Customer-Led Network Revolution

High Level Summary of Learning

Domestic Smart Meter Customers

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1. Introduction

This summary presents the **key messages** from the final analysis of the baseline domestic profile control group in the Customer-Led Network Revolution (CLNR) monitoring trials. It presents outputs from the largest study of household electricity use in the UK and provides integrated socio-technical analysis of domestic customer loads and electrical consumption on the basis of interdisciplinary multi-method research.

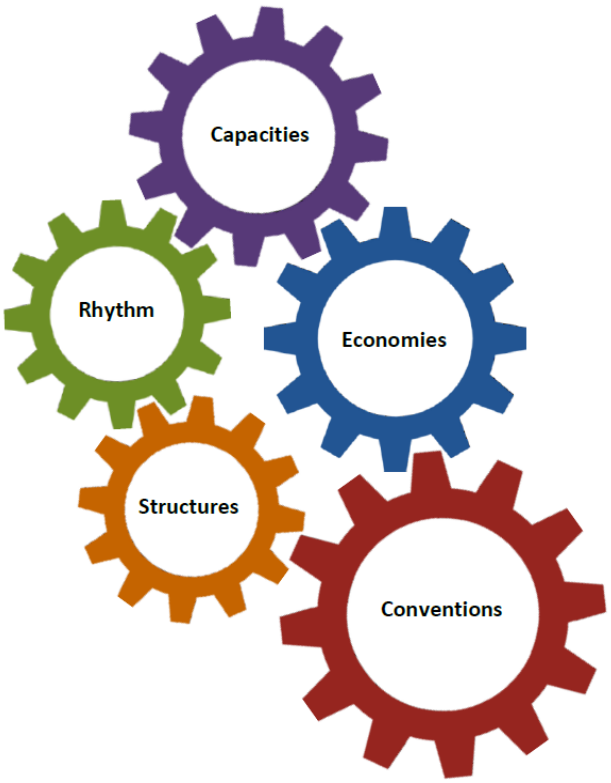
We present analysis of the control group test cell 1a (TC1a) that collected smart meter data for ca. 9000 customers across a two year period May 2011 to April 2013. This dataset has been used as a comparison against the impacts of technology and load-shifting interventions trialled in the CLNR project. These interventions are designed to modify how customers place demand on the electrical distribution network, e.g. by shifting demand out of peak periods, automatically pausing certain electrical goods, etc.

Using a socio-technical approach we take account of the ways in which **electricity use and its flexibility are shaped by social and material factors.** The approach developed through analysis conducted across the various test cells suggests that energy use is shaped by the interaction of **five core elements**:

- **Conventions**: people's shared sense of what is considered to be normal energy use. Conventions are shaped through, for example, standards, cultural expectations and design of appliances.
- **Capacities**: the ability and potential for objects, artefacts, and techniques to use energy and provide energy services, constituted through their design, physicality, knowledge and know-how.
- **Rhythms**: the multiple rhythms operating at daily, weekly, monthly, annual scales through which activities are organised and patterned.
- **Economies**: people's dispositions towards and management of social, natural and financial resources and investments.
- **Structures**: enduring features of the socio-material world, e.g. structures of employment, school hours, building structures, layouts and materials, systems of energy provision, family structures, household life-stages and social class.

The recurrent interaction of these elements, in the manner of cogs, leads to the reproduction and patterning of social practices, and shapes the ways in which people use electricity. We refer to these patterns as the CCRES model (Figure 1).

Figure 1: The Five Core Elements (COGS)



2. Methodology

This report draws on **qualitative and quantitative mixed method research conducted in Test Cell 1a (TC1a)** and details the final analysis of the base customer set in the monitoring trials.

The **quantitative research included a baseline of over** ca. **9000 domestic customers** from a wide range of socio-demographic backgrounds. Participating households were monitored to create an overall picture of current base domestic electrical energy consumption in the UK.

