands by weekday and weekend. In addition, in relation to peak power demand, a number of averages were derived including the average individual consumption over the peak period and average peak power demand over a period such as a week or a month. Calculating a range of figures is important because monitoring has demonstrated that individual peak power demand varies by time within a day, and between days. These different measurements are relevant to the needs of different electricity industry sectors.

The project also explored the correlation between peak demand and annual consumption and carried out clustering analysis of trial participants according to demand profiles, this enabled the analysis of customers that exhibit similar behaviour.
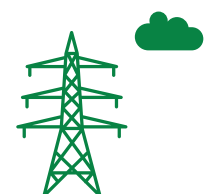
# 7. BASIC PROFILING OF DOMESTIC SMART METER CUSTOMERS, NO LCTS AND NO INTERVENTIONS (TC1A)

This trial used consumption data from around 9,000 British Gas domestic customers with smart meters, from both within and outside of the Northern Powergrid region. The split is approximately 50% within Northern Powergrid's region the North East, Yorkshire and northern Lincolnshire and 50% national. All smart meter data was collected as half-hourly electrical energy consumption in kWh and then converted to average half-hourly power in kW for analysis. The monitoring period was over two full years from 1 May 2011 to 30 April 2013.

The statistical approaches considered the CLNR socio-demographic groups and the Mosaic socio-demographic groups separately. The basic analysis involved applying the four key statistics (see section 6.2) to each of the demographic groups. By comparing these statistics across groups, it was possible to compare electrical energy consumption patterns. All aspects of the analysis had sufficient customer numbers to satisfy sensible confidence intervals, apart from rural off-gas customers in the CLNR demographics.

The summary statistics used throughout the report were means and standard deviations for the annual and monthly electrical energy consumption, as well as peak daily and peak annual demands. Overall, the analysis revealed a relatively consistent average demand profile across the different demographic groups, with much higher variability within groups than between them. This high variability is seen both in total consumption and in peak demand. The standard deviation across all groupings (both internally defined and the Mosaic social groupings) is roughly half the mean value for each group. This variation is seen not only within customer groups, but also within the year for individual customers.

**The datasets highlighted some expected behaviour:**

- The daily energy use profile is broadly divided into night/early morning (low demand), daytime (mid-level demand) and evening (higher demand)

- In the winter months, overall consumption and average daily peak demand are higher than in other seasons. Also in winter there is a greater variability in energy use between customers

- Most households have their peak daily demand during the 4-8pm period. However, there is a significant minority of households across all demographic groups whose peak demand occurs earlier in the day, around midday

In addition, the demographic analysis and the large number of detailed monitoring profiles provided a range of important new insights. The link between customer consumption and demographics is primarily driven by income but even then this is not a particularly strong driver. Most customer groups consume on average about 3,500 kWh during the year, with a range of roughly 200 kWh either side of that value.

Notable exceptions here are the high-income group (*ca* 4,100 kWh) and rural off-gas (*ca* 5,300 kWh). Further, the low-income group (*ca* 3,000 kWh) and renter group (*ca* 3,200 kWh) are outliers to this picture.

A similar pattern is also observed in the peak demand for these customer groups. The next major factor appears to be house energy efficiency. There is even less variance in the mean peak demand across groups, with the exception of the rural off-gas group. On the other hand, the maximum peak demand follows the annual consumption pattern more closely.

In terms of seasonal variation, as might be expected, there is higher electricity demand in winter when it occurs earlier in the evening. On the four days of greatest network stress, the average peak demand was 0.9 kW over the hour 5pm to 6pm. Electricity demand was broadly the same at peak hours whether it is on a weekday or at the weekend. However, rural off-gas and high-income customer subgroups average peak demand could exceed 1 kW at network peak in winter.

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### Network implications

DNOs need reliable information about domestic consumer load profiles for system planning. The current ACE49 standards are based on data which is over 30 years old. These findings have been used to propose possible revisions to ACE49. This is covered in our optimal solutions for smarter network businesses report[27].

The link between electricity use and income merits further investigation, as does the link with house energy efficiency. It could have implications for network planning if it implied a need for a higher after diversity maximum demand (ADMD) in more prosperous geographical areas.

Since maximum peak demand is well correlated with annual consumption, applying network charges on a per unit basis (as at present) is a good proxy for the burden placed on the network by a domestic customer.

The research has highlighted the need to concentrate on energy practices rather than attitudes or demographics and should help DNOs frame the way they should invite customers to participate in demand side measures.

# 8. ENHANCED PROFILING

## 8.1 Enhanced profiling of domestic smart meter customers, no LCTs, no interventions (TC2a)

This trial provided enhanced monitoring of individual disaggregated loads at 10-minute intervals, for a group of domestic customers. The dataset covers a monitoring period of 17 months from December 2012 to April 2014 with a total of around 80 customers[28]. The domestic loads monitored included: lighting, consumer electronics, the cooker, kitchen appliances, washing appliances and refrigeration.

Because of the intrusive nature of the monitoring, participants were recruited from the staff of the project partner organisations, their friends and family. The participants may therefore not be representative of the wider population as a result of their relationship to the energy industry and the trials. However, there is no obvious incentive for the households that we observed to alter their consumption behaviour, so while these households may be different from the UK average, the data should be a reasonably accurate reflection of their typical consumption patterns.

In order to gather the data required, circuit monitoring was installed for all circuits at the consumer unit, as well as for the household as a whole. This was supplemented by the use of up to seven smart plugs on specified appliances. No change was made to customers' existing tariffs.

It is worth noting that the results presented in Table 3 are average results over the cohort. Individual consumption profiles can and do vary significantly between households and, even within a single household, consumption may not observe a constant pattern. Indeed, the analysis from our surveys has already shown that a household's consumption between 4pm and 8pm can, on any one day, differ from its annual average by up to 50%.

Average annual consumption among the group in the trial was 4,192 kWh, between Ofgem's representative medium (3,200 kWh) and high (4,900 kWh) consumption figures. Figure 3 shows the average daily profile from this data, disaggregated by appliance type for the peak weekday in 2014 for which sufficient data on the appliance types is available. This indicates a pronounced early evening peak. About half of this consumption was not attributable to the devices that were monitored. The unattributable consumption was larger during the colder winter months and exhibits strong seasonal variation. We understand from surveys of these customers that some used portable electric heaters in the winter that were not monitored, and this could account in part for this pattern. More work is needed to explore this consumption and the reasons for its seasonal variation.

| | Annual consumption | Share of household demand | |
|---|---|---|---|
| | kWh | peak | baseload |
| **Lighting** | 225 | 7.6% | 5.4% |
| **Cooker** | 317 | 13.8% | 7.6% |
| **Kitchen appliances** | 161 | 2.9% | 3.8% |
| **Refrigeration** | 427 | 4.9% | 10.2% |
| **Washing appliances** | 423 | 12.3% | 10.1% |
| **Consumer electronics** | 470 | 7.2% | 11.2% |
| **Other devices** | 2,170 | - | - |
| **Total household** | 4,192 | 100% | 100% |

**Table 3:** Electricity consumption by appliance type on a peak weekday
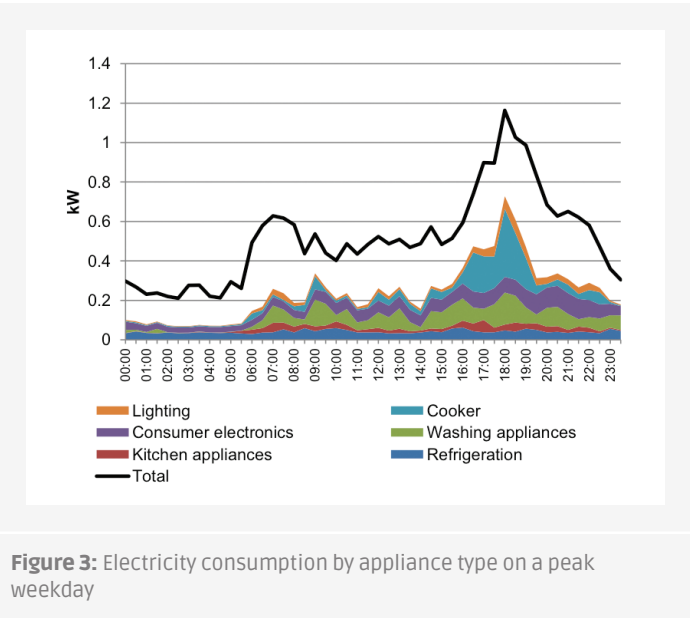


**Figure 3:** Electricity consumption by appliance type on a peak weekday

Where analogous consumption groupings exist in both sets of data, we have compared the data from this trial with equivalent summary data from the Household Electricity Survey (HES). HES monitored appliance level consumption data in 250 owner-occupied households across England from 2010 to 2011[29] and, at the time, was the most detailed monitoring of electricity use conducted in the UK. As such, it represents an appropriate point of comparison for the appliance level monitoring conducted as part of this test cell.

The patterns of consumption we observed for monitored appliances tend broadly to match those from HES. There is, however, a discrepancy in lighting demand, with HES consumption profiles exhibiting a far larger spike in lighting demand in the evening relative to our data. This may reflect the absence of lamps plugged into sockets in our data. There have also been changes to the efficiency of lighting since the HES survey was undertaken in 2010 as a result of phasing out of incandescent bulbs. Moreover, HES had only around 20% of consumption unattributed.

For lighting, we found that consumption is significantly larger in winter and autumn than during the summer; however this increase in demand seems only to affect the peaks (intuitively, when it is dark). Winter demand also ramps up earlier in the day as it gets dark earlier. The morning peak during winter is markedly different between workdays and weekends. Whereas half-hourly average demand exceeds 60 W on weekday mornings, it barely gets above 30 W on weekends. This may be the result of people opting to start their days later on the weekends during the dark winter months, and more variation in the timing of morning routines across households. Lighting has limited scope for use in demand side response, and further efficiency improvements are likely to prove far more effective in lowering peak demand, although motion sensors and timers could assist.

The load profiles for cooking display a significant variation between weekdays and weekends. On weekdays, there is a substantial evening peak at approximately 6pm, with comparatively little activity throughout the rest of the day – this is consistent with a large proportion of the sampled households being at work during the day, and preparing dinner during the evening. Load profiles on Saturday have a similar evening peak, but also exhibit a lunchtime peak (just over half the size of the evening peak). The lunchtime peak is higher on a Sunday, while the evening peak moves back closer to 5pm. This may reflect cultural traditions, such as the preparation of a roast dinner. There is also a seasonal trend: in general, cooker loads are lower during warmer seasons. There is limited seasonal variation across the use of kitchen appliances, although high summer use is notably lower. Since cooking amounts for about 20% of peak load, even a modest demand side response would be useful.

Space heating is potentially a highly movable source of demand. Use of storage heaters is dealt with in sections 8.2 and 8.3, but evidence from the HES survey (albeit on a small sample size) was that, on the coldest day in 2010, the 24 homes within the HES study that supplemented their gas or oil main heating system with electric heating used an average of 570 W for back-up heating during the peak hour, making up 84% of their electricity consumption at the time. The potential to substitute between multiple heating systems represents a potential source of demand side flexibility within such households. There is however an insufficient sample size of electric space heating in our data to carry out a robust analysis of load profiles for houses with electric space heating on standard tariffs, but this area could merit further study.

Refrigeration demand is extremely stable over the time frames measured. The frequent cycle of individual units results in a steady average base load demand for power. There is a slight, but noticeable increase in the evening, probably associated with opening of the unit's door for dinner. Although there is little variation among days, there is pronounced seasonal change, almost certainly driven by changes in the ambient temperature. As a result, refrigeration demand is consistently higher in the summer than in the winter or spring. Although refrigeration loads are not especially high during peak hours, the potential for

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time-shifting the load means that that could be 'partially switchable'. However, our survey analysis indicates that households generally do not envisage any scope for changes in refrigeration behaviour owing to the perceived risk to food safety. As a result, any demand side response from refrigeration appliances would be especially reliant on automation to provide households with confidence that any changes in consumption are kept within safe bounds. There are also a number of technical challenges that limit refrigeration's ability to play a more significant role in demand response. The need to maintain a reasonably tight temperature range makes it unlikely that demand could be safely deferred for a whole hour. The scope for delay is similarly restricted by opening of the door, which often occurs during the evening peak owing to the timing of meals. And, given the relatively short time spans over which it is possible to safely defer demand, it will also be more challenging to stagger the return of refrigeration demand such that it does not result in sudden demand changes at the end of the formal peak.

Water heating is among the most switchable of consumption categories where households have hot-water cylinders, as opposed to on-demand heating, particularly where water is heated electrically. The cylinders provide an existing thermal heat store and, provided the cylinder is suitably large and well insulated, allow hot water use to be separated from the associated electrical load. However, there has been a trend decline in the number of hot water tanks as older gas boilers have been replaced by more efficient combination boilers. Between 1995 and 2009, the number of dwellings in England with hot water cylinders fell from 16.7m to 12.5m[30]. If electric heating of hot water becomes more prevalent in future, the stock of cylinders might grow.

However, space constraints may mean that the cylinders are too small to fully separate the timing of hot water use and demand for electricity, resulting in more peaky hot water profiles. There is an insufficient sample size of hot water heaters in our data to carry out a robust analysis of load profiles for houses with electric water heating on standard tariffs.

Washing appliance use varies significantly between weekdays and weekends, as well as across seasons. Weekday demand rarely exceeds an average of 100 W, but exhibits a post-work peak, presumably as people activate washing machines after having returned home. Weekend demand is significantly larger reaching 180 W in spring and winter and is more evenly spread across waking hours. Night-time demand is very low on all days, suggesting that few, if any, households use a time delay to run these appliances during the night.

High summer demand is markedly lower than demand during the colder months. Washing appliances are potentially among the most flexible of sources of demand. Our own surveys and interviews indicated that households exhibited some flexibility as to the precise timing of use. This willingness to be flexible is not helped by equipment design.

Only 31% of UK households have a start delay function on their washing machine, and approximately 32% of dishwashers have a similar feature. These figures are low relative to some other European countries, for example France, where the equivalent figures are around 40% and more than 50% respectively[31]. A more significant barrier is likely to be safety concerns associated with running these appliances unattended. In particular, public safety organisations like the Chief Fire Officers Association advise against running these

appliances while asleep or absent, given the risk of fire.

Consumption from consumer electronics shows an evening peak, which builds through the afternoon and falls away sharply in the late evening. This evening peak is pronounced on weekdays, presumably because work patterns prevent earlier use, but is also clearly visible on weekends, when the peak builds more gradually throughout the day. The profiles also exhibit some seasonal variation, with markedly lower peak consumption in high summer, and to a lesser extent the summer.

Our survey findings show that the number of consumer electronics used in the home is growing, but that many of these new devices, such as laptops, smartphones, and tablets, are inherently flexible. These findings suggest that consumer electronics will become an increasingly important component of household electricity consumption. If these new devices are designed to be portable, and so have in-built batteries, they may also bring new options for households to shift their load.

