



# Customer-Led Network Revolution

## Customer-Led Network Revolution Social Science Interim Report 2

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## Executive Summary

It is not the purpose of this report to provide a comprehensive or final response to each of the Learning Outcomes or the research questions. Rather, we present here some indications of preliminary findings that can be drawn from the work that we have undertaken to date.

**It is vital that these findings are read and treated as emerging rather than final, as they may undergo revision as the data collection and analysis stages of DEI's work progresses.**

### Learning Outcome 1

Learning Outcome 1 (LO1) is concerned with the current loads on UK electricity distribution networks, and this report focusses specifically on domestic loads as reported by participants in test cells 1, 2, 3 and 5.

#### **LO 1.1 - Which practices are currently giving rise to electricity use in domestic contexts?**

At this stage analysis of the qualitative data suggests that the practices that are of most direct interest in terms of contribution to current loads and their potential ability to play a part in demand side management of the electricity distribution network are household chores, cooking and dining, laundry and dish washing.

The analysis we have conducted across the test cells (TCs) suggests to us that there at least 5 key factors which determine energy use associated with practices in domestic settings. Importantly, these are factors which affect electricity use for these practices prior to any trial interventions, i.e., these are LO1 findings rather than Learning Outcome 2 (LO2) findings. The factors are:

- 1. Ways Of Working**
- 2. The Household**
- 3. Materialities**
- 4. Economies**
- 5. Habits and Norms**

It is not our intention to suggest that these are independent factors – they certainly interact and affect different groups in different ways but they are presented here as a list, leaving open the possibility of analysis which seeks to understand how they combine to effect practices.

#### **LO1.2 - Emerging trends in electricity consumption**

LO1.2 is concerned with the emergence of trends in energy consumption and practices associated with smart meters and in-home displays (IHDs) (TC1), heat pumps (TC3) and PV (TC5).

**Smart meters and IHDs (TC1):** We found that smart meters are viewed positively, are thought to be easy to understand and very few concerns were expressed by participants about privacy or health. We find that people use the IHD in at least three distinct ways; to manage the household economy, to provide oversight on what families are doing, and to challenge themselves' to save energy. Negative

comments fall mostly into two categories; that their accuracy is not trusted and that engaging other family members with the IHD can be difficult.

**Heat Pumps (TC3):** Responses to the heat pump trial recorded in the face to face research were less often positive. For some users the technology aligned to their needs, but for others the air source heat pump (ASHP) was unable to provide the kinds of energy services they demanded. Several had concerns about whether running the system all day would in fact incur additional costs while others sought to distance themselves from the technology, which was regarded as complicated to operate, leading to anxiety that their actions may lead to the breakdown of the system. Despite these negative sentiments in the customer responses, at the time of the interviews, most householders had reached a point where they were able to operate the system at a basic level.

The context is critical for heat pumps. The potential for ASHP to actually increase energy consumption has led some researchers to conclude that depending on context, installation procedures and demographic factors, as well as variations in dwellings and the purposes they serve, a heat pump can be viewed as ‘a wolf in sheep’s clothing’ (Christensen et al 2011). However one potential counteraction to increased electricity consumption following installation of heat pumps in dwellings previously fitted with electric night storage heating are changes to the use of supplementary heating

**Solar PV (TC5):** We observe that as householders become familiar with and incorporate generation systems (in this case PV) into their household practices there are indications of changes in the times that some household practices are occurring – principally use of white goods, showering and battery charging.

## Learning Outcome 2 – Flexibility

Learning Outcome 2 is concerned with the ways in which customers may engage with a new systems and interventions for the demand side management of the electricity distribution network. In this report we consider the flexibility of dining and cooking practices, laundry and household chores by participants in test cells 9a and 20.

### LO2.1 - What does flexibility in energy use mean in a domestic context?

For the most part, dining still takes place at conventional meal times, between 4pm and 7pm, and for most households this is firmly fixed in time. In contrast, the analysis suggests that household chores are an interesting collection of linked practices in that they are affected by a wide range of factors, and it is these practices that large groups of householders feel are least fixed. When talking about these activities participants use either daily or weekly time-frames within which they may have proactive or reactive regimes for integrating these activities with wider household management and everyday life.