To set beside the consumption database, the social science team designed and analysed the results of **an online survey of domestic customers.** The domestic survey analysis includes results from the original survey of CLNR trial participants conducted by British Gas (Summer 2012) and the results of the second survey conducted by British Gas (Spring 2013). Taken together, the total number of responses to both surveys used in the analysis is 915.

In addition to the collection of survey results and consumption data through a range of monitoring and metering arrangements, Durham University's social science team recorded **250 face to face interviews as summarised** in Table 1. Each of these interviews was conducted on the participant's premises and involved a guided conversation about electricity use and flexibility as well as a tour of

the premises to record discussions of **how different rooms and appliances are used as part of everyday life.**

Table 1: Qualitative research summary

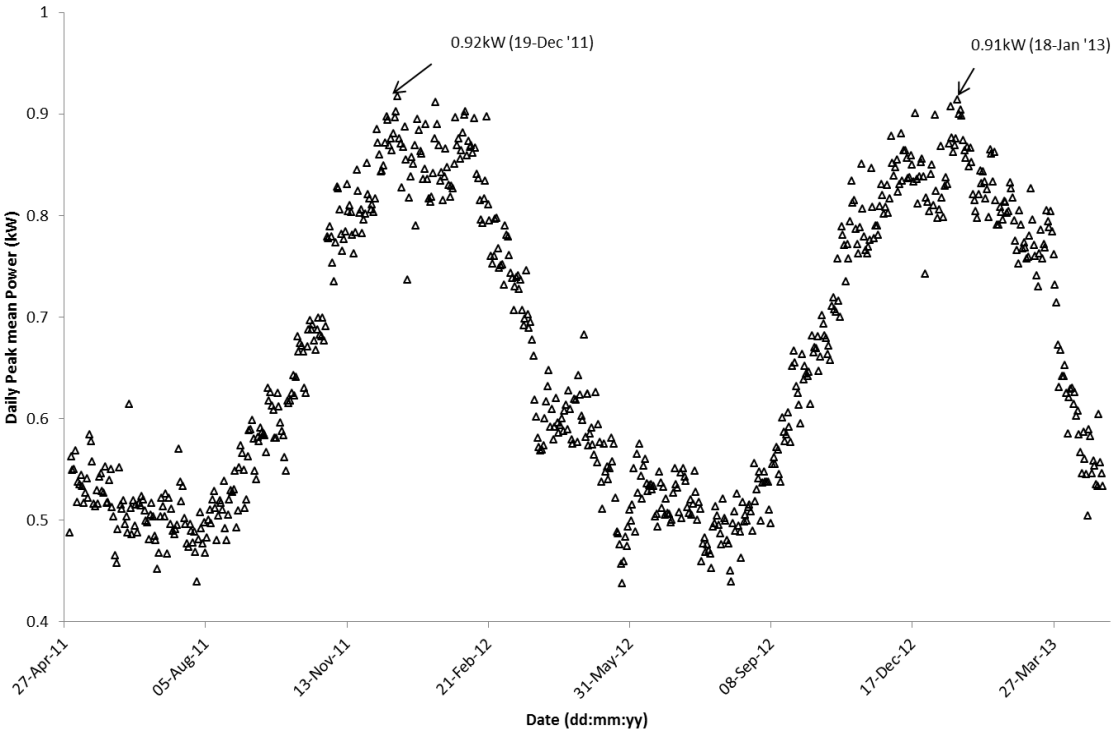
Total Number of Domestic Participants	**131**
Total Number of SME Participants	57
Total Number of Unique Participants	186
Total Number of Qualitative Research Interviews including Follow Ups	250

The aim of Leaning Outcome 1 of the CLNR project was to understand current electrical energy use and to identify factors that might shape future electricity use. **No interventions or other trials were performed on these customers.**

3. Household Electricity Demand

Test Cell 1 provides insight into the **seasonal nature of electricity demand**. It shows a 'curved' increase in consumption between summer and winter, which becomes steep in November before a peak in December, followed by a gradual reduction in January before a sharp decrease in February and March (Figure 2).