> " The average data for immersion heaters alone showed a peak at 8am, both during weekdays and at weekends.

### 8.2. Enhanced profiling of domestic smart meter customers, electrically heated hot water and/or storage heaters on a restricted hours tariff, (TC2aHW and TC2aHW+SW)[32]

This trial involved enhanced monitoring of customers with electrical immersion hot water heating or with immersion hot water heating and storage heaters and an existing Economy 7/10 tariff.

To gather the data required, in-line monitors were installed on both the immersion heater and the boost facility. Consumption data was recorded every 10 minutes. A hot water sensor and temperature strings (five sensors) were also installed to provide constant data on tank temperatures. Data was only available for four properties with immersion heaters alone and 13 properties with storage heaters (of which only eight had immersion heaters). As a result, the average profiles presented here will not be representative of the UK E7/E10 population as a whole. Instead, they should be interpreted as case studies, which can provide insights into the types of behaviour that individual consumers may exhibit.

Although specific data was not held on which tariff each specific customer was on, the average power consumption profiles broadly matched the profile of an E7 or E10 tariff. This is consistent with customers on these tariffs responding to the price incentives they provide. However, there were two exceptions. The average data for immersion heaters alone showed a peak at 8am, both during weekdays and at weekends. This may reflect a customer routine or an appliance setting. Second, both the hot water and storage heater profiles for properties that had both showed some power usage immediately after the morning off-peak periods have finished. It may be that this is the result of misconfigured appliances or meters. Storage heater use on all days was confined to the off-peak periods, probably reflecting appliance and/or meter settings.

### Network implications

Of the appliances monitored, washing machines and dishwashers offer the greatest flexibility in terms of time of use and our surveys suggest customers are prepared to be flexible. Few of the households studied had direct electrical heating and electrical water heating but these loads would merit further investigation into their potential for demand side response, as would the half of electricity consumption that was unattributed. It is worth noting that we looked for but could not find homes with on-peak electrical heating to take part in the trials. The findings suggest that other options worth exploring include efficiency of primary and secondary lighting, and upgrading gas boilers to reduce the need for direct electrical heating.

Our conclusion is that energy practices are important in understanding energy behaviour, and emphasises the need to gain a good understanding of how customers use particular appliances if their behaviour is to be influenced. This will need closer interactions between DNOs, suppliers and appliance manufacturers.

### Network implications

Our research has demonstrated that storage heaters, when combined with Economy 7/10 tariffs continue to be an effective means of reducing demand at peak times.

30 Sustainability First, What demand side services could household customers offer?, p.20
31 Sustainability First, What demand side services could household customers offer?, pp.26-27
32 In some CLNR supporting documents TC2aHW is referred to as TC10aHW and TC2aHW+SH as TC11aHW+SH

## 8.3. Enhanced profiling of domestic customers with air source heat pumps (TC3)

*This trial comprised ca. 340 domestic customers with air source heat pumps. Out of these, ca. 90 customers had sufficient quality heat pump data readings available over the one year period to be included in the analysis. There were a number of challenges recruiting customers for this test cell, but despite these challenges, this trial represented the largest UK trial with air source heat pumps to date.*

This trial comprised *ca.* 340 domestic customers with air source heat pumps. Out of these, *ca.* 90 customers had sufficient quality heat pump data readings available over the one year period to be included in the analysis. There were a number of challenges recruiting customers for this test cell, but despite these challenges, this trial represented the largest UK trial with air source heat pumps to date.

Heat pump consumption represented a significant additional electrical load compared to the rest of the house. The annual heat pump electricity consumption, averaged across all customers was 82% of the average annual household consumption in the baseline monitoring group (2,880 kWh for the heat pump alone compared with 3,498 kWh). This corresponded to an average annual load factor on the heat pump of approximately 9%-11%.

In the winter season, when household electricity demands were already high, the heat pump consumption was also the highest (both absolute and relative to the house consumption) due to the higher space heating demand. The trial results show that the average heat pump electricity consumption across customers in January was equivalent to 122% of the average baseline household consumption in January (13.96 kWh per day for the heat pump alone compared with 11.46 kWh per day).

Both household demand and heat pump demand are often highest in the winter evening peak period (4pm-8pm). For the evening peak period, averaged across customers for the month of January, the heat pump average electricity consumption is 102% of the average baseline household electricity consumption (3.17 kWh per day in the peak period for heat pumps compared to 3.11 kWh per day). Hence the overall effect of the heat pump is roughly double the electricity demand at the times when the electricity network is already likely to be experiencing high levels of demand.

The heating season half-hourly heat pump consumption profiles, averaged across customers and across each month, showed distinct morning (6am–9am) and evening (4pm–8pm) peak demands. These periods broadly coincided with the peak periods in house electricity consumption, as both are driven either by an increase in heating demand or appliance usage as people get up in the morning and arrive back home in the evening. For high or clustered uptake of heat pumps, this has implications especially for winter evening peak periods, when electricity demand is already highest. This impact could be reduced by using hybrid (gas and electricity fuelled) heat pumps or heat storage (which would have the effect of reducing the peaks).

In addition to the morning and evening peak period, the heat pumps in this trial showed a distinct peak in consumption around 3am. This is due to default timer settings for hot water heating. This is not inherent to heat pump operation and can be resolved by diversifying hot water charging times in the default settings of each heat pump.

The trial results show that the heat pump demand, when averaged across customers, increases much more quickly in the morning peak period compared to the evening peak period. With large or clustered uptake of heat pumps, this impacts network operation. It is often the case that load diversity is lower for appliances that are controlled by timers. Addressing this requires introducing other means of diversity (such as thermal storage, or automated randomisation).

The monitoring in this trial also included household electricity consumption. Although the consumption patterns were relatively similar to typical house profiles, the overall consumption level was significantly lower than the baseline average. This difference is to date unexplained, and hence caution should be taken with interpreting results from this data set.

The social science research indicates that participants may not always have made the best possible use of the heat pumps, and the research identified three key reasons for this:

- Customers found it difficult to understand the technology and how to operate it, both from a technical and an energy efficiency perspective

- There were no clear incentives to operate the heat pump in a specific way

- Customers were reluctant to 'interfere' with the heat pump operation

Take up of these new technologies could be supported by user friendly interfaces and a single point of contact for any issues with the appliance.

Despite incentives (shopping vouchers, free broadband and subsidy of the heat pump to make the cost comparable to a boiler) recruitment for this trial was particularly challenging.

> " The overall effect of the heat pump is roughly double the electricity demand at the times when the electricity network is already likely to be experiencing high levels of demand.

The changing regulatory framework, such as the delays to the residential Renewable Heat Incentive, meant that market uptake of heat pumps has been lower than anticipated. The social housing sector constituted a substantial proportion of participants due to additional funding available for social housing providers.

Heat pumps had a potential to improve heat services while reducing bills. Trial participants appreciated the quality of the heat and hot water provided and its use as a source of drying clothes as well as providing comfort. Concerns included whether running the system all day was most cost efficient and the perceived complexity of the technology (fearing their interventions would cause the system to break down).

### Network implications

As a heat pump load represent a near doubling of total household consumption, widespread rollout of the technology would present significant challenges to electricity systems. Technology solutions such as hybrid heat pumps or heat storage could reduce the impact, but future research is needed to understand technical feasibility, environmental performance and consumer acceptance. In the case of widespread heat pump deployment, steps may need to be taken to introduce diversity into heat pump operation, in particular the morning pick-up in demand.

The 3am spike is an important learning point. This is clearly a product-specific occurrence with heat pumps programmed to come on at that time (perhaps as part of a defrost cycle). The message for manufacturers, regulators and legislators is that it would be better to build diversity into the appliances e.g. by a random defrost time between 2am and 4am.

## 8.4. Enhanced profiling of domestic customers with micro-CHP (TC4)

The micro-CHP trial[33] investigated the enhanced profiling of domestic customers with a Baxi Ecogen Stirling engine (maximum heat output 6 kW, maximum electrical output 1 kW, an overall efficiency of 90%).

In each location, we monitored the electrical demand from and generation produced by the micro-CHP engine and the amount of electricity imported (or exported) from the grid by the house as a whole. Both were measured in average watts per measured interval, with measurements taken every minute. Trial monitoring began in December 2012 and ended in March 2014.

The micro-CHP generation profile has a high morning peak, and a lower, but longer evening peak, with the summer peaks being lower than the winter ones. The main effect of the use of the micro-CHP units was to reduce the average evening electricity demand peak by a few hundred watts in winter. The micro-CHP also generated electricity for export in the winter mornings, as heat demand drives micro-CHP export before morning electricity demand starts to rise.

This group was small in number, but exhibited a wide variation in electricity demand at peak from import of 2.5 kW to some trial participants exporting throughout the day.

### ⚡ Network implications

If micro-CHP becomes popular, the reduction in household load at peak could be significant for both network planning and electricity generation costs. The morning export peak could also impact on voltage levels. There would be benefit in a wider trial to establish more robust conclusions.

## 8.5. Enhanced profiling of domestic customers with solar photovoltaics (TC5)

Within this trial the maximum monitored number of customers was *ca.* 145, recorded in January 2013. The window of monitoring within the dataset was the full 12 months of 2013. During the year, customer numbers reduced marginally by December 2013.

On the day of peak export, participants in this trial group on average exported 1.3 kW at 12 noon. Export occurred in the six months April to September 2013, with July being the month of peak export.

Compared with trial participants with a smart meter but no PV, the following differences were statistically significant:

• Average annual gross electricity consumption was 700 kWh higher (4,216 kWh as against 3,507 kWh) and was significantly higher in nearly every month (but less so at weekends)

• Electricity consumption during the day was higher (at 30% compared with 27%)

• Average and maximum peak demand was higher (1.5 kW and 4.9 kW as against 1.2 kW and 4.2 kW, respectively) with the difference focused more in the summer months

In the absence of demographic comparisons, it is not clear whether the cause of higher consumption is the presence of PV or the presence of a higher income.

The results from the surveys and interviews indicated that, in general, PV ownership seemed to lead customers to more active ways of relating to energy. The individuals involved engaged in the calculation of their own energy use and production, as well as in monitoring and managing their use. For early adopters, the uptake and use of PV is being shaped by a new convention focused on investment and the potential financial returns from the feed-in tariff. On-site use of power was not widely recognised as a way to maximise financial benefits for PV owners.

Interviews conducted with participants suggested that the introduction of the in-home display created a shift in focus from export to using power when it is being generated. This creates an opportunity for network operators to engage with consumers to identify the potential and value of using PV power on-site and reduce the flow of PV generated power into low voltage networks.

### ⚡ Network implications

Despite the keenness of participants to use their domestically generated electricity, substantial exports of electricity took place with a peak around midday and therefore the potential to create voltage issues for networks. A technical paper has been produced on the diversity impact of PV, which concluded that the output of solar photovoltaic installations does diversify, because the panels point in different directions, and therefore produce their peak output at different times of day[34].

The monitoring results suggest that the existence of PV panels is associated with higher peak electricity demand and this may be relevant for network planning.

[33] CLNR-L086: Report on enhanced profiling of domestic customers with micro-CHP
[34] CLNR- L095: Technical note - Solar PV

## 8.6. Enhanced profiling of domestic customers with electric vehicles (TC6)

Around 150 EV-driving customers' had their total household and electric vehicle charging point demand monitored in a joint partnership between CLNR and Charge Your Car North Ltd (CYC), as well as via direct recruitment by British Gas. CYC operates a residential and public charging infrastructure provision in the Northeast of England, and recruited some of its residential charger customers to take part in the CLNR monitoring programme.

Although we collected demand data for both the household and the EV charger over an extended period from late 2012 to mid-2014, not all customers joined the trial and had monitoring equipment installed at the same time. From January 2014 there was both EV charging data and household demand data for over 100 customers. The analysis therefore relates to the period January to June 2014, and this limitation must be taken into account in understanding the findings.

There were 108 participants drawn from employees, or friends and family of employees, of Nissan Motor Manufacturing Ltd, in Sunderland. These individuals drove 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. However, these customers (generally working families, singles or couples) are assumed to be fairly representative of likely current and future EV owners.

Data from the trials were received as half-hourly kWh measurements from EV chargers, and as half-hourly average kW measurements from household metering. The household metering included all household demand except for the EV charger. The chargers were all 3.8 kW.

Amongst these participants, household electricity demand (exclusive of EV charging) was broadly comparable to typical households, perhaps with a rather higher proportion of peak to off-peak usage. The levels of average EV charger load (i.e. for each time period averaged across the data from the available participants) shows that at-home charging diversifies rapidly: i.e. the days and precise times on which participants charged their cars were fairly random (supported by the size of the standard deviations of the results).

Overall, charging tended to peak at around 8pm on weekdays with less charging during the day. Average peak charger demand on a weekday was around 0.9 kW in January compared with less than 0.4 kW in June (probably reflecting the extra charging associated with a car heater). Charging at weekends was less in total and less concentrated in the evening.

- The average daily energy consumption for an EV was 7.9 kWh in January 2014, which was the peak month. This steadily reduced down to 5.2 kWh by June 2014

- 96% of online survey respondents had a Nissan EV. 59% used their EV as a secondary car as against 36% using it as their primary car. EVs mainly came from an employer (67%) or were leased (31%)

- Some respondents would be interested in changing supplier to take advantage of cheaper/greener tariffs for charging the EV (57%)

- Charging was mostly done at night (61%) or when needed (14%) – when the battery is less than half full (39%) or less than a quarter full (27%). Open-ended answers suggested respondents charge regularly e.g. daily, when finished using it, or when near a charger

- 86% of respondents did not use timers; those who used timers did so to take advantage of off-peak electricity rates

Survey respondents told us the positive things about driving an EV were low running costs, the novelty, the driving experience and quietness. Negative experiences were range anxiety, availability of public charge points, cold weather driving, and battery life. EVs are typically owned by a working couple and used as a week-time car (work, daily commutes, school runs).

### Network implications

These results show that domestic charging of EVs has raised the level of domestic peak demand but that it is not yet a problem for network system design and operation. However, with greater geographical concentration or if there were more than one EV in a household, this would no longer be true. Furthermore, diversity could well be lower at particular times, e.g. pre-charging before bank holiday weekend.

EV users are already establishing habits to charge their car when it suits them and this may be difficult to break even with appropriate ToU tariffs. There is therefore a strong case for taking appropriate action to encourage off-peak charging behaviour at an early stage. At the time of recruitment to our project, there were insufficient EV users available for us to be able to test this proposition. Further work is needed to investigate ways of doing this.

In addition to the conclusions from the monitoring results above, the partnership with Charge Your Car led to a unique collaboration involving Newcastle University[35] and EV charging data from the Switch EV project. This explored domestic charging habits in rural and urban locations and their different impacts on the distribution network, which suggested that the impact on the network would be felt first in rural locations.