### LO 2.2 - What are the most effective interventions to deliver this flexibility?

LO2.2 considers the interventions used in Test Cells 9 (Time of Use Tariff) and 20 (Within premises use of PV power) in the Customer-Led Network Revolution (CLNR) project and assesses the extent to which these have been effective in creating flexibility in domestic electricity use via changes to everyday practices.

**Time of Use Tariff (TC9):** Our analysis suggests that participants in TC9 are avoiding laundry, chores, and dish washing, and in some cases are cooking differently within and around the 4-8 period, suggesting that the tariff is having an effect on these practices while in contrast we find that a financial incentive does not lead to a widespread shift in meal times. The results also confirm that the degree of alignment between the tariff and other schedules is important in shaping how and how much flexibility is realised.

**Systems to encourage use of PV power on site (TC20):** Participants with automatic water heating from PV reported only modest changes to practices and not all participants in this group attributed changes to the intervention. The small changes reported were most often related to when showers were taken. In contrast, when looking more specifically at evidence of changing practices to take advantage of the TC20 IHD we find that households are responding to the traffic light system of the TC20 IHDs. Households report that the device is easy to understand and has prompted them to make further changes to their practices. Often changes had originally been made as a result of the initial PV installation (prior to CLNR) but the IHD is associated with going further with these changes while for others the IHD identified new optimal alignments of PV and their practices. This suggests that IHDs are an essential adjunct to interventions for managing energy within the home and changing practices.

## Glossary of Terms

TC	Test cell
ASHP	Air source heat pump
PV	Photovoltaic (solar)
SME	Small and Medium Enterprise
CLNR	Customer Led Network Revolution
LCT	Low Carbon Technologies
DSR	Demand side Response
DSP	Demand side Participation
DEI	Durham Energy Institute
BG	British Gas
DSM	Demand side management
DECC	Department for energy and climate change 2011
PCA	Principle compact analysis
FIT	Feed in tariff
IHD	In Home Display
SM	Smart Meter
ToU	Time of use
kWh	Kilo Watt Hours
LV	Low Voltage

## Document Purpose

This report provides the second interim analysis of the data produced by the social science team. It provides findings in response to the overall Learning Outcomes of the CLNR project (listed below) and the more detailed questions being used to structure the social science team's activities. Its main purpose is to share findings with project partners and other stakeholders as they emerge in order that stakeholders can use the learning and feedback into the analysis process.

The report draws upon the data collected from 233 face to face research visits to households and SMEs undertaken between May 2012 and April 2013 as well as presenting initial analysis of an online survey of 731 domestic customers.

While the report builds on the themes and research findings outlined in the first interim report<sup>1</sup> and seeks to develop more detailed analyses it should however be considered a mid-term report of findings and emerging conclusions that stands between the first interim report (December 2012) and the final project reporting documents. This report makes initial comparisons between groups of householders identified through the analysis but does not provide comprehensive analysis of the differences between socio-technically or socio-demographically discreet categories.

## Key Findings

1. The analysis we have conducted across the test cells (TCs) suggests to us that there at least 5 key factors which determine energy use associated with practices in domestic settings.
  - a. **Ways Of Working**
  - b. **The Household**
  - c. **Materialities**
  - d. **Economies**
  - e. **Habits and Norms**
2. Our analysis suggests that participants in TC9 are avoiding laundry, chores, and dish washing, and in some cases are cooking differently within and around the 4-8 period, suggesting that the tariff is having an effect on these practices while in contrast we find that a financial incentive does not lead to a widespread shift in meal times.
3. Participants with automatic water heating from PV (TC20a) reported only modest changes to practices and not all participants in this group attributed changes to the intervention. The small changes reported were most often related to when showers were taken. In contrast, when looking more specifically at evidence of changing practices to take advantage of the TC20 IHD we find that households are responding to the traffic light system of the TC20 IHDs.

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<sup>1</sup> DEI Social Science Working Paper 7.

## 1 Introduction

The core objectives of the DEI social science team's contribution to the CLNR project are to provide insight into the nature of energy demand amongst households (domestic) and small and medium enterprises (SMEs) and to consider how, why and with what implications such demand might be 'flexible'.