Figure 2: Daily mean peak power demands considering all customers in TC1a across two years (1st May 2011 – 30th April 2013)

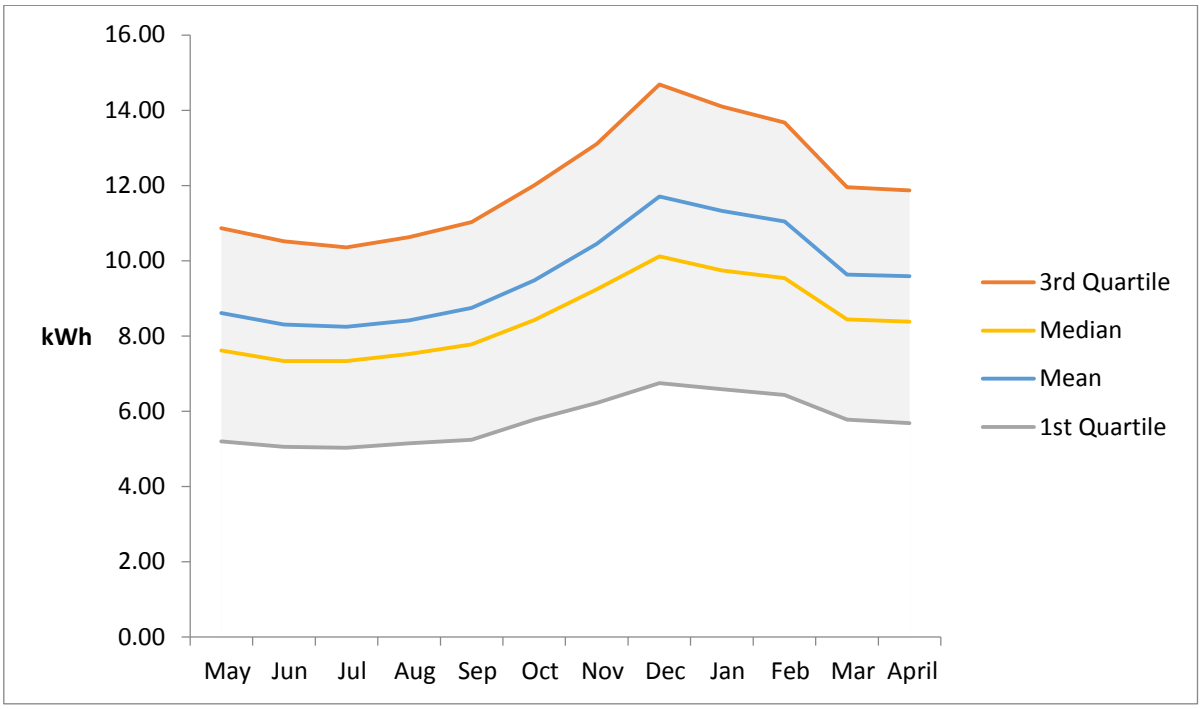


Along with increase in total electricity demand, the diversity of levels of electricity consumption increases in winter months. When looking at the daily average electricity demand we found that the gap between the 25% percentile and the 75% percentile increases when demand rises in winter, which has the effect of widening the gap between mean and median consumption as illustrated on Figure 3 below. The qualitative data reveals some evidence of changes in how **practices are performed relating to the seasons**, most notably, laundering and heating (thermal comfort) practices (Social Science Report April 2014):

> *Obviously, in the summer I never, ever use my tumble dryer. I always put them out on the line. 'Cause I prefer it, they smell's nicer when it comes in from the air. […] Winter- obviously, I do put the tumble dryer on. (Lynda)*

High income is associated with considerably higher demand. Of particular interest here is that the **difference between high and low income groups varies substantially over the year**. The 'income gap' – the difference between average demand of high and low income households – ranges from 2.9 kWh per day in the months of June and July to 4.7kWh per day in December. Low income groups have the most uniform distribution and greatest likelihood of having lower peak demand, than high income households.

