



## High Level Summary of Learning

# Domestic Smart Meter Customers on Time of Use Tariffs

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## 1 Introduction

This report presents the key messages from the final analysis of the time of use (ToU) tariff trial group in the Customer-Led Network Revolution (CLNR) monitoring trials. It presents outputs from a significant study of household electricity use and ToU tariff behaviour in the UK and provides integrated socio-technical analysis on the basis of interdisciplinary multi-method research. The aim of this research has been to study how smart grid interventions might be designed and implemented and to understand social responses to such interventions.

This summary draws upon reports produced by Durham University and Newcastle University which compare the results from this trial with those of the control group in TC1a to distil key findings and their implications<sup>1</sup>.

### 1.1 Trial design and methodology

A total of 628 participants in ToU trial (Test Cell 9a) volunteered to undertake a trial of a three band static time of use tariff and were equipped with an in-home display unit which provided a near real time signal of their current electricity load through a traffic light system and retrospective visualisations of gas and electricity consumption. Participants in the control trial were also equipped with smart meters and the same in-home display units as the participants in Test Cell 1a (the baseline domestic profile control group,). The rates and time bands of the tariff are shown in Table 1. While the trial of the tariff ran for almost two years, this report analyses the data gathered for the 12 months of the trial (October 2012 – September 2013) when the largest number of participants' energy consumption records could be analysed.

Customers were recruited from a population of British Gas' existing Foundation stage smart meter customers as well as customers who met the criteria for a smart meter installation at the time. Recruitment was especially successful, exceeding the original target. This was despite this being a test cell where customers were required to "opt in"<sup>2</sup>. As with other test cells, in order to incentivise participation, customers were offered a subsidy of £50-worth of vouchers on joining the trial and a further £50-worth of vouchers at the end of the trial<sup>3</sup>. British Gas offered the tariff, branded as the 'Off-Peak Saver 3-Rate tariff' to approximately half of their addressable population who already had a smart meter and the other half was to those who were eligible for smart meters at the time.

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<sup>1</sup> (i) CLNR-L052: Social Science Report 3, April 2014 (ii) CLNR-L093: Insight Report: Domestic Time of Use Tariff, December 2014 (iii) CLNR-L100: Domestic Survey Results and Analysis

<sup>2</sup> When asked by British Gas' call centre agents the reason for their interest in the tariff, the overwhelming reason for sign up was related to cost reduction **rather than the voucher incentive**.

<sup>3</sup> Staff involved in the recruitment reported that customers showed interest in joining the ToU tariff as they thought they could reduce their bills, even before the voucher incentive was explained

As part of the Terms & 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.

**Table 1: Time of use tariff details**

Time Period	Description	Rate
07.00 – 16.00	Day	4% below standard rate*
16.00 – 20.00	Evening	99% above standard rate*
20.00 – 07.00	Night	31% below standard rate*
<b>Notes:</b> <b>The night rate applies all weekend (Saturday / Sunday)</b> <b>A standing charge is applied in addition to the per-unit costs</b> <b>*The standard rate against which the tariff was calculated changed over the period of the trial to keep it in line with the standard British Gas electricity tariff.</b>		

Energy data was monitored and analysed from participants in the trial over the period October 2012 to September 2013. The quantitative analysis of electrical demand data collected from the trial participants included a data validation check, followed by calculation of group electrical consumption properties, such as mean, variability, and totals, over varying time periods. The direct measurements from the field trials were then matched with survey and interview findings to elaborate and explain observed or reported behaviours.

The social science team conducted research with households to investigate their current patterns and practices of electricity use and how this had changed in relation to participation in the various interventions developed under the CLNR project. The qualitative research involved: a semi-structured interview focused on current forms of electricity use; a tour of the participant's premises in order that they could 'walk through' the ways in which different technologies, devices and spaces were used in relation to energy consumption; and a further discussion reflecting on the flexibility of everyday electricity use in relation to the specific practices undertaken by the participant. Dedicated voice recorders and cameras were used to collect voice recordings, photos, basic categorical information about the participants (e.g. their heating and lighting technologies), as well as diagrams drawn by participants (participants were asked to sketch the property's floor plans and load profiles).