Understanding energy demand has become a complex and contested matter within the social sciences, with contending perspectives suggesting that psychological, sociological, economic, material and practice based accounts are best able to offer an explanation of the ways in which energy is used. The approach taken in the CLNR project is explicitly multi-disciplinary, is informed by relevant work in several disciplines and engages with a range of conceptual approaches. This is in line with the emergence of other 'integrated' energy research (see Wilson & Chatterton 2011, for example).

### 1.1 Learning Outcomes and Research Questions

The social science team have focussed their research activities on Learning Outcomes 1 and 2. In more detail, the social science work will contribute to addressing the following Learning Outcomes and research questions:

#### **LO1.1 - What are today's domestic and SME demand (load and generation) profiles, and how do they vary or group?**

- 1) Which practices are currently giving rise to electricity use in domestic/SME contexts?
- 2) Which of these practices are the most intensive in terms of electricity use?
- 3) What are the factors that shape the use of electricity for these practices?
- 4) What are the factors that are shaping the generation of electricity in domestic/SME contexts?
- 5) How do energy practices and generation vary in socio-demographic and socio-technical terms?

#### **LO1.2 - How are load and generation profiles likely to change for all customer types? And what are the drivers for change in terms of load and generation?**

- 1) How and why does energy use/practice change over time? What evidence is there that energy use/practice and generation within households or SMEs are currently shifting?
- 2) How does the emergence of new forms of energy use/practice/generation vary in socio-demographic and socio-technical terms?
- 3) What are the factors that are shaping the emergence of new forms of energy use/practice?
- 4) How do these factors vary in socio-demographic and socio-technical terms?
- 5) How are changing household dynamics likely to shape current and future energy use?
- 6) How are changing economic conditions likely to shape current and future energy use?

- 7) How might the financing, policy and regulation of Low Carbon Technologies (LCTs) shape future generation profiles?

#### **LO2.1 - What does flexibility in energy use mean in a domestic and SME context?**

- 1) What does flexibility in energy use mean in a domestic and SME context?
- 2) In what ways and why are customers currently fixed or variable in their use of electricity in the 4-8 period?
- 3) How and why does fixity or variability change temporally – on a daily, weekly, seasonal basis, special occasion – and geographically?
- 4) Which kinds of energy use and energy practice are the most and least flexible and why?

#### **LO2.2 - What are the most effective interventions to deliver this flexibility?**

- 1) What evidence is there of change per test cell (TC), per attribute?
- 2) What are the factors which have driven the changes?
- 3) Are there daily, weekly, seasonal variations in the nature and types of flexibility that interventions can achieve?
- 4) What do the results suggest in terms of from whom, when and where flexibility might be forthcoming?

#### **LO2.2.1 - What is the most effective form of engagement to achieve sustained customer participation?**

- 1) What are the factors which shape the degree to which customers are prepared to engage with demand side response (DSR) (i.e. specific requests for response to change or shift demand)? How/why does this vary (e.g. TCs, socio-demographic, geographical)?
- 2) What are the factors which shape the degree of demand side participation (DSP) (i.e. sense of commitment and engagement with reducing or shifting demand)? How/why does this vary (e.g. TCs, socio-demographic, geographical)?
- 3) How did the customer engagement used in the trial shape participation and response? How does this compare to other trials, and what lessons can be learnt from this experience?

#### **Structure of the Document**

This report responds to these questions where possible while also integrating the insights that have been part of academic writing in Q1 and Q2 2013. Section 2 provides an account of our research methodology, Section 3 presents the emerging findings and is internally organised around the research questions while Section 4 sets out the direction of future work in the coming period.

## 2 Research Methodology

The social science team at DEI have developed two methodologies to help us understand the social dimensions of the CLNR trial: surveys (two instruments, one to be deployed with SMEs one with domestic customers); and qualitative face-to-face research visits.

We have drawn on the existing literature to design research instruments which, as well as making a contribution to the existing academic knowledgebase, can deliver the learning outcomes required by project partners.