Figure 3: Daily average electricity consumption for Test Cell 1a for 12 months



Demand not only rises in the winter (as indicated in Figure 2 above) but also becomes more intensive in the peak period. The qualitative analysis has shown that when we divide the day into three time periods, we see that the four hour evening peak (4pm – 8pm) is a period of higher consumption with, on average, TC1a participants using 25% of their electricity in just 17% (1/6) of the day. This translates to **a demand for 1.69 times as much electricity in the peak period (4pm – 8pm) as at other times of the day** (Social Science Report April 2014).[1]

The domestic survey shows that of all the socio-demographic attributes, income has the strongest association with electricity demand with higher income households (combined household income of more than £30,000) consuming on average 2.9 kWh per day in June and July and 4.7 kWh per day in December more than lower income households (combined household income of less than £14,999).

[1] CLNR-L052: Social science report April 2014

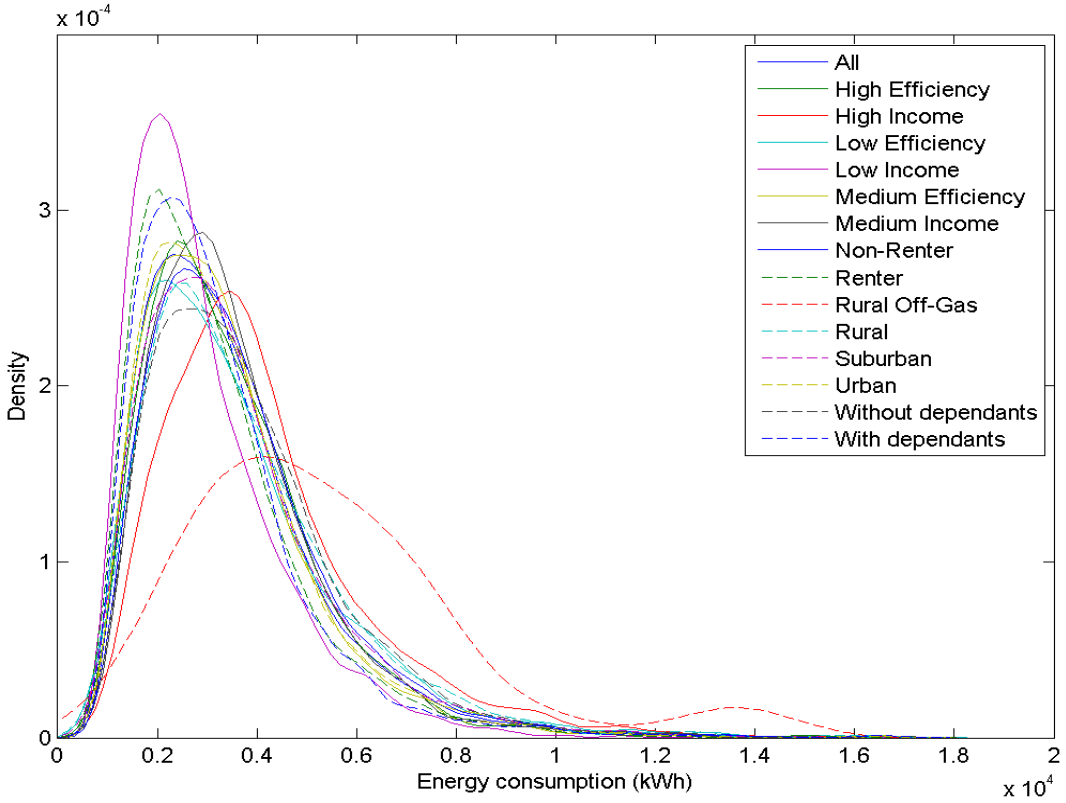
4. Annual Consumption and Peak Demand

Looking more closely at the variability of households' evening consumption, we find that **different socio-demographic groups have differing degrees of variability**. Figure 4 (below) shows that electricity consumption is related to income where stratifications of low and high income produce the largest effect (Table 2).