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# 9. DOMESTIC CUSTOMERS WITH DEMAND SIDE INTERVENTIONS

## 9.1. Domestic smart meter customers on time of use tariffs (TC9a)

*Ca.* 630 British Gas customers in Northern Powergrid's operating region transferred to the tariff during 2012 and agreed to be monitored through conventional smart metering at 30-minute intervals.

By comparing trial participants on the ToU tariff with smart meter customers in the baseline monitoring control test cell over the period from October 2012 to September 2013, we made several statistically significant findings:

- The average peak power demand during the 4pm to 8pm period (i.e. the average across the year for each customer of the highest half-hour demand each day within this time period) was lower on average, by 96 W (from 1.219 kW to 1.123 kW). When analysed by month, the difference in average peak power demand was statistically significant from November 2012 to March 2013 but not for other months

- The annual maximum peak during the 4pm to 8pm period (i.e. the highest half-hour recorded on any day of the year for each customer) was lower on average by 261 W (from 4.188 kW to 3.927 kW). Again, the difference is focused more on weekdays and in the winter months

- There was no statistically significant new increase in demand in either the period preceding or the period following the peak period on an annual basis, although there is scope for further analysis of the monthly data for the 2-4pm period[36]

- Annual energy consumption during the peak period was lower by 55 kWh (from 861.6 kWh to 806.6 kWh), with the difference focused on weekdays. However, there was no statistically significant difference in total annual electricity consumption (on average, about 3,500 kWh) between the two groups, despite the survey finding that three quarters of those ToU participants considered that they had made a slight or significant reduction[37]

- There was no statistically significant difference between the two groups in average peak demand at the half hour of highest aggregate demand

- Testing of demographic differences to the ToU tariff was limited to housing tenure (renter/home owner) and the presence of dependants in the household. Home owners and households without dependants were more likely to respond to the ToU tariff than renters and those with dependants

Trial participants were told from the outset that they had a safety net and would not lose money from the use of ToU tariffs. It is not clear what effect this had on behaviour. Trial participants were given no feedback about whether analysed, there was no feedback to participants on whether they were saving or losing money under the ToU tariff until the end of the trial. Some 40% of participants would have ended up with electricity bills higher than under a flat-rate (had they not been guaranteed that they would not lose money). Because an average customer making no changes to their behaviour would have neither gained nor lost from the ToU tariff, those who would have lost money were those whose monitored usage had a higher than average proportion at peak times. They may or may not have changed their behaviour in response to the trial.

The majority of people surveyed said they changed the timing of appliance use in response to the ToU tariff. Those who claimed to have changed their electricity use in response to ToU tariffs tended to be older, home-owners or those renting from registered social landlords, without a NEET (young person not in education, employment, or training) in the household, and/or a two person household. Most considered that they used less energy overall while on the ToU tariff. Laundry was identified by most respondents as an activity that they had moved to a different time. This was followed by washing dishes and cooking.

The vast majority felt the tariff was quite or very easy to understand. Those who found it quite difficult have a lower average age. In addition;

- Participants in this trial were told that they were protected from an increase in electricity bills, which were capped at the level they would have been at under a flat-rate tariff. An enhanced level of response might be expected in a trial without a 'safety net'

- As implemented, this ToU tariff rewarded a reduction in consumption during the peak period throughout the year - and was effective in doing so - but did not reduce demand at the times of greatest system peak demand. Alternative ToU tariffs, such as Critical Peak Pricing, might be tried as a way of reducing demand during these times[38]

- There was no difference in annual electricity consumption between ToU customers and trial participants with a smart meter alone. The trial was not designed to measure any impact from the installation of a smart meter itself

- Identifying traditional socio-demographic groups for commercial propositions may not be appropriate. Instead, it may be most appropriate to focus on 'socio-technical' groups (e.g. customers with high income, large houses, and 2+ fridges) or different kinds of 'flexibility capital' (e.g. shift workers, those with dishwashers that can be programmed)

- Realising value for DNOs from customers may require interventions in specific geographical/network areas

> **⚡ Network implications**
>
> The difference in peak demand seen in this trial is unlikely to be significant enough in itself to help with network planning. However, time of use tariffs could be used as part of a solution, or would help if imposed by another player, an energy supplier for example. Our advice is that a supplier would be unlikely to introduce a time of use tariff if there is no demand from a distribution network operator.

## 9.2. Domestic customers on the smart washing machine restricted hours trial (TC10a)

The restricted hours trial tested customers' willingness to accept a default time-based restriction on the use of a specific appliance, and the degree to which they exercised the override function that we provided. This combined the ToU tariff with an automated service that switched certain appliances off during the four hour peak period from 4pm to 8pm on weekdays, with technology provided to allow customers to override this automated service when they wished.

Trial participants received a smart washing machine and could set it to turn off automatically as peak time began, turn on automatically at the most economical time, or choose the most convenient time themselves. The trial participant could chose to pause the cycle or disable the energy control mode at any time without penalty.

The restricted hours operation and tariff appeared to be successful, the main findings were that:

- There was significant variation in the demand profile between weekdays and weekends, with the weekend peak at midday being nearly twice the weekday peak at 9am, probably correlating with higher occupancy rates and people having more time to do domestic chores

- When compared to the customers on the enhanced domestic monitoring trial (TC2a), customers showed a higher appliance demand in mornings and reduced appliance demand in the 4-8pm period. This is indicative that customers may have planned their appliance usage ahead of the peak period.

- There was evidence of increased consumption on weekdays after 9pm, indicating customers delayed use of the washing machine until after the restricted hours period

- Peak consumption from the appliances was around 2kW although a high degree of diversity means that the average annual peak consumption attributable to the appliances is less than 0.05kW in any half-hour period.

- Weekend consumption gave similar patterns in terms of a lower level of appliance use between 4-8pm even though the cheaper tariff applied across the full 48-hour period

Overall, trial participants responded positively to their new washing machines. In particular, the big drum meant fewer loads for some, it was more economical and the spin speed meant drier clothes.

> **⚡ Network implications**
>
> For those who had engaged the 'energy control', the trial successfully reduced load during the peak period. The peak that occurred following the end of the peak period could be reduced by the manufacturers including a randomisation element. The level of engagement was low and the reasons for this need further examination. If energy control buttons on washing machines become more prevalent, finding ways to encourage engagement could prove valuable in reducing peak load.

[36] The previously announced discovery of a reduction in load during the peak period accompanied by a new peak after 8 pm came from a small initial sample comparing behaviour before and after introduction of the ToU tariff

[37] Note that this compared smart meter users with a ToU tariff with those with a smart meter alone. It could not therefore take account of the change the installation of a smart meter would have

[38] Though our social science research suggests that this may not be the case, because the shifts come in change in routines/ practices, and critical peak pricing if not done 'routinely' will not lead to this shift. Where CPP is used, e.g. around air-conditioning, it has become habitual because it is used so often

## 9.3. Domestic customers on the smart washing machine direct control trial

This trial involved *ca*. 80 British Gas customers who received a smart washing machine worth approximately £1,000 and were installed for free.

Under the terms of the direct control proposition, up to a maximum of 15 interruption events could be called in any one year, between 4pm to 8pm on weekdays. During the trial, 11 events were called during March 2014. Each of these events lasted for four hours, from 4pm to 8pm.

An average of 4% of customers who received the signal delayed the washing machine cycle, while a further 12% ran their machines during the DSR period. This is consistent with DSR having an effect on behaviour. On almost a third of occasions when the user attempted to start a cycle on the machine during a received DSR event, they delayed it.

This is likely to underestimate the effect of the DSR events, since it is possible that users avoided starting cycles during the peak times, without using the delay function. By comparing the average washing machine power usage of individuals receiving DSR events to days without DSR events, we find a statistically

significant (at the 5% level) decrease in average power during the 4pm to 8pm peak window of 11 W (the decrease in average power used between the peak time of 6pm to 6:30pm is 26 W, although not statistically significant).

Due to communication failures, 37% of DSR events were not received by customers. This highlights the need for continuing technical developments to increase the effectiveness of this type of DSR. However, even including these customers, the fall in peak demand is almost statistically significant at the 5% level.

These results show that some consumers clearly do respond to events, although the small number of households interviewed asserted that there had been no change to their previous washing regimes. This discrepancy may reflect the fact that washing routines vary by household. For example, households which routinely carried out washing on weekends would be unaffected by the DSR events.

> An average of 4% of customers who received the signal delayed the washing machine cycle, while a further 12% ran their machines during the DSR period.

**Network implications**

Given the small numbers involved in the trial, any conclusions must be treated with caution. Nevertheless, this trial is ground-breaking as it has demonstrated the end-to-end process of a DNO successfully calling a response from a DSR supplier automatically using 'smart grid' systems and that direct control of appliances can reduce peak load, albeit not by much at present (partly due to the relative infrequency with which most households use a washing machine compared to other appliances such as heating). The technology is new and will improve. The small reduction in peak means that this intervention is unlikely to have much impact on distribution network planning. However, if the technology becomes more widespread (and particularly if mandated by product standards), this intervention could be of use for national system balancing.

## 9.4. Domestic customers with air source heat pumps on time of use tariffs (TC12)

This trial included 17 customers between 1 September 2013 and 1 May 2014.

The peak during the day occurred at 4pm at only 0.6kW, and consumption reduced from this level by 5pm. The elevated consumption in the 4-8pm period was much less marked than for the heat pumps with direct control (test cell 14). In contrast, the peak in test cell 14 occurred at 7-8am with a similar peak during evening at 7-8pm. While it is difficult to make a direct comparison between these two test cells, this could indicate the impact of a ToU tariff in displacing some consumption out of the peak time. However, the proportion of daily consumption during the peak time of 4-8pm was similar for both these test cells: 21% with ToU and 20% with direct control. With data for just seven trial participants for the entire trial period, there is unfortunately insufficient data to provide a statistically valid comparison with the group control group of air source heat pumps on unrestricted tariff (test cell 3).

We observed a significant peak in heat pump demand at 4am, in the same way that we observed a 3am peak in heat pump demand in test cell 3 and which was attributed to pre-set programming.

## 9.5. Domestic customers with air source heat pumps on direct control trials (TC14)

This trial comprised 17 domestic customers, including some non-British Gas and out of region customers. Participants received a DECC-subsidised ASHP installation, worth an average of £3,500 and a year's free broadband worth £277.

Because of the difficulty with finding suitable and willing participants despite a national recruitment campaign, some of the participants were recruited from among the staff of the project partners, and the participants may not therefore be representative of the wider population as a result of their relationship to the energy industry. Given the small size of this trial, the high level of the subsidy received on joining and the fact that recruitment for this trial was not random the learning that can be drawn from this test cell is largely qualitative in nature.

All participants were supplied with a 'smart grid enabled' ASHP, which included integrated direct control functionality and 10-minute load monitoring. This was supplemented by additional heat meters and temperature sensors. A thermal store was also installed, to provide heat when the heat pump was switched off during 'direct control' mode and reduce load.

Data collected in this trial suggests that heat pump electricity consumption has two distinct peaks – one of around 2 kW in the morning, and then a smaller one (1.5 kW) in the evening. This profile is different to the sample profiles published in DECC's heat pump trials, and may reflect a particular characteristic of the operation of these heat pumps with storage (for example, these may be the times when priority is given to charging the heat store).

Over a 36 day period during the peak heating season in February and March 2014, 14 interruptions were called. The first four interruptions lasted half an hour. Thereafter the interruptions lasted an hour. Four events were called between 4pm and 4.59pm, two events were called between 5pm and 5.59pm and eight events were called between 6pm and 7pm. All interruptions were called on weekdays.

The equipment used for this trial would cancel the interruption if the consumer adjusted their thermostat during (or immediately before) the interruption. Consumers may have therefore inadvertently cancelled interruptions, and further research into the user interface for thermostats could be helpful to determine whether this was the case. Nevertheless, interruptions were successfully carried out the majority (67%) of the time. For those customers that did not cancel the interruption (during three interruptions occurring between 6pm and 7pm), electricity consumption fell close to zero during the time of the intervention (compared to around 1.5 kW on days without DSR events). We carried out 21 semi-structured interviews with domestic customers but found that the negative experiences of overcoming a new technology made it impossible to explore their reaction to the interventions.

**Network implications**

The existence of peak loads in the morning and early evening on non-intervention days and the peak immediately following an intervention suggests a particular characteristic of the type of ASHP with thermal storage used. This characteristic, together with the mixed attitude of customers and the additional space requirement for the thermal store, limits the potential benefit of this intervention at present. Nevertheless, the trial has been ground-breaking, using innovative equipment, and clearly demonstrates the technical potential for this intervention. The size of the peak reduction makes it of interest to a DNO, but the utility of the intervention will depend on what cost the DNO would have to bear, and whether the large payback spikes can be mitigated.

## 9.6. Domestic solar PV customers with automatic in-premises balancing for hot water charging (TC20 Auto)

We carried out trials of two separate solutions to load-balancing within the customers' premises.

The first trial used hot water heating, engaged automatically without the need for user intervention. The main findings were:

- Households on the automatic balancing trial showed higher self-consumption of electricity generated on-site (87%), compared with those on the manual balancing trial (79%)

- Average annual gross electricity consumption for these customers was 5,352 kWh, which is 14.5% higher than for the PV customers with manual balancing. It should be noted that households in both load-balancing solar trials had higher annual energy consumption compared with the baseline domestic trial (TC1a)

- The average annual PV generation was 4.9% higher than for manual balancing customers at 2,019kWh compared to 1,925kWh

- On the day of lowest demand the peak export was lower in the automatic trial (1kW) compared with the manual balancing trial (1.3kW)

These effects may not entirely be due to the effect of the automatic balancing system and may be due to demographic differences; however changes in consumption were seen to correlate with PV output, with evidence of increased consumption on sunny days.

Energy export was about half that for manual balancing customers at 209kWh compared to 413kWh. While this might suggest that the automatic balancing is more effective at managing export, it should be noted that the significantly higher average annual consumption for the automatic balancing customers could equally explain the relatively low level of energy export.
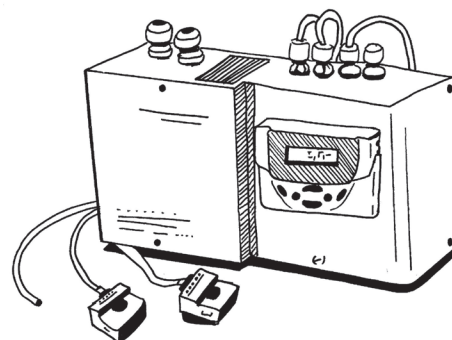
## 9.7. Domestic solar PV users using in-home displays for manual in-premises balancing (TC20 IHD)

The second trial used an in-home display (IHD) to provide a visual stimulus that net exporting was occurring, so customers had an opportunity for load-balancing.