It is important when conducting research of this kind to minimise the extent to which findings are influenced by the research team in advance. In order to minimise this risk we have taken care to avoid leading participants toward particular answers, and do not imply preferred responses.

The qualitative research is designed to allow the drivers, interactions and ingredients of everyday practices to emerge at the point of interaction between researcher and participant without imposing preconceived ideas. This approach calls for less formalised or structured instrumentation and places more emphasis on the skilled interviewer to encourage the participants to elaborate on how and why they conduct their everyday practices. Tours of the participants' premises are designed so that technologies and everyday items can act as prompts for the participant to discuss their practices. However, there are some key areas of focus which need to feature in each qualitative visit in order to ensure that results are comprehensive and comparable. The instruments prompts make sure that the interviews and tours cover these areas.

### 2.1 Survey

#### 2.1.1 Instrument Design

The online surveys were developed following consultation with several sources. National Energy Action (NEAs) experience of conducting different types of household surveys informed the initial set of questions, while feedback from our external advisory group was particularly instrumental for revising the attitudinal questions in the domestic survey. Reviewing examples of energy focussed 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 (BG) and Northern Powergrid.

The surveys are designed to produce quantitative data which directly addresses the two overarching learning outcomes (LO1 and LO2) of the CLNR project. To that end, the questions included in the survey address issues of current and future energy use and flexibility of energy use in both domestic and small to medium enterprise contexts<sup>2</sup>. The Interim Report dated November 2012 (Appendix 1) lists the survey questions and provides a more detailed account of the rationale for inclusion plus the provisional hypotheses (where appropriate) that each question is designed to test. We do not anticipate testing for associations between individual questions and energy consumption or flexibility patterns, but will instead seek to run multivariate analyses on clusters of questions in relation to the smart meter data associated with each respondent.

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<sup>2</sup> See survey design rationale documents DEI-CLNR-RE028 (domestic) and DEI-CLNR-RE030 (SME) for a detailed description of the rationale for question selection.

Our intention is that all of the survey data should be used in conjunction with smart meter data since that is the only way we will be able to demonstrate the relationship between any of the social profiles we are able to develop and actual energy consumption. By examining smart meter data longitudinally, we should be able to develop realistic forecasts for future energy consumption and levels of flexibility by customer profile and test cell. We may also be able to develop interesting insights into the relationship between smart meter data, survey data, and qualitative data about the connections between everyday practice and energy use.

### **2.1.2 Responses**

Currently there have been 152 responses to the SME survey and 741 responses to the domestic survey.

## **2.2 Face to Face Visits**

### **2.2.1 Choice of Technique**

In order to develop the qualitative methodology, the social science team undertook reviews of qualitative methodologies previously and currently being used to study energy use practices, and produced documents summarising the state of art<sup>3</sup>.

In addition the social science team setup an expert advisory group to facilitate in-project peer review. The first meeting of the group focussed on methodological issues and provided a very useful sounding board and forum through which to sense check and refine the methodologies to be deployed. Having undertaken these review processes it was decided that face to face visits to premises would be the principle qualitative research technique.

### **2.2.2 Instrument Design**

The qualitative instruments developed split each qualitative visit conducted in the first round (May – September 2012) into three parts; the first part being an introductory semi-structured interview focussing on LO1 learning, the second part being a tour of the participant's premise and the third part being a further semi structured interview, this time focussing on LO2 and linking the practices and materialities emerging in the first two parts of the visit.

Researchers used dedicated voice recorders and cameras to collect voice recordings, photos, some categorical information about the participants (heating and lighting technologies used, for example) as well as diagrams drawn with participants (participants were asked to sketch their floor plans and load profiles).

The semi-structured interview focuses on building rapport with the participant while discussing their energy use in general terms. These conversations include information about occupancy, major electrical loads, heating regimes, 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.

The tour of the premises is participant led although the participant is prompted by the researcher to talk about all aspects of their electricity use using electrical equipment as catalyst for conversation.

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<sup>3</sup>

See DEI's CLNR Researching Practices Working Paper for further detail.

Furthermore, multimedia data is collected by the researcher, with permission, to further enrich analysis. The participant led approach is reflected in the instrument design which does not constrain the respondent or presuppose the factors which are most relevant to the participant.