Low income customers have the lowest annual electricity consumption across all CLNR customer groups, with a mean of 2954 kWh where demand at the 90th percentile is lower than the mean (5337 kWh) of the rural off gas customer group at 4980 kWh.

High income users yield a mean of 4124 kWh per annum and are the highest consuming group outside of the customer group who are based in rural areas (rurality).

Figure 4: Annual consumption density plots for income, efficiency and rurality TC1a customer groups.



Renters consume a lower proportion of their total electricity use during the evening peak hours, whereas owners' tend to consume more during this period (Figure 4, Table 3).

Table 2: Annual consumption

Annual consumption (means)	Mean	Standard deviation
Low income	2954.967	1578.560
Medium income	3581.738	1945.291
High income	4134.928	2115.547
Low efficiency	3640.461	2258.280
Medium efficiency	3444.168	1828.649
High efficiency	3496.438	1789.479
Non renter	3653.169	1895.898
Renter	3232.034	1967.130
Rural	3732.484	2038.590
Rural off gas	5336.846	2739.336
Suburban	3542.134	1877.000
Urban	3429.101	1907.053

The quantitative analysis shows that electricity consumption is related to income where stratifications of low and high income produce the largest effect. Besides rural off gas customers, high income customers have the highest annual consumption of all other groups. High income customers also have a higher early morning and evening peak. We conclude that **high electricity users tend to show greater 'peakiness' behaviour**, whereas **low consumers show a greater dispersion of electricity consumption across the peak and into the later evening.**

5. Key Household Practices

Our analysis reveals evidence of the impact of wider social trends relating to economic downturn, housing shortage, unemployment, changes in household composition and patterns of electricity use. In detail, the **current trends in domestic electricity use can be seen in household structure** (discussed below); **household economy** related to increased cost of energy, **socio-technical capacities,** and **new ways of working.**

The **extent of mobility within and between households shapes electricity practices in ways that are difficult to capture**, because of their variety and sometimes temporary nature. This emerging situation indicates that there are opportunities and challenges for the electricity distribution networks and suppliers, particularly in overcoming notions of households as static. For example, even when maintaining separate households, family homes can remain open to adult sons, daughters and grandchildren to return regularly to receive hospitality; ranging from Sunday lunches to regular meals and periodic stays.

> *We have friends over for a weekend sometimes. And we have a son who lives down in [city] and when he comes up, that's him with his wife and two little children as well. They all come for the Sunday lunch if they're up here, everybody comes. (Elliot)*

Increased sensitivity to the cost of energy has led 49% of participant households (n = 131) to change their use of electricity. While there is no single new approach, domestic customers reported that **managing energy is now commonly understood to be part of managing the home economy.**

The emergence of new patterns of paid work results in impacts on domestic electricity use. For 59% of all households visited (n = 131) we found evidence that boundaries between home and work (both education and employment related) are becoming blurred, enabled by the widespread adoption of smartphones and flexible working arrangements. For many homes **the capacity to establish and maintain connectivity is becoming a new essential feature of domestic life** though to be at least as highly valued as other longer established and electricity enabled practices. The reliance on connectivity suggests opportunities for demand flexibility, as mobile devices such as laptops, smartphones and tablets can continue to provide valued connectivity without a power connection for extended periods of time.

5.1 Social Trends and Household Dynamics

Analysis of the qualitative data indicates that practices are organised on a daily or weekly basis, and may be adjusted seasonally depending on the particular practice. In many households routines related to personal hygiene or cleanliness are performed on a daily basis, for example bathing, showering, or dish-washing. Others, such as washing and drying laundry and vacuuming tend to be carried out daily, inter-day or weekly, depending on the number of people in the household; ideas about virtuous housekeeping, and rhythms of working patterns.