Compared with trial participants with a smart meter but no PV, the following results were statistically significant:

- Average annual gross electricity consumption was 1,170 kWh higher (4,675 kWh as against 3,507 kWh) and was significantly higher in nearly every month (but less so at weekends)

- The proportion of electricity consumption which took place during the day (10am-4pm) was higher (at 30% compared with 27%)

- Average and maximum peak demand was higher (1.6 kW and 4.9 kW as against 1.2 kW and 4.2 kW, respectively) with the difference focused more in the summer months

There was, however, no significant difference in any of these variables between trial participants with PV and manual in-premises balancing and those with PV alone.

In the survey and interviews, participants said that, through the use of the IHD's traffic light display, they had made shifts in laundry and dishwashing. However, on the basis of the monitoring, manual in-premises balancing would be unlikely to make a significant contribution to DSR.
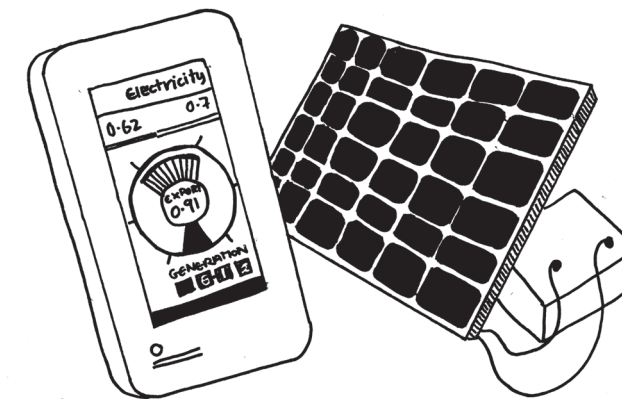
# 10. SMALL AND MEDIUM-SIZED ENTERPRISES

## 10.1. Basic profiling of small and medium-sized enterprise customers (TC1b)

This dataset provided half-hourly smart meter data in kW for a range of SME business customers. The published dataset covers a monitoring period of one full year from 1 September 2011 to 30 August 2012 with a total of *ca*. 1,500 customers.

SME consumption per customer 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 demand profiles of individual SMEs also vary to a much greater extent than households. They are heterogeneous in terms of their business activities, and hence also in terms of their overall demand for power and the timing of that demand during the day. This heterogeneity presents particular problems when trying to extrapolate conclusions from the trials to the wider SME market.

For SMEs, the daily demand profile tends to be shaped differently to that of domestic consumers. Weekday demand is characterised by high demand between 9am and 5pm, with no early evening peak. The peak demand generally is spread across the standard working day of 8am to 5pm. Power demand is driven by the firm's specific business activity, which for many activities, may be relatively more constant throughout the working day. Weekend demand has a peak until early afternoon.

Many businesses consume less electricity per hour during the early evening peak than during the day or at night. Smaller businesses tend to consume a higher proportion of their total electricity in the early evening peak. Larger businesses consume more evenly across the 24hr period.

There is some seasonal variation, but this is not as marked as for domestic premises. Seasonally electricity demand for SMEs is highest in January and February, whereas the peak for domestic occurs in December. It is highest for commercial and office enterprises and lowest for those in the public sector and other industry classifications. This means that the kind of business with the highest electricity demand could be those

involved in the wholesale and retail trade, hotels and restaurants, transport, storage and communication, financial intermediation, real estate, renting and business activities, while the lowest consuming group included education, health and social work, other community, social and personal service activities.

The largest firms do not necessarily have the highest power demand. In terms of business size, organisations with 10 to 49 employees had proportionately the highest demand (more than those with 50 to 249), suggesting that the relationship between number of employees and electricity demand is not linear.

On the day of greatest network stress, the mean peak demand was 6.2kW between 10am and 2pm.

From the surveys and interviews, most SME trial participants think reducing energy use is important (72%), but most have no environmental policy or don't know whether they have one (90%). Some have sought professional energy advice (32%).

Some businesses operated 24-hours a day and many are open at weekends. Most own their own premises (68%). Most do not have a display energy certificate (72%). Most have central heating (69%). Half have programmable thermostats. Energy use is dominated by lighting, administration and office equipment, cooling and heating equipment. Some processes are re-schedulable but not interruptible. Some businesses have intermittent demand for high loads that could be flexible. Interconnectedness is seen as critical.

Many had installed at least one energy efficiency measure. Most popular were double-glazing, loft insulation and cavity wall insulation. Only two trial participants had installed some micro-generation i.e. solar panels.

> "
> SME consumption per customer 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.

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🌲 **Network implications**

These findings are important in an area where little research has been done to date and where the data that does exist is poor. Because of the considerable variability in the SME community, the overall results themselves do not have implications for network planning or operation, but provide an important baseline. However, the fact that most SMEs do not contribute significantly to the evening peak is important. There could be value in targeting those that do have an evening peak.

## 10.2. Enhanced profiling of small and medium-sized enterprise customers (TC1b)

This test cell monitored up to 80 British Gas customers, all with smart meters. All participants already had a smart meter installed or were scheduled to do so. Data and technical information was provided at 10-minute intervals for the total meter load and the disaggregated for loads beyond the meter, which accounted for over 50% of on-site consumption.

The trial did not stipulate any changes to supply tariffs. The participants therefore remained on their existing tariff and were able to renew their contract during the course of the trial should this be required.

Detailed demand profiles were collected as part of this trial for a range of different appliances used by SMEs. We were interested in the following two questions for each appliance in relation to their potential for DSR:

- Does the demand profile suggest there is sufficient demand in the peak hours currently to shift?
- Could this load be interrupted and moved outside of the peak period?

The trial has produced detailed demand profiles for 11 different technologies across six different SMEs. Therefore for some of the SMEs there is data for more than one load or appliance.

| Appliance | Profile |
|---|---|
| **SME1 – Heater** | This heater is set to be on mostly between the hours of 5am and 9am. This is indicative of a form of storage heating, which could have the potential to be set to run at different times. In particular, this heater is currently set to run during the network peak (4pm and 8pm). If this is a common feature of SME heating systems, there may be benefits available to DNOs if it is possible to delay the start time of these systems. |
| **SME2 – Air conditioning** | Demand for air conditioning by this firm is a diurnal activity; concentrated between 8am and 8pm. Usage of the air conditioning, while present in the evening peak period, is often tapering down between 5pm and 8pm. The peak usage is focused on the weekend, suggesting the activity of this firm may relate to a leisure activity. The potential for weekday reductions in peak demand is still present but much reduced compared to the weekend. Demand is very weather dependent, so winter demand is considerably lower, and so air conditioning demand from this firm does not correlate well with winter system peaks, suggesting that this type of appliance is not a strong candidate for DSR. However there may still be value for managing summer peaks (for instance, in central London). |
| **SME3 – Chillers** | Typical for a refrigeration load, the power cycles rapidly throughout the day, with greater demand between the hours of 7am and 8pm. Demand is therefore high throughout the evening peak suggesting there is some potential for load shifting. Intuitively demand should increase in warm weather, and this seems to be borne out in the data although it only has a small effect, with demand remaining high in each of the seasons. The firm had a consistent pattern of demand between weekdays and weekends suggesting it is operating seven days a week e.g. a retail business. In winter the average demand during the peak remains high with limited variability around the mean. This suggests there is some potential for load shifting if the chillers can be switched off earlier than currently is the case, without any adverse impact on the refrigerated products. |
| **SME3 – Shop floor fridges** | The demand for power from the fridge units is volatile during the day as is typical for this type of load. There is greater demand between the hours of 6am and 9pm, likely to be consistent with the opening hours of the business. Demand is therefore high throughout the evening peak. The profiles do seem to be weather dependent to a small degree with the highest demand in the high summer period. The pattern of demand is consistent between weekdays and weekends. In winter the average demand during the peak remains high suggesting there is potential to shift demand for short periods of time provided the business can be assured of the refrigerated product quality being maintained. |

| Appliance | Profile |
|---|---|
| **SME3 – Fridges walk in** | The results are different to those of the chiller, and fridges on the shop floor, despite being from the same firm (perhaps suggesting that in this case the heat exchanger is external and operates at ambient temperature, while the others exhaust within the building). There is still considerable volatility as is expected for a fridge, but these fridges have their highest demand during the night. This suggests that they may be used for restocking of the retail business overnight, and are less likely to be accessed during the working day. Throughout the peak period therefore the potential for DSR is considerably less. Although this is a refrigeration technology it has a very different profile to other fridges used by the same SME. This suggests that there are a broader set of factors which also determine the degree of flexibility potential, beyond simply the appliance itself. |
| **SME3 – Lighting** | The power demand does not vary to a large extent by day of the week or season. In one sense, the potential for DSR is high since demand is constant throughout the evening peak. This varies little during the winter period, as evidenced by the very small confidence interval around the mean, but the potential can only be realised if lighting can be reduced without impact on the retail experience for customers. |
| **SMEs 4 and 5** | Both provided examples of an intermittent high power load (such as a welder or a table saw). There may be more potential for these 'high power' practices to be flexible and therefore amenable to DSR interventions. The loads are generally focused during working hours, and the variability of when they will be used is high. However, they also usually fall outside of the evening peak periods suggesting their usefulness for DSR may be limited. |
| **SME6 - Swimming pool** | The pool is heated between 5pm and 7am in winter, and 7pm and 5am in the summer. It then effectively retains its heat during the day, leading, with a high degree of certainty, to a significant increase in demand during the winter evening peak period. As a result there could be benefits if the heating of the pool could be delayed until after the evening peak.<br><br>The overall company-wide load was also monitored. In 10.1 above, we found that, for SMEs, the daily demand profile tends to be shaped differently to domestic consumers, with a less pronounced evening peak. Power demand is driven by the firm's specific business activity, which for many activities, may be relatively more constant throughout the working day. Although the sample size here is much smaller, a similar picture is visible. |

### Network implications

These results provide valuable new information about detailed SME loads. Some loads, such as lighting, are less susceptible to demand side management, although lighting load could be reduced significantly through timers, motion sensors, and energy efficient lighting such as LEDs. The operation of others, chillers for example, can be moved out of the peak if working priorities permit. There is also scope for better energy management, for instance setting timers to begin operation after the peak period. Whilst these interventions would reduce electricity consumption in peak periods, there is no evidence yet that they would contribute to reducing peak load and so there may be no specific network benefits.

## 10.4. SME customers with restricted hours tariff (TC10b)

The restricted hours trial was designed to look at the impact of the same 3-rate ToU tariff used in test cell 9b and was therefore constructed in the same way. However, it also included the restricted use of electricity consuming equipment during the super peak period, although the customer could override. For the direct control trial, it was intended that SMEs' disaggregated loads would be made available for direct control by the network operator

It was extremely challenging to recruit for these test cells. While this limited the insights from customer behaviour under the tariff from this test cell, we have gained significant learning about the problems associated with recruiting SMEs for DSR trials. Over 20,000 SMEs were approached about participating in CLNR trials. Despite the fact that several hundred expressed an interest in participating in the restricted hours and direct control trials, only two businesses actually joined the restricted hours trial and none joined the direct control trials.

Difficulties in securing SMEs' involvement in these trials were driven by the risks they perceived about the impact of electrical interruption on the daily running of the business. Feedback suggests that unwillingness to join in the trial did not reflect a fundamental opposition to the principles of the project as a whole, which was evidenced by many of those approached participating in other test cells.

SMEs cited a number of reasons why they were concerned about uncertain electrical interruptions:

- They were service providers and the hours and the type of process used were controlled and driven by their clients, and there was little or no movement on these time frames

- The need to capture passing trade in the case of shops, restaurants, hotels and public houses, as well as retaining clients, requires flexibility in opening times

Regulatory concerns were central for a lot of SMEs:

- In the farming sector animal welfare is a major concern and is governed by the requirements of DEFRA and other agencies; and

- Within hotels, public houses and restaurants the need for environmental and Health and Safety requirements is a major consideration. For example the need to prevent the loss of hot water in toilets, safely store prepared foodstuffs and avoidance of prosecution due to infringement of regulations or personal injury

In addition to concerns about electrical interruptions, there was also a range of practical issues which limited participation. For example, many of the SMEs who initially expressed an interest in participation failed the physical survey to check the state of installation for metering equipment. Similarly there were issues with change of ownership on the site or security issues around the equipment.

**Two customers signed up to the restricted hours tariff:**

- A hospitality business, where the interruptible load was a chiller unit in a beer cellar; and

- An office, where the interruptible load was an immersion heater (unfortunately, the data collected displayed irregularities that meant it could not be robustly analysed)

Both of these types of load involved thermal processes (cooling or heating) which store energy. They were therefore well suited to load interruption.

The chiller unit was automatically switched off every day during the super peak hours (4pm to 8pm), unless the hospitality business chose to override this signal. It is evident from the monitoring that the DSR generally worked: load during the 4pm-8pm window is almost always zero. Closer examination of the data reveals that there were only three occasions on which the business owner used the override and ran the chiller. Two of these occurred within the first week, and one on the final day. They could therefore represent technical issues in setting up the timer. Absolutely no usage of the chiller occurred in the intervening 214 days, despite the increasing temperatures in summer. Although we can't be sure of the temperature of beer, this is evidence that the owner was satisfied with the temperatures achieved.



### 10.3. SME smart meter customers on time of use tariffs (TC9b)

This grouping was constructed in exactly the same way as that in 10.2, but for a different set of SMEs. During the course of the 12-month monitoring period each participant was placed on a static 3-rate time of use tariff. The tariff structure varied throughout the day with prices around 80% higher in the super peak period compared to the day time, and varied slightly depending on the profile class of each SME. However, the rates were not dynamic, i.e. they did not change at short notice and were fixed for the whole 12-month monitoring period.

Because of the heterogeneity of the participants, any comparative assessment is only possible by comparing the performance of the same SME with and without the ToU tariff. Unfortunately, we had such data for only one SME.

#### Network implications

There is clearly interest from SMEs in ToU tariffs and so further work would be useful. However, it demonstrates the need, because of the heterogeneity of the SME community, to conduct monitoring both with and without the ToU tariff for the same SME.

#### Network implications

Albeit from a final sample of one, it is evident that restricted hours DSR can be successful in reducing load during the peak window. This potentially is of use to both suppliers and DNOs. The difficulty remains in recruiting suitable SMEs and meeting their concerns about being able to continue operating their mainstream business despite the intervention.

# 11. CONCLUSION, LESSONS LEARNT AND IMPLICATIONS FOR DNOS

## 11.1. Lessons learnt about the conduct of large-scale customer trials

Some 13,000 GB electricity customers took part in the CLNR project, making it one of the largest investigations into customers' electrical usage and behaviour in the world. Aside from the importance of the research findings from the project, there are valuable lessons to be learnt from the experience of carrying out such a project.

The project brought together a unique group of partners to deliver an integrated trial that focused on the customer and network side of the smart grid issue. In so doing, it had to work across boundaries and cultural differences both in the energy industry itself and between the industry and the range of academic disciplines that were involved.