In addition, all participants in the CLNR trial were invited to participate in a social survey of their attitudes and reported behaviour in relation to energy use, conducted by British Gas in Summer 2012 and Spring 2013. Taken together, the total number of responses to both surveys was 915, with

105 respondents from TC9a answering specific questions on the tariff and how they had changed their everyday practices. The tariff was largely well understood by customers, with 87 of 105 survey respondents reporting that it was either quite or very easy to understand. Only one person reported finding the tariff very difficult. With this in mind we can consider that observed changes in electricity use and peak power demand were either intentional or resulted from a disregard for the tariff but not as a result of misunderstanding it.

The research activity and analysis has led to the development of a socio-technical framework for understanding the provision and use of energy services. Responses to the tariff are found to be shaped through the interaction of five different core elements. These core elements we identify as follows:

- **Conventions:** a shared sense of what is considered to be normal energy use. Conventions are shaped through, for example, standards, cultural expectations, 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:** 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, social class.

The recurrent interaction of these elements leads to the reproduction and patterning of social practices, and shapes the ways in which people are able to adapt to the tariff.

## 2 Effects of the tariff on electricity used

Analysis of the final datasets created on the trial show that the average TC1a participant used 861.673 kWh in the 4-8pm period over the course of the twelve trial months considered in this analysis, whereas the average TC9a participant used 806.621 kWh in the same period. This difference of 55.052 kWh (or 6.39%) is modest but statistically significant at the 95% level of confidence ( $p=0.011$ ).<sup>4</sup> The range of consumption in TC9a was 12.50 kWh to 2559.69 kWh (14.33% - 297.06% of the average TC1a consumption). A similarly large range of electricity consumption was found in TC1a of 23.52 – 5175.41 kWh (2.73% - 600.62% of the average TC1a consumption). We also found high levels of variation in the day to day use of electricity by individual households in TC1a. In this context of a control group and trial in which there is large variation in electricity use an overall lower level of consumption amongst trial participants is particularly noteworthy.

Overall, we find that participants in the time of use tariff trial used less electricity during the 4-8pm period than those who were not on the tariff. We note that the demographic make-up of TC9a differed from TC1a. Analysis of the MOSAIC Groups (a geodemographic categorisation of the characteristics of individual households developed on a commercial basis for the UK by Experian) in both test cells shows that E and K were under-represented in TC9a (E: Active Retirement TC1a 4.45%, TC9a 1.67; K: Upper Floor Living TC1a 1.14%, TC9a 0.17%), and J was over-represented in TC9a (J: Claimant Culture TC1a 6.34%, TC9a 10.35%).

All other MOSAIC groups were close matches between both trials. At the same time it should be noted that being classified in any one MOSAIC Group was not found to statistically determine levels of electricity use in the control group (TC1a).

Comparing the electricity consumed outside of the 4-8pm period by TC1a and TC9a reveals that whilst TC9a participants did exhibit higher energy use outside of this period, this was not found to be statistically significant.

We can conclude that over the 12 months of data analysed, TC9a participants used on average around 55kWh less electricity in the 4-8pm period but around 37kWh more electricity at other times than TC1a participants, **meaning that there was both a shift out of the peak period and a net difference of 18kWh observed**. This figure of 18kWh is close enough to the total difference in all electricity use over the year detected in aggregate analysis of the same data (25.6kWh) to indicate that **the TC9a group saved the equivalent of around two to three days' worth of electricity use over the year** (or 0.8%) and that a feature of this was a statistically significant lower electricity use in the 4-8pm period. We must be clear in stating however that while annual energy use was lower for those trialling the tariff intervention, the difference, whether 18kWh or 26kWh, is not found to be statistically significant by a t-test. At the same time, our analysis does not show how far any individual household reduced their electricity use while on the trial in comparison to their previous levels of consumption.

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<sup>4</sup> CLNR-L093: Insight Report: Domestic Time of Use Tariff, December 2014

These observed differences between the control group and the time of use tariff trial participants resonate however with findings from their survey responses. When asked to what extent the new tariff had caused them to increase or reduce energy consumption the most common response from participants was that it led to a slight decrease (which accounted for over half of all responses).

**We conclude that those on the trial tariff exhibited lower energy use in the 4-8pm period at a statistically significant level. This difference was greater than their higher energy use at other times, meaning that those on the tariff had slightly lower total energy use over the year which is observable in their energy consumption data and in their self-reported change in electricity use.**

## 2.1 Demographics

Qualitative analysis research revealed that higher income households exhibited a greater ability to shift the profile of their energy use away from the 4-8pm, compared to lower income groups. Our work with the control group suggests that these households had greater evening loads and thereby have the greatest potential load flexibility during the 4-8 period. Their homes had greater **capacity** for energy use as a result of their household size but also **economic** disposition and activity. These factors combined to mean that more appliances and devices were found in these homes and because the occupants were already using timers (particularly for laundry) to help manage the time pressures of working life they were already socio-technically equipped to incorporate the tariff into their active **rhythms** of household management.