> *I usually put it on [washing machine] on a Tuesday night – overnight… just a habit I've got into. ... Used to be cheaper on a night; don't know if it still is. Habit. (Freda)*

Laundering is practiced frequently by busy families, as illustrated in the excerpts below:

> *[We] all put our clothes in the basket; the washer is on every day without fail, even Christmas day, at least once a day. (Sam)*

> *Two to three [wash loads] a day. … Well, if I missed a day I'd probably do 5 loads the next day. (June)*

We see the **home economy is a constantly adaptive socio-technical process** in which technologies, tariffs and activities internal and external to the home) are aligned to the pursuit of everyday life within loosely defined parameters and the logics of particular domestic settings. We also notice that a minority of households are prepared to pay for what they perceive to be a better quality of life:

> *I changed from cooking in the evening to lunchtime, but I couldn't get my head around that so we've gone back to cooking in the evening. So now we realise if we're using the oven in the evening we have to pay for it. … I didn't enjoy it. I didn't enjoy it I'm so used to it. If I was working away I would have my dinner in the evening and if we were at home I would come in, have a drink and then we'd have our dinner in the evening and I enjoy that. The thing is it's gone on for years and years and I'm eighty odd now and I suppose if my wife dug her heels in we could do it, but for now I don't mind the cost. (Mary)*

> *We just eat when we're hungry … (Daughter) will eat about half five, six-ish, and I'll have mine any time after 3 o'clock. … I probably have a sandwich before I go to bed. (Susan)*

Our findings also evidence the impact of wider social trends relating to economic downturn, housing shortage, unemployment and the incidence of divorce on energy use and patterns of consumption. Most apparent are effects relating to an increase in the numbers of adult offspring returning to live in the parental home, while others are unable to leave.

Conventions surrounding gender are diffused across the life cycle of households and are sometimes superseded by other important influences on practices that use electricity, such as those related to child-care. For **households with young children, cooking/eating, cleaning, laundry and bathing are primarily organised around their needs**, school and other structural routines. In households with older children, structured routines may be more fluid with less commensality and people eating at different times, so various 'parallel electricity lives' are lived in the same household:

> *With a 16 and 19 year old … they're out all the time. … We cook when people are wanting food. (Molly)*

We discovered how electricity **use is shaped by ownership of appliances and the practices they are associated with.** The practices that are of most direct interest to this study, and associated with the bulk of energy consumption in the home, are cooking, heat and hot water, lighting, bathing, chores, entertainment, and standby and 24-hour loads. The everyday household practices most directly relevant to demand side management are those which meet the following criteria:

- Practices with a likelihood of being performed during the 4pm – 8pm period
- Practices which include appliances owned by many households
- Practices which have a high electrical load.

On this basis, we find that the household practices most relevant to domestic demand-side interventions are household chores, cooking and dining, laundry and dish-washing.

6. Conclusions and Implications

The key determinant to both annual consumption and peak demand are driven by income, as recorded in the demographic data. However, there does not appear to be a 'smooth' transition through income levels. **In terms of annual consumption and peak demand, most demographic groups behave very similarly**. The exceptions to this are the high income and rural off gas (higher than average), and with low income and renters groups as opposed to owners.

The link between electricity use and income merits further investigation, as does the link with house thermal 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 variability found in how and when electricity is used reflects the diversity and complexity in the make-up and management of households. The household should not be treated as one static unit. We need to consider transitions and dynamics of household composition across time. **Households are dynamic sites** often related to other households; and can be characterised by different kinds of and often temporary practices. As Strengers noted, to speak of household dynamics in respect of electricity is to speak of shifting relations between people and people, between people and things and, sometimes, between people and animals or plants (2014).

Our model of electricity use referred to at the start of the report relating to **conventions, capacities, rhythms, economies and structures demonstrates the constellation of factors implicated in the ways that people use electricity** and the ensuing extent of their consumption. These patterns are set to alter in the face of emerging technological trends, such as the spread of electric vehicles and other low carbon technologies. These kinds of changes will mobilise the five cogs of the model to engage according to the type of household, its composition and socio-technical evolution.

Targeting households in terms of kinds of practices/things, household layout and relationships between inhabitants might prove more useful in terms of seeking to change patterns of use rather than focusing on socio-demographic attributes and attitudes motivated by 'rational' choice.

For enquires about the project
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