The industry and regulator are often criticised for being too conservative, and not having sufficient capacity to innovate. CLNR trialled a whole host of social and technical innovations on real networks, with real customers and in real-time. With innovation comes risks, both of failure and delay. We addressed these risks as they arose and found ways to deal with the challenges caused. It is important to ensure that the project management is capable of reacting in an agile way to areas of uncertainty. Three key areas where we had to be flexible in our approach were; the recruitment of trial participants, installation of smart appliances and monitoring equipment and data recording and analysis.

A number of issues arose which affected the recruitment of customers to the trials. We considered it important to document the ways in which we addressed these challenges and the lessons they provide for the future projects and so we commissioned a report on our trial recruitment process[39].

**Our key observations were:**

- The high ambition level of the project has driven innovative approaches towards successful test cell recruitment and brought forward creative and workable solutions. This high bar for the project from its inception, should also deliver a strong dividend from the project in terms of new insights, lessons and outcomes

- Despite the technology-related challenges in filling some test cells, there were also a number of instances in which the trial team anticipated customer problems which in the end did not materialise.

Rather than second-guessing customers' possible negative responses, focus groups and/or similar small-scale customer exploration might help to avoid unduly 'low expectation' in design of possible 'customer offers'

- A trial with such a large number of test cells, and demographic and technical sub-groups within those test cells, adds significant complexity. A balance needs to be found between testing a sufficiently varied range of options and real-world constraints

- Working with a recognised and respected university gives the trials credibility and encourages customer participation

- Inclusion of smart meters (and IHDs) in the trial-offer does seem to make the offer more attractive in recruiting participants

- Domestic customers are interested in time of use (ToU) tariffs and also in exploring tariffs involving restricted use and direct control. It needs to be clarified how far this interest extends further to other customers who might have to change usage patterns significantly to benefit

- SMEs contacted expressed initial keen interest in the prospect of lower bills. However, in the end the firms contacted were not amenable to remaining with the trial for restricted hours or for direct control tariffs

- There is an appetite among PV owners to enhance the use of their PV units

During the project several issues arose in relation to installation of smart appliances and monitoring equipment:

- Arranging times for installation proved to be difficult as it often involved people having to take time off work.

- Installation of secondary monitoring equipment (which was needed for non-British Gas customers) often 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

- Many premises did not have access to broadband or even a telephone land line. This is important for the future installation of smart appliances

- Smart appliances are still at an immature stage. There are issues of compatibility between devices and manufacturers, and communications issues

Inevitably, with such a large project, data issues arose. These included failure of data communication in customers' premises, data compatibility issues between project partners and the amount of effort needed to get the data into a suitable state for analysis. For future projects, a data manager, whose role would be to ensure the end-to-end integrity and compatibility of data flows, would be advisable.

> " CLNR trialled a whole host of social and technical innovations on real networks, with real customers and in real-time. With innovation comes risks, both of failure and delay. We addressed these risks as they arose and found ways to deal with the challenges caused.

## 11.2. Implications for DNOs

**Understanding of current, emerging and possible future customer (load and generation) characteristics**

The basic and enhanced monitoring of customers with smart meters has provided valuable information about domestic consumer load profiles and their make-up. The data created an overall picture of current domestic electrical energy consumption in the UK. This has been used to provide a key input to the recommendations to update ACE49[40]. The enhanced monitoring provided a more detailed picture of the make-up of domestic demand than had been available previously. It was larger and more recent than the Household Electricity Survey (HES). The data, together with the results from the survey and interviews, also provided a baseline against which to measure the impact of the installation of LCTs and/or various types of customer intervention.

Of the domestic appliances monitored, washing machines and dishwashers offer the greatest flexibility in terms of time of use and our surveys suggest customers are prepared to be flexible. We had limited data on direct electrical heating and electrical water heating but these would merit further investigation into their potential for demand side response as would the half of electricity consumption that was not attributable to monitored appliances.

Enhanced monitoring of LCTs provided important new information to assist system planning as increased numbers of LCTs are introduced. Micro-CHP led to a small reduction in the evening peak, but of limited significance for system planning. The network impact of

concentrations of ASHPs and PV is dealt with in our optimal solutions for smarter network businesses report, but the suggestion from the monitoring that the existence of PV panels is associated with higher peak electricity demand may need to be taken into account in network planning.

Domestic charging of EVs has raised the level of domestic peak demand but is not yet a problem for network system design and operation. However, with greater geographical concentration or if there were more than one EV in a household, this would no longer be true. Research suggests that the impact on the network of EVs would be felt first in rural locations and EV users are already establishing habits to charge their car when it suits them and this may be difficult to break, even with appropriate ToU tariffs. There is therefore a strong case for taking appropriate action to encourage off-peak charging behaviour at an early stage.

We also discovered effects apparently associated with equipment used. The ASHPs had a 3am demand spike. The heat pumps with thermal storage had peaks in the early morning, early evening and after a planned interruption. It would be desirable to work with the manufacturer to find ways to avoid this.

**To what extent are customers flexible in their load and generation, and what is the cost of this flexibility?**

For a DNO, what is needed in terms of customer flexibility is a lower level of load at times of particular network stress, for example

at network peak or after an interruption. It also needs to be specific to the location of network stress. A reduction in electricity consumption at other times, even if this occurs during the early evening period, is of less interest.

The ToU trial, while encouraging a lower level of electricity use over the 4pm to 8pm period compared with the control group, did not result in a lower level of peak demand significant enough in itself to impact network planning. However, ToU could be used as part of a solution or would help if imposed by another player e.g. an energy supplier. Alternatively, critical peak pricing might lead to a more significant response.

The use of Economy 7 and 10 tariffs are effective in conjunction with storage heaters in reducing demand at peak. There was insufficient evidence to determine their impact on electrical water heating.

Given the small numbers involved in the smart washing machine direct control trial, any conclusions must be treated with caution. The small difference in peak means that this intervention is unlikely to have much impact on distribution network planning. However, if the technology becomes more widespread (and particularly if mandated by product standards), this intervention could be of use for national system balancing.

[39] CLNR-L036 Lessons learned from trial recruitment: Customer-Led Network Revolution trials
[40] CLNR-L185: Review of the distribution network planning and design standards for the future low carbon electricity system

Direct control of ASHPs with thermal store highlighted the existence of peak loads in the morning and early evening on non-intervention days and the peak immediately following an intervention. This suggests a particular characteristic of the type of ASHP used. This limits the potential benefit of this intervention at present. Nevertheless, both direct control trials have been ground-breaking, using innovative equipment and clearly demonstrating the technical potential for this intervention. The size of the peak reduction in the case of the ASHP makes it of interest to a DNO, but the utility of the intervention will depend on what cost the DNO would have to bear.

While the average annual PV export in TC20Auto is half that of TC20IHD, significant differences in baseline consumption between the two test cells means it is not possible to identify automatic balancing as being the reason behind the reduction in export. More work is required in this area.

Our commercial arrangements report examines, in the light of our findings, the role of the various customer-led interventions and their value to the electricity system, especially for DNOs[41]. Our conclusion in relation is that there were no major barriers to implementation of domestic DSR, although there are pre-requisites to enabling roll-out as business as usual. These were smart metering, three-rate distribution use of system (DUoS) tariffs and modified settlement codes. Clear incentives for suppliers to offer the tariffs and for customers to take them up are needed. Domestic ToU tariffs are expected to become more prevalent toward the end of ED1 and into ED2 price control periods.

**SMEs**

Our findings are important in an area which has been little studied in the past and where data is poor. Some loads, such as lighting, are not susceptible to demand side management. Others have the capability of being moved from peak time if working priorities permit. There is also scope for better energy management, for instance setting timers to begin operation after the peak period. Whilst these interventions would reduce electricity consumption in peak periods, there is no evidence yet that they would contribute to reducing peak load and so there may be no specific network benefits.

Although few conclusions on the impact of ToU or restricted hours tariffs on SMEs can be drawn from our trials, there is clearly interest from SMEs in ToU tariffs and so further work would be useful. However, it demonstrates the need, because of the heterogeneity of the SME community, to conduct monitoring both with and without the ToU tariff for the same SME. The restricted hours tariff trial was successful in reducing load during the peak window. This potentially is of use to both suppliers and DNOs. The difficulty remains in recruiting suitable SMEs and meeting their concerns about being able to continue operating their mainstream business despite the intervention.

Because of the considerable variability in the SME community, the monitoring results themselves do not have implications for network planning or operation, but provide an important baseline.

## 11.3. Implications for electricity suppliers

Electricity suppliers have different needs in relation to demand side response from DNOs. They are interested in reducing electricity consumption at times when generating costs are high and they can aggregate the responses achieved over a wide geographical area.

Since static ToU tariffs have been demonstrated to reduce the amount of electricity consumed during the peak period, this could prove to be of value to suppliers. An enhanced level of response might be expected in a trial without a 'safety net'. Given the lack of different response between demographic groups, it may be that using traditional socio-demographic groups to test commercial propositions may not be appropriate. Instead, it may be most appropriate to focus on 'socio-technical' groups (e.g. customers with high-income, large houses, and 2+ fridges) or different kinds of 'flexibility capital' (e.g. shift workers, those with dishwashers that can be programmed).

On the 'smart' proposition, customers are more accepting of new, complex and innovative technology, propositions and tariffs than might have been anticipated. The mass take up of residential heat pumps in the 'able to buy market' is not likely in the short-medium term and debatable in the long term. The penetration of EVs is similarly uncertain. Through CLNR we have a much greater understanding of smart/connected home communications technology and the challenges with big data analysis. We gained insights into the skill sets that might be required from the 'engineer of the future' who will require ICT skills. We have learnt the importance of working with the technology manufacturer for DSR appliances and the subtleties of implementing a solution that is acceptable to customers.

[41] CLNR-145: Commercial Arrangements Report

# APPENDIX 1: A GUIDE TO THE TEST CELLS

| | Test Cell | Description | Customer Type | Load | Intervention |
|---|---|---|---|---|---|
| **Learning outcome 1: Existing and future load and generation** | TC1a | Basic profiling of domestic smart meter customers | Domestic | General | None – monitoring only |
| | TC1b | Basic profiling of small and medium sized enterprise (SME) customers | SME | General | |
| | TC2a | Enhanced profiling of domestic smart meter customers | Domestic | General | None – detailed monitoring only |
| | TC2a HW[42] | Enhanced profiling of domestic customers with electric hot water immersion heating | | General, with electric hot water immersion heating | |
| | TC2a HW+SH[43] | Enhanced profiling of domestic customers electric hot water immersion heating and storage heating | | General, with electric hot water immersion heating and storage heating | |
| | TC2b | Enhanced profiling of small and medium sized enterprise (SME) customers | SME | General | |
| | TC3 | Enhanced profiling of domestic customers with air source heat pumps | Domestic | Heat pump | None – monitoring only |
| | TC4 | Enhanced profiling of domestic customers with Micro-CHP | Domestic | Micro-CHP | |
| | TC5 | Enhanced profiling of domestic customers with solar photovoltaics (PV) | Domestic | Solar PV | |
| | TC6 | Enhanced profiling of domestic customers with Electric Vehicles (EVs) | Domestic | Electric vehicles | |

| | Test Cell | Description | Customer Type | Load | Intervention |
|---|---|---|---|---|---|
| **Learning outcome 2: Customer flexibility** | TC9a | Domestic smart meter customers on time of use tariffs | Domestic | Regular | |
| | TC9b | SME smart meter customers on time of use tariffs | SME | Regular | |
| | TC10a | Domestic customers on the smart washing machine restricted hours trial | Domestic | Regular | |
| | TC10b | SME customers with restricted hours tariff and customer override | SME | Regular | |
| | TC11a | Domestic customers on the smart washing machine direct control trial | Domestic | Regular | |
| | TC12 | Domestic customers with air source heat pump on time of use tariffs | Domestic | Heat pump | |
| | TC14 | Domestic customers with air source heat pumps on direct control trials | Domestic | Heat pump | |
| | TC20 Auto | Domestic solar PV customers with automatic in-premises balancing for hot water charging | Domestic | Solar PV | |
| | TC20 IHD | Domestic solar PV customers using in-home displays for manual in-premises balancing | | | |

[42] Some CLNR documents refer to TC2aHW as TC10aHW
[43] Some CLNR documents refer to TC2aHW+SH as TC11aHW+SH

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# APPENDIX 2: EQUIPMENT INSTALLED

## Whole house/premises monitoring

For all trial participants involved in the trials, there was a project design requirement to collect whole house/premises electricity consumption, import and export. Depending on the trial and the technology, building, communication or operational constraints, this was collected in one of three different ways:

1. **A smart meter**, installed by British Gas Smart Metering as part of its smart meter foundation programme. The smart meter collects half hourly consumption data in kWh, via British Gas' smart meter head end system.

2. **A non-fiscal secondary** meter, installed by British Gas' installation partners on the project, Passiv Systems. This meter collects import/export data in kWh on either a 10-minute or one minute resolution, dependant on the trial via Passiv System's zigbee enabled hub and communicated either via broadband or 3G modem. The installation of this type of meter required the installer to isolate the customer's electricity supply via a double pole isolation switch which must be installed only by a regulated meter operator appointed by the customer's electricity supplier.

3. **A non-fiscal polymeter**, installed by British Gas' installation partners on the project, Passiv Systems, at the customer's consumer board, collecting import/export in kWh at a one minute resolution from up to 16 individual circuits in the home

## Individual loads

Many of the trials required the collection of electricity consumption/generation from an individual load, such as an appliance or low carbon technology; this data was collected in one of three different ways:

1. In-line meter or smart plugs also installed by Passiv System collect import/export data in kWh on either a 10-minute or one minute resolution (dependant on the trial) via **Passiv System's zigbee enabled hub** and communicated back to **Passiv's Head End System** either via broadband or 3G modem.

2. Smart washing machine. **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. Both British Gas and appliance manufacturer Indesit both felt it was in the best interest of customers to implement a simple customer override of all automatic scheduling.

3. Smart heat pump. '**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 four hours of the evening peak for a three bed semi in the North East, the thermal store also improves efficiency, increasing economic benefits compared to alternative heating methods.

### PV within-premise balancing

**Coolpower's EMMA system** was installed by British Gas' installation partners on the project, Solar and 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.

### In Home Displays (IHDs)

Two types of IHDs were used throughout the trials:

1. **Landys+Gyr Eco Meter.** Trial participants would have been provided a Landys+Gyr Eco Meter IHD at point of installation of their smart meter by a British Gas Smart Energy Expert. Using this IHD, customers can view the cost of energy they are using over the last week, the last 28 days or the last year, they can also see their carbon emissions over different periods of time. The IHDs are also equipped with traffic lights to make it easy to see how much electricity they are using. A red light means a customer's energy usage is high. If it's green, then it's low. The IHD also has a blue light, which notifies of a message that has been sent to the device by British Gas.

2. **Passiv Controller.** Trial participants on the (test cell 20IHD) were provided with an IHD from British Gas' installation partner on the project, Passiv Systems 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 advises them to use this in their home, rather than exporting to the grid.