Comparing the differences between changes in total annual energy use and 4-8pm electricity use of demographic sub-groups present in both TC1a and TC9a at the end of the trial in light of the full data reveals the **differences observed between sub- groups are too small to be described as significant at the level of individual sub-groups**. The differences in annual energy use and energy use in the 4-8pm period can only be said to be statistically significant at the level of the whole sample. This is also supported by the survey of participants as when subjected to ANOVA tests of significance, the small differences between responses to the question about total energy use change provided by members of different sub-demographic groups were found to be non-significant. **This suggests that socio-demographic factors have not shaped the response of participants to the tariff to any significant degree.**

### 3 Effects of the tariff on peak power demand

Comparing the (mean) average of the peak power demanded in the 4-8pm period over the year for TC1a and TC9a reveals a modest but statistically significant average lower peak power demand ( $p=0.001$ ) which we can be 95% confident will be between 0.039 kW and 0.152 kW less than for those not on a time of use tariff. In short, the mean average of the maximum power reading in the 4-8pm period for every day of the year is lower for those on the time of use intervention than for those in the control group.

Looking at the mean average of the maximum power reading (the mean average of each household's maximum level of power demand over the trial period) we found that this was statistically significantly lower in TC9a in the 4-8pm period when compared to TC1a ( $p=0.003$ ). We can be 95% confident that if rolled out to a similar population the maximum power demanded by customers on the TC9a tariff would be between 0.090 kW and 0.431 kW lower than customers on a flat rate tariff. The 95% confidence interval (0.090kW to 0.431kW) is a statistical calculation based on the trial sample population that represents the range of values the full population's average is believed to lie within<sup>5</sup>, with a probability of 95%.

Looking more closely at how these changes are observed over the year we find that there are lower monthly averaged maximum readings on weekdays in the 4-8pm period for all months, and seven of these months (which are the winter months of November 2012 – March 2013) exhibited statistically significant lower readings for participants in the time of use trial.

While the same is not true of weekend readings, where no significant difference was observed, this confirms that **time of use pricing can reduce peak power demands in the mid-week 4-8pm period, and that the effect remains significant throughout the winter period with which networks have been most concerned**. Nonetheless, we note that the tariff did not result in a lower peak power demand on the day of peak demand, when compared to the control group. It provides a reduction in network risk by driving down demand in the peak evening period but additional interventions may be required to enable customers to respond to the days when there is highest strain on the network.

There were no significant differences between TC9a and TC1a in terms of peak power demand in the 8-10pm period and similarly there is no evidence of a new peak being created in the 2-4pm period, meaning that **despite some concerns in the research and industry communities the tariff trialled did not create new peaks as customers prepared for and subsequently came out of the 4-8pm period**.

#### 3.1 Demographics

In contrast to the analysis of energy use reported above, analysis of differences between sub-demographic groups' annual mean and maximum peak power demand in the 4-8pm period reveals some significant differences. Firstly, those without occupants younger than five or older than sixty

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<sup>5</sup> This assumes that the full population is adequately represented by the sample.

five in TC9a were found to have significantly lower peaks in the 4-8pm period than their counterparts not on the tariff. This was not the case for those with occupants younger than five or older than sixty five meaning that the **absence of occupants younger than five or older than sixty five can be thought of as an identifier of available peak power flexibility in the 4-8pm period that can be accessed by a tariff intervention**. It suggests that households without young children or older people are likely to be more flexible in their electricity use. This was evident in the qualitative data, where it could be seen that having young children at home in particular introduced a strong sense of **convention** that a daily **rhythm** of bathing and cooking is normal, essential and non-negotiable. **The ability of customers to be flexible is therefore not only related to the design of the tariff and the incentive it provides but linked to existing patterns and structures of social life. These wider social factors may explain why some customers were more able to engage with the tariff than others.**

It was also found that for those in rented housing there was no significant difference between peak power demand between TC1a and TC9a. However there was a significantly lower average peak power demand in the 4-8pm period for home owners in TC9a compared to their counterparts in TC1a. **This indicates that home ownership can be thought of as an indicator of available peak power flexibility in the 4-8pm period that can be accessed by a tariff intervention.** Furthermore, it may point to an underlying relationship between income or social class (which are commonly positively correlated with home ownership in official data<sup>6</sup>) and flexibility. While we are unable to test for this relationship in the quantitative analysis, our qualitative data suggests there is an association here that is worthy of further investigation.