Test Cell 20a:
Installed devices
diagram of main components
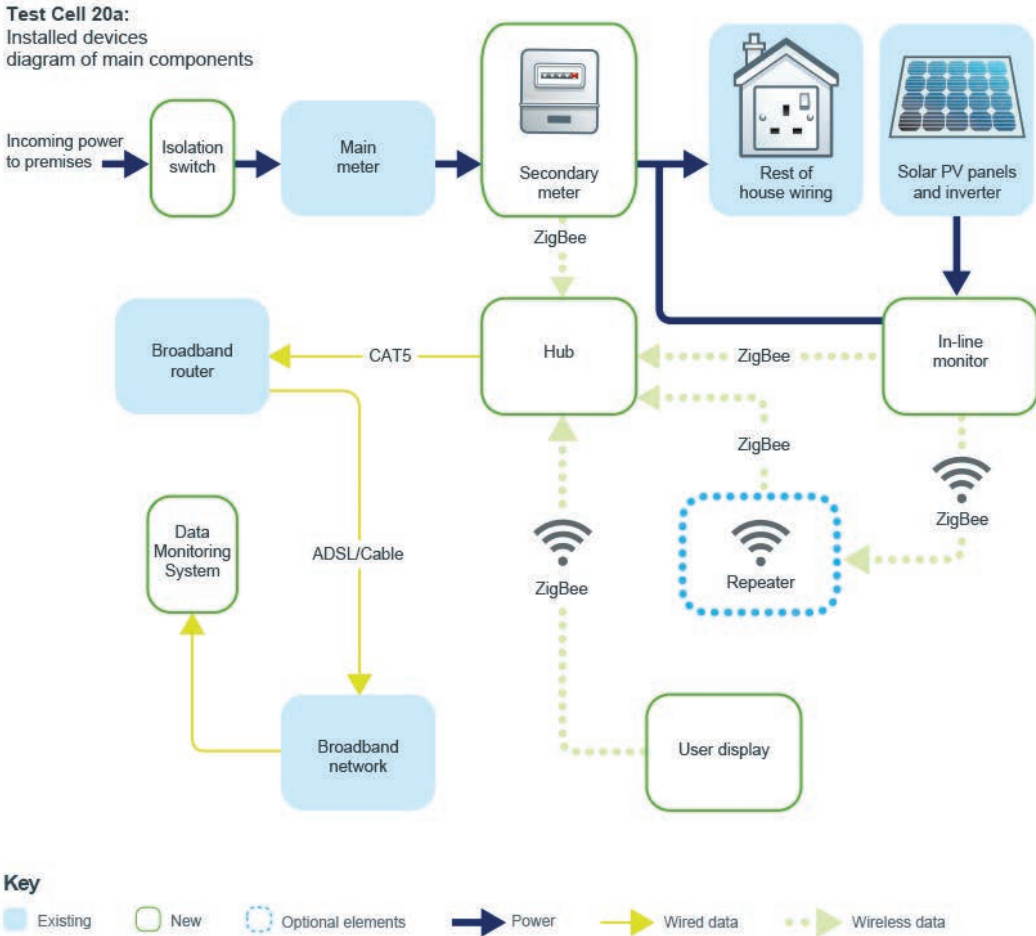
# APPENDIX 3: TRIAL RECRUITMENT AND RETENTION OF DOMESTIC CUSTOMERS

The following tables set out key aspects of the recruitment and retention of customers for the domestic monitoring and intervention trials. We had a gross target of a 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 target was a third lower than the gross target. In reality the actual dropout rate during the trials was very low.

## Test Cell 1a: Basic profiling of domestic smart meter customers (no LCTs, no interventions)

### TRIAL DESCRIPTION

| Proposition: | Smart Meter Monitoring Trial |
|---|---|
| Description: | Monitoring of customers' domestic overall consumption. |
| Purpose: | Allows network operator to understand in more detail energy usage across the day and how this varies with demographic profile. This also acts a control cell for the CLNR trial. |
| Customer Target: | 9,000 British Gas Smart Meter Customers (6,000 net target). |
| Non-British Gas Customers | No. |
| Out of Region Included | Yes 50% in region, 50% out of region. |
| Equipment: | British Gas Smart Meter (30-minute data). |
| Tariff: | Remains on existing tariff. |
| Channels: | Opt-Out letter British Gas smart metering population. |
| Payment to Customer: | N/A. |

### RECRUITMENT CAMPAIGN

| Opt-Out Reasons | Customers |
|---|---|
| Believes Would Not Benefit From Trial | 7 |
| Cost Reduction | 1 |
| Customer Does Not Have Broadband | 7 |
| Elderly | 42 |
| Happy With Current Situation | 9 |
| Happy With Current Tariff | 13 |
| Inconvenience Of Installing Equipment | 4 |
| Lifestyle Not Suited | 78 |
| Moving Home | 14 |
| Not Interested | 73 |
| Technology Driven | 1 |
| Terms and Conditions | 2 |
| Wants More Information | 4 |
| **Total** | **255** |

### CUSTOMER JOURNEY

| | | |
|---|---|---|
| **Customer Consent to Join Trial** | | **9137** |
| Drop-Out Pre-Activation | Customer Request | 228 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| Set Up | Low Carbon Technology Installed | 0 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 0 |
| | Tariff Switch | 0 |
| Drop-Out During Activation | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| | Moved to another Test Cell | 0 |
| **Customers Activated** | | **8909** |
| Drop-Out During Trial | Customer Request | 467 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| Decommissioning During Trial | Early Exit | 0 |
| | Technical Issue | 0 |
| | No Extension | 0 |
| | End of Trial | 0 |
| **Customers at End of Trial** | | **8442** |

### TRIAL SERVICING

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **9113** |
| Service Calls/Service Visits | **0** |

### ISSUES WITH RECRUITMENT

Interoperability of some of the smart meters already installed and meter agent assigned to them.

## Test Cell 2a: Enhanced profiling of domestic smart meter customers (No LCTs, no interventions)

**TRIAL DESCRIPTION**

| Proposition: | Enhanced Home Monitoring Trial |
|---|---|
| Description: | Enhanced monitoring of customers' disaggregated domestic loads and overall consumption. Domestic loads to be monitored include:<br><br>• Cooking • Space and Water Heating • Cold and Wet Appliances<br>• Consumer Electronics • Home Computing • Lighting. |
| Purpose: | Allows network operator to understand in more detail energy usage across the day and how this varies with demographic profile. This also acts a control cell for the CLNR trial. The additional monitoring in this cell differentiates from Test Cell 1, giving usage of particular appliances as well as whole home. |
| Customer Target: | 600 gross (400 net target). |
| Non-British Gas Customers | Yes. |
| Out of Region Included | Yes. |
| Equipment: | • Circuit monitoring of all circuits at consumer unit plus overall premises consumption - MicroWatt Polymeter 16 (10-minute data)<br><br>• Up to seven smart plugs on specified appliances – Passiv Systems (10-minute data)<br><br>• Passiv Hub |
| Tariff: | Remains on existing tariff . |
| Channels: | 'Friendlies' British Gas, Northern Powergrid, Durham University and EA Technology. |
| Payment to Customer: | £50 Joining / £50 Extension/ £50 End of Trial – M&S Vouchers. |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 264 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 31 |
| | Technical Issue | 1 |
| | Non-Contactable | 18 |
| **Set Up** | Low Carbon Technology Installed | N/A |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 187 |
| | Tariff Switch | N/A |
| **Drop-Out During Activation** | Customer Request | 13 |
| | Technical Issue | 7 |
| | Non-Contactable | 0 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **187** |

| Customer Consent to Join Trial | | 264 |
|---|---|---|
| **Drop-Out During Trial** | Customer Request | 4 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Decommissioning During Trial** | Early Exit | 4 |
| | Technical Issue | 0 |
| | No Extension | 14 |
| | End of Trial | 165 |
| **Customers at End of Trial** | | **170** |

**TRIAL SERVICING**

| Total no. of customers for which any data was received during the trial | 180 |
|---|---|
| Service Calls/Service Visits | 125 |

**ISSUES WITH RECRUITMENT**

British Gas decided to recruit Partner Company employees to this test cell as they were concerned about the intrusiveness of the large circuit monitoring 'box' required.

## Test Cell 2a HW: Enhanced profiling of domestic smart meter customers with electrically heated hot water on a restricted hours tariff

**TRIAL DESCRIPTION**

| Proposition: | Peak Electricity Saver Trial |
|---|---|
| Description: | Monitoring of cumulative energy consumption and tank temperature of an immersion heater through an Economy 7/10 tariff as well as outside of Economy 7/10 hours through the boost facility. |
| Purpose: | Given the lack of industry data, this allows network operator to understand in more detail the consumption profile of immersion heaters and whether this matches the existing Economy seven tariffs. |
| Customer Target: | 150 |
| Non-British Gas Customers | Yes. |
| Out of Region Included | Yes. |
| Equipment: | • Mains isolation switch – British Gas Metering Operations<br><br>• Secondary meter on main supply – Passiv Systems (10-minute import/export)<br><br>• In-line monitor on immersion heater – Passiv Systems (10-minute data)<br><br>• In-line monitor on boost facility – Passiv Systems (10-minute data)<br><br>• Hot water sensor and temperature strings (5 sensors) - Passiv Systems<br><br>• (Providing a constant data feed of tank temperatures, indicating heating times, standing losses and usage) |
| Tariff: | Existing Economy 7/10 Tariff. |
| Channels: | British Gas Supply Customers, Community Groups, Social Housing. |
| Payment to customer: | £50 Joining / £50 Extension/ £50 End of Trial – M&S Vouchers. |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 218 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 2 |
| | Technical Issue | 27 |
| | Non-Contactable | 5 |
| **Set Up** | Low Carbon Technology Installed | 0 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 145 |
| | Tariff Switch | 0 |
| **Drop-Out During Activation** | Customer Request | 6 |
| | Technical Issue | 11 |
| | Non-Contactable | 1 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **145** |

| Customer Consent to Join Trial | | 218 |
|---|---|---|
| **Drop-Out During Trial** | Customer Request | 4 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Decommissioning During Trial** | Early Exit | 4 |
| | Technical Issue | 0 |
| | No Extension | 14 |
| | End of Trial | 165 |
| **Customers at End of Trial** | | **170** |

**TRIAL SERVICING**

| Total no. of customers for which any data was received during the trial | ~ |
|---|---|
| Service Calls/Service Visits | **65** |

**ISSUES WITH RECRUITMENT**

Finding customers with electric-only Economy 7 hot water from supplier based records was difficult. Social housing stock proved to be a better target group.

# Test Cell 2a HW+SH: Enhanced profiling of domestic smart meter customers with electrically heated hot water and storage heaters on a restricted hours tariff

**TRIAL DESCRIPTION**

| Proposition: | Peak Electricity Saver Trial |
|---|---|
| Description: | Monitoring of cumulative energy consumption and tank temperature of an immersion heater through an Economy 7/10 tariff as well as outside of Economy 7/10 hours through the boost facility. |
| Purpose: | Given the lack of industry data, this allows network operator to understand in more detail the consumption profile of immersion heaters and storage heaters and whether this matches the existing Economy seven tariffs. |
| Customer Target: | 150 |
| Non-British Gas Customers | Yes. |
| Out of Region Included | Yes. |
| Equipment: | • Mains isolation switch - British Gas MO<br><br>• Secondary meter on main supply – Passiv Systems (10-minute import/export)<br><br>• In-line monitor on immersion heater – Passiv Systems (10-minute data)<br><br>• In-line monitor on boost facility – Passiv Systems (10-minute data)<br><br>• Hot Water sensor and temperature strings (5 sensors) - Passiv Systems<br><br>• In-line monitor per radiator - Passiv Systems (10-minute data)<br><br>• Room Temperature Sensor - Passiv Systems<br><br>• Radiator Temperature Sensors - Passiv Systems |
| Tariff: | Existing Economy 7/10 Tariff. |
| Channels: | British Gas Supply Customers, Community Groups, Social Housing. |
| Payment to customer: | £50 Joining / £50 Extension/ £50 End of Trial – M&S Vouchers. |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 194 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 12 |
| | Technical Issue | 2 |
| | Non-Contactable | 9 |
| **Set Up** | Low Carbon Technology Installed | 0 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 75 |
| | Tariff Switch | 0 |
| **Drop-Out During Activation** | Customer Request | 44 |
| | Technical Issue | 34 |
| | Non-Contactable | 7 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **75** |

| Customer Consent to Join Trial | | 194 |
|---|---|---|
| **Drop-Out During Trial** | Customer Request | 7 |
| | Technical Issue | 4 |
| | Non-Contactable | 0 |
| **Decommissioning During Trial** | Early Exit | 7 |
| | Technical Issue | 3 |
| | No Extension | 24 |
| | End of Trial | 38 |
| | Exhausted | 3 |
| **Customers at End of Trial** | | **75** |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **39** |
| Service Calls/Service Visits | **65** |

**ISSUES WITH RECRUITMENT**

Finding customers with electric-only Economy 7 hot water from supplier based records was difficult. Social Housing stock proved to be a better target group.

# Test Cell 3: Enhanced profiling of domestic customers with air source heat pumps

**TRIAL DESCRIPTION**

| Proposition: | Heat Pump Monitoring Trial |
|---|---|
| **Description:** | In line monitoring of customer's ASHP's electrical power consumption and whole house consumption. |
| **Purpose:** | Understand the pattern of use that ASHP users have and their electrical power consumption in 'real-world' scenarios as part of broader understanding of what impacts widespread HP adoption is likely to have. |
| **Customer Target:** | Gross target 600 (net target 400). |
| **Non-British Gas Customers** | Yes (Majority). |
| **Out of Region Included** | Yes. |
| **Equipment:** | • Smart Meter (British Gas Customer) – British Gas Smart Metering (30-minute data)<br>• Secondary Meter (non-British Gas Customer) – Passiv Systems (10-minute import/export)<br>• Mains Isolation Switch (non-British Gas Customer) – Electricity Supplier<br>• ASHP In-line monitor – Passiv Systems (10-minute data)<br>• Air Source Heat Pump – Existing/British Gas New Energy |
| **Tariff:** | Remains on existing tariff. |
| **Channels:** | Business Development Activity - British Gas New Energy, British Gas Community Energy, Northern Powergrid. |
| **Payment to Customer:** | • £50 Joining / £50 Extension/ £50 End of Trial – M&S Vouchers<br>• Average £3,500 DECC Subsidised ASHP installation<br>• One Year Free Broadband - £277 |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 402 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 14 |
| | Technical Issue | 0 |
| | Non-Contactable | 12 |
| **Set Up** | Low Carbon Technology Installed | 333 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 333 |
| | Tariff Switch | N/A |
| **Drop-Out During Activation** | Customer Request | 16 |
| | Technical Issue | 7 |
| | Non-Contactable | 9 |
| | Moved to Another Test Cell | 47 |
| **Customers Activated** | | 345 |
| **Drop-Out During Trial** | Customer Request | 0 |
| | Technical Issue | 8 |
| | Non-Contactable | 3 |

| Customer Consent to Join Trial | | 402 |
|---|---|---|
| **Decommissioning** | Early Exit | 6 |
| | Technical Issue | 7 |
| | No Extension | 32 |
| | End of Trial | 276 |
| | Exhausted | 4 |
| **Customers at End of Trial** | | 296 |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **180** |
| Service Calls/Service Visits | **315** |

**ISSUES WITH RECRUITMENT**

Low number of heat pumps installed, since it was necessary to find customers willing to accept (and pay part of) installation of pump.

# Test Cell 4: Enhanced profiling of domestic customers with micro-CHP

**TRIAL DESCRIPTION**

| Proposition: | Micro Combined Heat and Power Boiler Monitoring Trial |
| --- | --- |
| **Description:** | Monitoring of Micro CHP units (μCHP) installed in homes and whole home monitoring via sub-meter of home. |
| **Purpose:** | Understand the pattern of use that μCHP systems have in 'real-world' scenarios and how customers interact with units vs. their normal daily consumption patterns. |
| **Customer Target:** | 20 as a 'proof of concept'. |
| **Non-British Gas Customers** | Yes. |
| **Out of Region Included** | Yes. |
| **Equipment:** | • Secondary meter on main supply – Passiv Systems (10-minute import/export)<br>• Mains Isolation Switch – British Gas Metering Operations<br>• Mains Isolation Switch (non-British Gas Customer) – Electricity Supplier<br>• In line monitoring of μCHP – Passiv Systems (10-minute energy profile)<br>• Baxi Ecogen μCHP unit – British Gas Central Heating Installations (CHI) |
| **Tariff:** | Remains on existing tariff. |
| **Channels:** | British Gas Central Heating Installations, PH Jones and Partner organisations, plus 'Friendlies' from: Northern Powergrid, Durham University and EA Technology. |
| **Payment to Customer:** | • £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers.<br>• £5,000 subsidised μCHP installation / £5,000 parts + Free engineer labour. |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 15 |
| --- | --- | --- |
| **Drop-Out Pre-Activation** | Customer Request | 2 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Set Up** | Low Carbon Technology Installed | 11 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 11 |
| | Tariff Switch | N/A |
| **Drop-Out During Activation** | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 1 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | 11 |
| **Drop-Out During Trial** | Customer Request | 1 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |

| Customer Consent to Join Trial | | 15 |
| --- | --- | --- |
| **Decommissioning** | Early Exit | 1 |
| | Technical Issue | 0 |
| | No Extension | 0 |
| | End of Trial | 9 |
| | Exhausted | 1 |
| **Customers at End of Trial** | | 9 |

**TRIAL SERVICING**

| Total no. of customers for which any data was received during the trial | 11 |
| --- | --- |
| Service Calls/Service Visits | 0 |

**ISSUES WITH RECRUITMENT**

Need to find customers willing to accept (and pay part of) installation of micro-CHP unit and who could fit unit into their home.

# Test Cell 5: Enhanced profiling of domestic customers with solar photovoltaic (PV)

**TRIAL DESCRIPTION**

| Proposition: | Micro Combined Heat and Power Boiler Monitoring Trial |
|---|---|
| Description: | Monitoring of customers energy use and PV performance. |
| Purpose: | Understand the pattern of use that PV owners have: total generation, in-home use of this and export in 'real-world'. |
| Customer Target: | 150 gross target (100 net target). |
| Non-British Gas Customers | Yes, includes Gentoo recruitment of social housing rent-a-roof customers to backfill customers lost to A Shade Greener rent-a-roof customers. |
| Out of Region Included | No. |
| Equipment: | • Solar PV – Existing installation<br>• Mains isolation switch - British GasMO<br>• Mains Isolation Switch (non-British Gas Customer) – Electricity Supplier<br>• Secondary meter on main supply – Passiv Systems (10-minute import/export)<br>• In line monitoring of PV - Passiv Systems (10-minute energy profile) |
| Tariff: | Remains on existing tariff. |
| Channels: | British Gas New Energy, British Gas Community Energy /Social Housing groups, British Gas FiT payments, Northern Powergrid G83 Applications. |
| Payment to Customer: | £50 Joining / £50 Extension/ £50 End of Trial – M&S Vouchers. |

**RECRUITMENT CAMPAIGN**

| Opt-Out Reasons | Customers | % |
|---|---|---|
| Cost Reduction | 9 | 14 |
| Cost Reduction – Lifestyle | 0 | 0 |
| Cost Reduction – Behaviour Change | 0 | 0 |
| Eco-Friendly | 44 | 67 |
| Technology Driven | 6 | 9 |
| Vouchers Incentive | 6 | 9 |
| Wants More Information | 0 | 0 |
| None Given | 1 | 2 |
| **Total** | **66** | |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 271 |
|---|---|---|
| Drop-Out Pre-Activation | Customer Request | 8 |
| | Technical Issue | 57 |
| | Non-Contactable | 33 |

| Customer Consent to Join Trial | | 271 |
|---|---|---|
| Set Up | Low Carbon Technology Installed | 0 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 160 |
| | Tariff Switch | N/A |
| Drop-Out During Activation | Customer Request | 5 |
| | Technical Issue | 4 |
| | Non-Contactable | 1 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **160** |
| Drop-Out During Trial | Customer Request | 3 |
| | Technical Issue | 1 |
| | Non-Contactable | 3 |
| Decommissioning | Early Exit | 3 |
| | Technical Issue | 1 |
| | No Extension | 4 |
| | End of Trial | 147 |
| | Exhausted | 5 |
| **Customers at End of Trial** | | **152** |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **156** |
| Service Calls/Service Visits | **33** |

**ISSUES WITH RECRUITMENT**

Need to find PV customers who owned their unit and weren't on a 'rent-a-roof scheme'.

## Test Cell 6: Enhanced profiling of domestic customers with electric vehicles (EVs)

**TRIAL DESCRIPTION**

| Proposition: | Electric Vehicle Customers (Existing Tariff) |
|---|---|
| **Description:** | Monitoring of customers' electric vehicle charging patterns and electricity usage on existing tariff. |
| **Purpose:** | Understand the pattern of use that electric vehicle users have for charging their vehicles (loads, times, length of charges etc.) in 'real-world' scenarios as part of broader understanding of what impacts widespread EV adoption is likely to have. |
| **Customer Target:** | 150 gross target (100 net target). |
| **Non-British Gas Customers** | Yes. |
| **Out of Region Included** | British Gas included out of region, charge your car (CYC) all in region |
| **Equipment Installed:** | • If British Gas customer: Smart Meter – British Gas Smart Metering (30-minute data)<br><br>• Secondary Meter (non-British Gas Customer) – Passiv Systems (10-minute import/export)<br><br>• Mains Isolation Switch (non-British Gas Customer) – Electricity Supplier<br><br>• In-line monitor for EV charge point – Passiv (10-minute data) |
| **Tariff:** | Remains on existing tariff. |
| **Channels:** | Charge your Car participants and direct recruitment by British Gas. |
| **Payment to Customer:** | £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers. |

**ISSUES WITH RECRUITMENT**

EV-driving customers' household and electric vehicle charging demand were monitored, the majority being recruited via a joint partnership between CLNR and Charge Your Car (North) Ltd (CYC), and a smaller number recruited directly by British Gas.

# Test Cell 9a: Domestic smart meter customers on time of use tariffs

**TRIAL DESCRIPTION**

| Proposition: | Off-Peak Saver 3 Rate Tariff Trial |
|---|---|
| Description: | Monitoring of customers smart meter (half-hourly) with three tariff rates depending on time of day. |
| Purpose: | Testing the impact of time of use pricing designed to move energy usage away from network peaks (i.e. 4pm–8pm). |
| Customer Target: | 600 gross (400 net target). |
| Non-British Gas Customers | No. |
| Out of Region Included | No. |
| Prerequisites: | Smart Meter/ Eligibility Criteria British Gas Smart Meter Foundation Programme. |
| Equipment: | Smart Meter – British Gas Smart Metering (30-minute data). |
| Tariff: | • 07:00 - 16:00 Day – 4% Below Standard Rate<br>• 16:00 - 20:00 Peak – 99% Above Standard Rate<br>• 20:00 - 07:00 Night – 31% Below Standard Rate<br>• Weekends are flat night rate all weekend<br>• A standing charge will be applied in addition to these unit rates |
| Channels: | 600 existing British Gas supply customers some of these may have smart meter installed already. |
| Payment to Customer: | £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers. |

**RECRUITMENT CAMPAIGN**

| Opt-Out Reasons | Customers | % |
|---|---|---|
| Cost Reduction | 99 | 12 |
| Cost Reduction – Lifestyle | 342 | 41 |
| Cost Reduction – Behaviour Change | 204 | 25 |
| Eco-Friendly | 54 | 7 |
| Technology Driven | 38 | 5 |
| Vouchers Incentive | 8 | 1 |
| Wants More Information | 0 | 0 |
| None Given | 83 | 10 |
| **Total** | **828** | |

**CUSTOMER JOURNEY**

| | |
|---|---|
| **Customer Consent to Join Trial** | **843** |
| | 0 |
| **Drop-Out Pre-Activation** | 0 |
| | 0 |
| | N/A |
| **Set Up** | 288 |
| | 682 |
| | 0 |
| | 0 |
| **Drop-Out During Activation** | 0 |
| | 0 |
| | 0 |
| **Customers Activated** | **682** |
| | 161 |
| **Drop-Out During Trial** | 0 |
| | 0 |
| **Decommissioning During Trial** | 0 |
| | 0 |
| | 0 |
| **Customers at End of Trial** | **570** |
| **Total Customers Decommissioned** | N/A |
| **Customers Exhausted** | 0 |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **682** |
| Service Calls/Service Visits | **0** |

**ISSUES WITH RECRUITMENT**

None.

# Test Cell 10a: Domestic customers on the smart washing machine restricted hours trial

**TRIAL DESCRIPTION**

| Proposition: | Smart Washing Machine and Peak Electricity Saver |
|---|---|
| **Description:** | Monitoring of customers' smart meter with three tariff rates depending on time of day, in addition restricted use of a Wet White Good (e.g. Washing Machine) which will be provided free of charge. |
| **Purpose:** | Testing the impact of time of use pricing with appliance automation designed to move energy usage away from network peaks (i.e. 4pm–8pm). |
| **Customer Target:** | 600 gross, (400 net target). |
| **Non-British Gas Customers** | No. |
| **Out of Region Included** | No. |
| **Equipment installed:** | • Smart Meter – British Gas Smart Metering (30-minute data)<br>• Smart Washing Machine – Hotpoint AQUALTIS model AQ113D 69 EH/A<br>• Gateway – Datamobile GRID BOX |
| **Tariff:** | **ToU Tariff:**<br>7am to 4pm Day – 4% Below Standard Rate.<br>4pm to 8pm Peak – 99% Above Standard Rate.<br>8pm to 7am Night – 31% Below Standard Rate.<br>Weekends are flat night rate all weekend.<br>A standing charge will be applied in addition to these unit rates.<br><br>**Restricted Hours:**<br>Wet White Good will not work as default in Peak (4pm to 8pm).<br>Customers are able to override without penalty, but would be charged at peak rate for consumption. |
| **Channels:** | 75 British Gas supply customers, then 'Friendlies' British Gas, Northern Powergrid, Durham University and EA Technology. |
| **Payment to Customer:** | • £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers.<br>• Washing machine to be installed free of charge. |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 85 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 9 |
| | Technical Issue | 25 |
| | Non-Contactable | 0 |
| **Set Up** | Low Carbon Technology Installed | 53 |
| | Smart Meter Installed | 29 |
| | Monitoring and Equipment Installed | 53 |
| | Tariff Switch | 53 |
| **Drop-Out During Activation** | Customer Request | 0 |
| | Technical Issue | 1 |
| | Non-Contactable | 0 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **53** |

| Customer Consent to Join Trial | | 85 |
|---|---|---|
| **Drop-Out During Trial** | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 1 |
| **Decommissioning** | Early Exit | 0 |
| | Technical Issue | 0 |
| | No Extension | 0 |
| | End of Trial | 53 |
| | Exhausted | 0 |
| **Customers at End of Trial** | | **53** |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **49** |
| Service Calls/Service Visits | **26** |

**ISSUES WITH RECRUITMENT**

Off-the-shelf technology proved to be unavailable and resulted in delay. In the end a new 'product' was developed straight from the laboratory.

# Test Cell 11a: Domestic customers on the smart washing machine direct control trial

**TRIAL DESCRIPTION**

| Proposition: | Smart Washing Machine and Peak Electricity Saver |
|---|---|
| Description: | Monitoring of customers' smart meter, in addition direct control of a Wet White Good (e.g. Washing Machine) which will be provided free of charge. |
| Purpose: | Testing the impact of direct control to move energy usage away from periodic network peaks to manage the grid loads. |
| Customer Target: | 600 gross, (400 net target). |
| Non-British Gas Customers | No. |
| Out of Region Included | No. |
| Equipment installed: | • Smart Meter – British Gas Smart Metering (30-minute data)<br>• Smart Washing Machine – Hotpoint AQUALTIS model AQ113D 69 EH/A<br>• Gateway – Datamobile GRID BOX |
| Tariff: | Remains on existing tariff.<br><br>**Direct Control:**<br>Network operator / supplier able to interrupt use of single appliance for a number of specified periods throughout the year (customer has ability to override).<br><br>Maximum 15 times – four hours each interruption – may not be called upon. |
| Channels: | "Friendlies" British Gas, Northern Powergrid, Durham University and EA Technology. |
| Payment to Customer: | • £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers<br>• Washing machine to be installed free of charge |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 161 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 9 |
| | Technical Issue | 45 |
| | Non-Contactable | 3 |
| **Set Up** | Low Carbon Technology Installed | 100 |
| | Smart Meter Installed | 50 |
| | Monitoring and Equipment Installed | 100 |
| | Tariff Switch | 0 |
| **Drop-Out During Activation** | Customer Request | 0 |
| | Technical Issue | 1 |
| | Non-Contactable | 0 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | 100 |

| Customer Consent to Join Trial | | 161 |
|---|---|---|
| **Drop-Out During Trial** | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Decommissioning** | Early Exit | 0 |
| | Technical Issue | 0 |
| | No Extension | 0 |
| | End of Trial | 84 |
| | Exhausted | 16 |
| **Customers at End of Trial** | | 100 |

**TRIAL SERVICING**

| Total no. of customers for which any data was received during the trial | 100 |
|---|---|
| Service Calls/Service Visits | 51 |

**ISSUES WITH RECRUITMENT**

Off-the-shelf technology was not available and resulted in delay. In the end a new 'product' was developed straight from the laboratory.