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<sup>6</sup> Frogner M L, 2002, "Housing tenure and the labour market" *Labour Market Trends* **110** 523-534

## 4 Customer engagement with the tariff



In home display device used on the trial

Analysis of shadow billing data provided by British Gas indicates that 243 of the 628 participants (39%) would have paid more money for their electricity by being on the tariff had they not been compensated by the project for the increased bills incurred in-trial. Of these the (median) average increase would have been £18.40. All MOSAIC categories are represented in the group of customers who would have incurred this additional cost, along with all DEI demographic categories. Analysis suggests that no specific demographic group or MOSAIC category would have had to pay more under the tariff, and that those who did are representative of the TC9a population.

Rather than being determined by socio-demographic variables, those customers who lost out on the trial were those whose electricity use was concentrated in the 4-8 pm period. This may reflect their pre-trial pattern of electricity use though our analysis cannot determine whether or not this is the case. Our qualitative research suggests that the factors that shape electricity use and its flexibility include conventions, capacities, rhythms, economies and structures. For some households this creates what we term **flexibility capital** – the ability to be flexible in when and how they use electricity. For other households, this flexibility capital is limited. For example, our analysis suggests that those households with younger children or older people did not respond to the tariff to the same extent as those households who did not include these generations. At the same time, owner-occupier households were more likely to respond. **Further research which records energy consumption and demand before and after trial interventions alongside qualitative social science is required in order to understand how such different factors combine to shape the capacity of customers to benefit from Time of Use Tariffs.**

Developing this further, if those who paid more on the trial are excluded from analysis and only those who saved money are included, we can see that this group exhibited even lower peak power demand figures compared to TC1a than the TC9a group as a whole (10-21.5% at the 95% confidence level). This **suggests that** the nature of household's flexibility capital and their ability to lower electricity consumption during the peak period is critical to the success of the trial for networks and for participants. **Current consumer categorisation techniques such as MOSAIC and conventional socio-demographics do not map neatly onto groups of customers that are or are not able to achieve such reductions and further research is needed to determine the factors that can enable customers to engage with such interventions.**

#### 4.1 Effects on practices

Across the whole trial group however, the results above suggest that the tariff was effective in reducing electricity during the 4-8pm period. In short, it was capable of leading people to perform some aspects of their daily lives that might usually occur in the 4-8pm period at other times of the day or week. Indeed, responses to the survey indicate that the **vast majority of people did change the time they used some appliances** with 33 people agreeing and 60 people strongly agreeing that they had done so (out of 105).

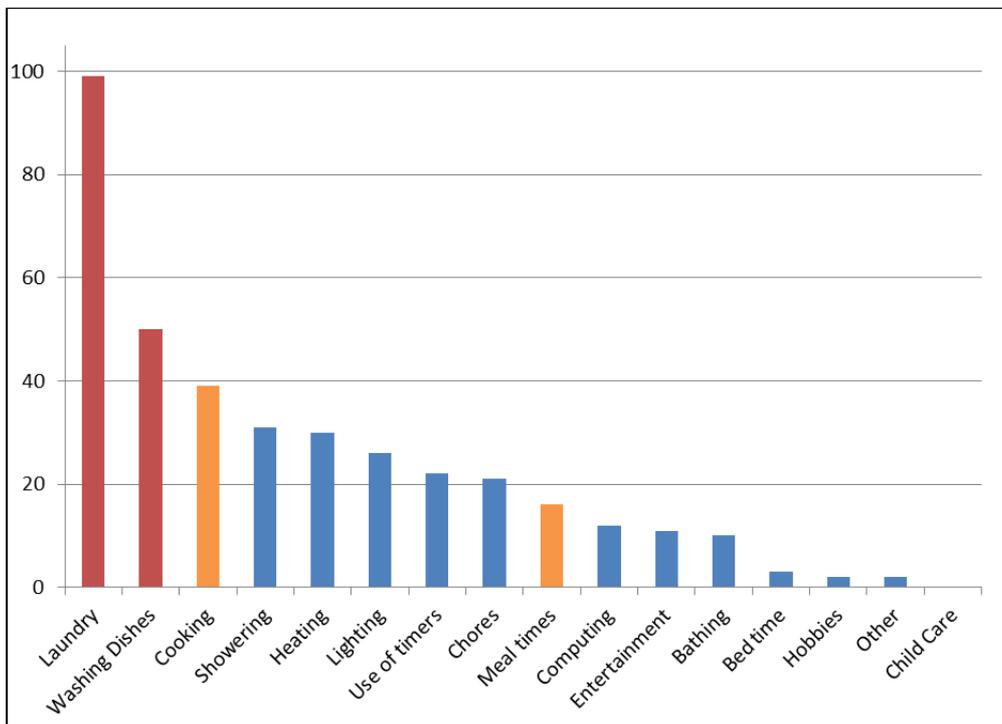
Our qualitative research with 32 participants in Test Cell 9 suggests that **laundry and dish-washing practices were most responsive to the tariff** as these do not need to be coordinated with other routines that position them as having to be performed in the 4-8pm period whereas meal times are less flexible. This contrast between how aspects of daily life are affected by the tariff can be seen in these two quotations from interviewees.