# Test Cell 12: Domestic customers with air source heat pumps on time of use tariffs

**TRIAL DESCRIPTION**

| Proposition: | Heat Pump and Off-Peak Saver 3 Rate Tariff Trial |
|---|---|
| **Description:** | Monitoring of customers' Air Source Heat Pump (ASHP) electrical power consumption and customer's smart meter consumption with three tariff rates depending on time of day. |
| **Purpose:** | Understand the pattern of use that ASHP users have and their electrical power consumption in 'real-world' scenarios as part of broader understanding of what impacts widespread HP adoption is likely to have; and specifically testing the impact of Time of Use pricing designed to move energy usage away from network peaks (i.e.4pm to 8pm) with HP owner. |
| **Customer Target:** | 600 gross, (400 net target). |
| **Non-British Gas Customers** | No. |
| **Out of Region Included** | Yes. |
| **Equipment installed:** | • Smart Meter – British Gas Smart Metering (30-minute data)<br>• ASHP In-line monitor – Passiv Systems (10-minute data)<br>• If not an existing installation: Air Source Heat Pump – British Gas Renewable Heat Team |
| **Tariff:** | **ToU Tariff:**<br>7am to 4pm Day – 4% Below Standard Rate<br>4pm to 8pm Peak – 99% Above Standard Rate<br>8pm to 7am Night – 31% Below Standard Rate<br>Weekends are flat night rate all weekend<br>A standing charge will be applied in addition to these unit rates. |
| **Channels:** | Business Development Activity - British Gas New Energy, British Gas Community Energy, Northern Powergrid. |
| **Payment to Customer:** | • £50 Joining / £50 End of Trial – to be delivered in vouchers. Average £3,500 DECC Subsidised ASHP installation<br>• One Year Free Broadband - £277 |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 81 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 4 |
| | Technical Issue | 2 |
| | Non-Contactable | 1 |
| **Set Up** | Low Carbon Technology Installed | 12 |
| | Smart Meter Installed | 12 |
| | Monitoring and Equipment Installed | 12 |
| | Tariff Switch | 7 |

| Customer Consent to Join Trial | | 81 |
|---|---|---|
| **Drop-Out During Activation** | Customer Request | 3 |
| | Technical Issue | 5 |
| | Non-Contactable | 2 |
| | Moved to Another Test Cell | 47 |
| **Customers Activated** | | **12** |
| **Drop-Out During Trial** | Customer Request | 5 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Decommissioning** | Early Exit | ~ |
| | Technical Issue | ~ |
| | No Extension | ~ |
| | End of Trial | ~ |
| | Exhausted | ~ |
| **Customers at End of Trial** | | **7** |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **7** |
| Service Calls/Service Visits | **0** |

**ISSUES WITH RECRUITMENT**

The length and complexity of the customer journey: heat pump, mains isolator, broadband, telephone line, smart meter, time of use tariff and monitoring kit all required for this test cell made it difficult to recruit and retain customers.

# Test Cell 14: Domestic customers with air source heat pumps on direct control trials

**TRIAL DESCRIPTION**

| Proposition: | Heat Pump and Energy Supply Manager Trial |
|---|---|
| **Description:** | Monitoring of customers' ASHP electrical power consumption, customers' smart meter consumption and response to direct control of HP draw. |
| **Purpose:** | Understand the pattern of use that ASHP users have and their electrical power consumption in 'real-world' scenarios as part of broader understanding of what impacts widespread HP adoption is likely to have; and specifically testing the impact of direct control to move energy usage away from periodic network peaks to manage the grid loads. |
| **Customer Target:** | 150 gross (100 net target). |
| **Non-British Gas Customers** | Yes. |
| **Out of Region Included** | Yes. |
| **Equipment installed:** | • Smart Meter – British Gas Smart Metering (30-minute data)<br>• Secondary Meter (non-British Gas Customer) – Passiv Systems (10-minute import/export)<br>• Mains Isolation Switch (non-British Gas Customer) – Electricity Supplier<br>• ASHP – British Gas New Energy ('Smart Grid capable' variety with integrated direct controls functionality, 10-minute load monitoring and additional heat meters and temperature sensors as required for the DECC subsidy)<br>• Thermal store (provides heat while heat pump in 'direct control' mode) |
| **Tariff:** | Remains on existing tariff.<br><br>**Direct Control:**<br>Network operator / supplier able to prevent use of single appliance for a number of specified periods throughout the year.<br><br>Maximum 15 times – four hours each interruption – may not be called upon (note that for ASHP full four hour interruption unlikely to be achievable due to technical constraints on thermal storage size, heat pump would be off for part of the interruption and operating at a reduced duty cycle for the remainder). |
| **Channels:** | Business Development Activity - British Gas New Energy, British Gas Community Energy, Northern Powergrid. |
| **Payment to Customer:** | • £50 Joining / £50 End of trial – to be delivered in vouchers<br>• Average £3,500 DECC Subsidised ASHP installation<br>• One Year Free Broadband - £277 |

**CUSTOMER JOURNEY**

| Customer Consent to Join Trial | | 19 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Set Up** | Low Carbon Technology Installed | 17 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 17 |
| | Tariff Switch | 0 |
| **Drop-Out During Activation** | Customer Request | 1 |
| | Technical Issue | 1 |
| | Non-Contactable | 0 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **17** |
| **Drop-Out During Trial** | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Decommissioning** | Early Exit | ~ |
| | Technical Issue | ~ |
| | No Extension | ~ |
| | End of Trial | 16 |
| | Exhausted | 1 |
| **Customers at End of Trial** | | **16** |

**TRIAL SERVICING**

| Total no. of customers for which any data was received during the trial | 22 |
|---|---|
| Service Calls/Service Visits | 0 |

**ISSUES WITH RECRUITMENT**

This intervention required finding customers willing to accept (and pay part of) installation of a heat pump. There were also difficulties finding homes technically suitable to accommodate the smart heat pump with a thermal store, particularly in social housing. In addition the concept of an interruptible heating supply was completely new and required a big leap of faith on behalf of customers.

# Test Cell 20 Auto: Domestic solar PV customers with automatic in-premises balancing for hot water charging

## TRIAL DESCRIPTION

| Proposition: | Solar Panel Electricity Generation and Usage Trial |
|---|---|
| **Description:** | Monitoring of customers' Passiv sub-meter (half-hourly) energy use and PV performance with automatic diversion of any excess generation (normally exported to the grid) into hot water storage. |
| **Purpose:** | Understand the pattern of use that PV owners have: total generation, in-home use of this and net generation use within the home to establish if automatic intervention can prevent mass-export on networks in the future (entire streets of housing exporting electricity up to the grid on sunny days). |
| **Customer Target:** | 600 gross (400 net target across both PV balancing test cells combined). |
| **Non-British Gas Customers** | Yes, includes Gentoo recruitment of social housing rent-a-roof customers to backfill customers lost to A Shade Greener rent-a-roof customers. |
| **Out of Region Included** | No. |
| **Equipment installed:** | • Solar PV – Existing installation<br>• Cool Power 'EMMA' system, for PV to hot water control, includes 10-minute monitoring of generation and import/export |
| **Tariff:** | Remains on existing tariff. |
| **Channels:** | British Gas New Energy, British Gas Community Energy / Social Housing groups, British Gas FiT payments, Northern Powergrid G83 Applications. |
| **Payment to Customer:** | • £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers. |

## RECRUITMENT CAMPAIGN

| Opt-Out Reasons | Customers | % |
|---|---|---|
| Cost Reduction | 63 | 79 |
| Cost Reduction – Lifestyle | 0 | 0 |
| Cost Reduction – Behaviour Change | 0 | 0 |
| Eco-Friendly | 11 | 14 |
| Technology Driven | 5 | 6 |
| Vouchers Incentive | 0 | 0 |
| Wants More Information | 0 | 0 |
| None Given | 1 | 1 |
| **Total** | **80** | |

## CUSTOMER JOURNEY

| Customer Consent to Join Trial | | 208 |
|---|---|---|
| **Drop-Out Pre-Activation** | Customer Request | 0 |
| | Technical Issue | 51 |
| | Non-Contactable | 0 |
| **Set Up** | Low Carbon Technology Installed | 99 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 99 |
| | Tariff Switch | 0 |
| **Drop-Out During Activation** | Customer Request | 6 |
| | Technical Issue | 14 |
| | Non-Contactable | 0 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **99** |
| **Drop-Out During Trial** | Customer Request | 0 |
| | Technical Issue | 0 |
| | Non-Contactable | 0 |
| **Decommissioning** | Early Exit | 0 |
| | Technical Issue | 0 |
| | No Extension | 0 |
| | End of Trial | 0 |
| | Exhausted | 0 |
| **Customers at End of Trial** | | **99** |

## TRIAL SERVICING

| Total no. of customers for which any data was received during the trial | **99** |
|---|---|
| Service Calls/Service Visits | **0** |

## ISSUES WITH RECRUITMENT

Finding PV customers who owned their unit and not on a 'rent-a-roof scheme' and had sufficient space for the EMMA unit proved difficult.

# Test Cell 20 IHD: Domestic solar PV customers using in-home displays for manual in-premises balancing

**TRIAL DESCRIPTION**

| Proposition: | Solar Panel Electricity Generation and Usage Trial |
|---|---|
| Description: | Monitoring of customers' energy use and PV performance with additional real-time notice of excess generation (export to the grid) e.g. when PV generation exceeds current consumption do customers turn on other appliances. |
| Purpose: | Understand the pattern of use that PV owners have: total generation, in-home use of this and net generation use within the home to establish if real-time information can prevent mass-export on networks in the future (entire streets of housing exporting electricity up to the grid on sunny days). |
| Customer Target: | 600 gross, 400 net target across both PV balancing test cells combined. |
| Non-British Gas Customers | Yes, includes Gentoo recruitment of social housing rent-a-roof customers to backfill customers lost to A Shade Greener rent-a-roof customers. |
| Out of Region Included | No. |
| Equipment installed: | • Solar PV – Existing installation<br>• Mains isolation switch - British GasMO<br>• Secondary meter on main supply – Passiv Systems (10-minute import/export)<br>• In line monitoring of PV - Passiv Systems (10-minute energy profile)<br>• In-home display – Passiv Systems |
| Tariff: | Remains on existing tariff. |
| Channels: | British Gas New Energy, British Gas Community Energy / Social Housing groups, British Gas FiT payments, Northern Powergrid G83 Applications. |
| Payment to Customer: | £50 Joining / £50 Extension / £50 End of Trial – M&S Vouchers. |

**RECRUITMENT CAMPAIGN**

| Opt-Out Reasons | Customers | % |
|---|---|---|
| Cost Reduction | 73 | 72 |
| Cost Reduction – Lifestyle | 0 | 0 |
| Cost Reduction – Behaviour Change | 0 | 0 |
| Eco-Friendly | 18 | 18 |
| Technology Driven | 2 | 2 |
| Vouchers Incentive | 4 | 4 |
| Wants More Information | 2 | 2 |
| None Given | 2 | 2 |
| **Total** | **101** | |

**CUSTOMER JOURNEY**

| | | |
|---|---|---|
| **Customer Consent to Join Trial** | | **233** |
| Drop-Out Pre-Activation | Customer Request | 18 |
| | Technical Issue | 24 |
| | Non-Contactable | 13 |
| Set Up | Low Carbon Technology Installed | 0 |
| | Smart Meter Installed | 0 |
| | Monitoring and Equipment Installed | 156 |
| | Tariff Switch | 0 |
| Drop-Out During Activation | Customer Request | 0 |
| | Technical Issue | 7 |
| | Exhausted / Non-Contactable | 1 |
| | Moved to Another Test Cell | 0 |
| **Customers Activated** | | **156** |
| Drop-Out During Trial | Customer Request | 12 |
| | Technical Issue | 2 |
| | Non-Contactable | 0 |
| Decommissioning | Early Exit | 3 |
| | Technical Issue | 2 |
| | No Extension | 4 |
| | End of Trial | 143 |
| | Exhausted | 7 |
| **Customers at End of Trial** | | **152** |

**TRIAL SERVICING**

| | |
|---|---|
| Total no. of customers for which any data was received during the trial | **153** |
| Service Calls/Service Visits | **33** |

**ISSUES WITH RECRUITMENT**

We had difficulties in finding PV customers who owned their unit and weren't on a 'rent-a-roof scheme'.

# APPENDIX 4: RELATED DOCUMENTS

This table presents key related documents for further reading.

| Reports on the Domestic and SME Customer Trials | |
|---|---|
| **Baseline monitoring of domestic and SME customers** | • CLNR-L216: Insight report – Domestic baseline profiles<br>• CLNR-L242: High level summary of learning - Domestic smart meter customers<br>• CLNR-L099: Insight report - Small and medium enterprises (SMEs) |
| **Enhanced monitoring of domestic customers** | • CLNR-L094: Insight report - Enhanced domestic monitoring |
| **Time of use tariffs (ToU)** | • CLNR-L093: Insight report - Domestic time of use tariff<br>• CLNR-L243: High level summary of learning - Domestic smart meter customers on time of use tariffs |
| **Solar photovoltaic (PV)** | • CLNR-L090: Insight report - Domestic solar PV customers<br>• CLNR-L244: High level summary of learning - Solar PV customers |
| **Electric vehicles (EV)** | • CLNR-L092: Insight report - Electric vehicles<br>• CLNR-L254: High Level Summary of learning - Electric vehicle users<br>• CLNR-L038: IEEE ISGT 2013: Integrating smart meter and electric vehicle charging data to predict distribution network impacts |
| **Heat pumps (ASHP)** | • CLNR-L091: Insight report - Domestic heat pumps<br>• CLNR-L245: High level summary of learning - Heat pump customers |
| **Micro-CHP (mCHP)** | • CLNR-L086: Report on enhanced profiling of domestic customers with micro-CHP |
| **Domestic direct control** | • CLNR-L096: Insight report: Domestic direct control trials |
| **Trial design** | • CLNR-L107: CLNR test cell protocol |
| **Lessons learned reports** | • CLNR-L036: Lessons learned from trial recruitment: Customer-Led Network Revolution trials<br>• CLNR-L262: Lessons Learned Report: Customer Trial Equipment Installations |
| **Social science outputs** | • CLNR-L052: Social science report (April 2014)<br>• CLNR-L100: Domestic survey report<br>• CLNR-L101: SME survey report<br>• CLNR-L102: Domestic customers, energy practices and flexibility<br>• CLNR-L103: SME customers: energy practices and flexibility<br>• CLNR-L104: Heat pump survey results<br>• CLNR-L106: Driving the Electric Vehicle: Survey data visualisation<br>• CLNR-L236: Key social science findings, domestic and SME customers |
| Additional Outputs | |
| **Reports** | • CLNR-L247: Developing the smarter grid: the role of industrial and commercial and distributed generation customers<br>• CLNR-L248: Developing the smarter grid: optimal solutions for smarter network businesses<br>• CLNR-L145: Commercial arrangements study – Phase 2<br>• CLNR-L185: Review of the distribution network planning and design standards for the future low carbon electricity system |

All documents are available on the project library