*“The washer, dryer and dishwasher we haven’t been putting on between 4 and 8”*

*“I know it’s the wrong time to do it but what time am I supposed to have me tea!?”*

This is particularly the case for families with children, who are shown in the above to be less flexible than those without occupants younger than five or older than sixty five, and working households. For some households not working around a conventional weekday work pattern, there was more movement of cooking practices in response to the TOU tariff, with participants cooking at a different time and or/by using a different method to avoid the highest electricity prices. Although meal times were among the least flexible aspects of daily activity, cooking was relatively more responsive, **revealing an opportunity to create flexibility in the energy used to maintain continuity in this important feature of home-life**. These changes are visualised in Figure 1 which presents survey participants responses when asked what they did differently in response to the tariff.

Where participants felt that their use of electricity did not respond to the time of use tariff, this appears to be most strongly related to: (a) social conventions in terms of how practices are conducted; (b) rhythms of day to day life, including the importance of leisure time at home in the evening; and (c) activities that connect householders to external structures or social groups, examples being working hours, social activities and school life.



**Figure 1 - Number of people who reported that they changed the time at which they do each activity (people could choose more than one activity)**

Importantly, these factors mean that some elements of the domestic evening are resistant to interventions seeking to change their timings by appealing to economic logic as other logics that continue to hold them in place. These other powerful logics, such as wanting to spend time with other members of the household, wanting to coordinate with other people's schedules and wanting to eat after work but before the 'night time', also feature time-structures (as does a time of use tariff) and place-constraints (they require someone or a group of people to be in the same place). These features make these socio-spatial logics powerful in determining the ways in which people can respond to a static tariff intervention.

It is also noticeable that reported differences in how practices changed in response to the tariff were greater than any differences found in the qualitative research in terms of how sub-groups of people responded. This suggests that **flexibility varied more between practices than people**, and so future interventions designed to create and engage forms of flexibility may be able to target flexible practices more accurately than they can target flexible customers.

## 5 Finding future flexibility

Table 2 summarises the key findings in terms of **the key factors that shape customer flexibility as identified in the qualitative research**. This suggests that the future design of tariff interventions designed to create flexibility in electricity use in the 4-8pm period may need to take into account these factors and the ways in which they combine to create different forms of **flexibility capital** for customers and hence different abilities to engage with tariff instruments.

**Table 2: Customer flexibility key factors** <sup>7</sup>

	Most Flexible Demand	Least Flexible Demand
<b>Practices</b>	Laundry <sup>iii, i</sup> Dishwashing <sup>iii, i</sup> Cooking <sup>iii, i</sup>	Meal times <sup>iii, i</sup> Entertainment <sup>iii</sup> Hobbies <sup>iii</sup> Bathing <sup>iii</sup> Computing <sup>iii</sup>
<b>People</b>	Home Owners <sup>ii</sup> Those without occupants younger than five or older than sixty five <sup>ii</sup> Higher Income Groups <sup>i</sup>	Renters <sup>iii</sup> With occupants younger than five or older than sixty five <sup>ii</sup> Lower Income Groups <sup>i</sup>

<sup>7</sup> (i) CLNR-L052: Social Science Report 3, April 2014 (ii) CLNR-L093: Insight Report: Domestic Time of Use Tariff, December 2014 (iii) CLNR-L100: Domestic Survey Results and Analysis



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