The third part of the visit enables a discussion of the principal issues with which the project is concerned as they relate to the participant's context and focuses on the topics of flexibility, peak consumption, key practices with potential for DSP and engagement.

### 2.2.3 Research Conducted

Participants were recruited to take part in the face to face visits by telephone. BG provided lists of customers who had explicitly consented to being contacted by DEI to take part in further research. Research has been possible with test-cells with sufficient numbers of participants as of Winter 2012 i.e.

- 1a (control group)
- 2b (SME distributed monitoring)
- 3 Heat Pumps
- 5 (photo voltaic with no further incentive)
- 9a and b (domestic time of use tariff and SME)
- 20 (photo voltaic panels with automatic or manual within premises balancing).

Each interview has been assigned an anonymous interview number for future reference which is linked to the anonymous CLNR ID number used to identify the customers in all other project activities.

The social science team has recorded 233 face to face interviews with CLNR participants interviews distributed across the test cells as shown in Table 1 below.

**Table 1 - Completed Qualitative Research**

Test Cell	Interviews Complete Summer 2012	Interviews complete Winter 2012– Spring 2013	Unique participants
TC1a	18	10	18
TC1b	0	0	0
TC2a	0	16	16
TC2b	17	5	17

TC3	0	18	14
TC4	0	1	1
TC5	14	6	14
TC9a	32	30	32
TC9b	12	0	12
TC10a	0	0	0
TC10b	9	0	9
TC11a	0	0	0
TC11b	9	0	9
TC20	18	13	18
Informal SME Participants	5		
<b>Total</b>	<b>134</b>	<b>99</b>	<b>169</b>

#### 2.2.4 Qualitative Analysis Methodology

The data captured in the face to face interviews are photographs, audio interviews, and scanned notes pages which include load curves and in some cases floor plans. The data were analysed using the qualitative data analysis software package NVivo. NVivo acts as a database for all the data and organises it around 'nodes'. A node was created for each interview which associates the data generated at each visit with a unique interview ID. The research team then collaboratively developed a set of themes which are being used to structure our analysis of the qualitative data. These themes were developed through successive discussions of the qualitative research process and literature reviews. The list of themes is not exhaustive and at this stage there is scope to modify the list for analysis of collected material and to feed into the design of winter fieldwork activity. Analytic themes used as of June 2013 are as follows, with the dominant themes in bold:

- Accomplishing energy services & practices
- Agency - power - politics
- Community
- Digital
- Economies
- Engagement with System of Provision and the Trial
- Health and Wellbeing
- Hubs and environments
- Knowledge and know-how
- Motivations and Drivers, Responsibilities, Apathies
- Non-Humans and Technology Requirements
- Normality
- Participant Identity
- Prosumers
- Refurbishment
- Rhythms and Thresholds
- Role of Policy & Government
- Social Networks
- Technical legacies and novelties
- The good life

### 2.3 Analysis of Domestic Qualitative Data

To analyse the data we have constructed queries in NVivo which interrogate the data in structured ways to identify data about particular items of interest. These include practices which take place in the 4-8 peak period, what participants regard as their most and least flexible practices, their responses to the interventions in TC9 and TC20, their interaction with IHDs and several wider themes that have come to be important in the development of our research. NVivo queries can be thought of as similar in many ways to queries that would be run in a conventional SQL database – they are repeatable structured searches which find data (segments of audio, photos, scanned documents) which have been tagged (coded) by the social science researchers as being related to Participant IDs and one or more themes. This process has enabled us to navigate and become attuned to the data and to extract data relating to particular research questions.

### 2.4 Social Science and Academic Dissemination

The Social Science team has attended and presented CLNR related papers at the following academic meetings:

**Table 2 - Social Science Dissemination**

Date	Conference	Title
Q1 2012	Association of American Geographers	Diagrams of Power: Politics and the Co-Production of the Smart Grid
Q3 2012	Royal Geographic Society incorporating the Institute of British Geographers	The Emergence of Smart Grids from Energy Markets

Q3 2013	Beyond Behaviour change Symposium, Melbourne	Systems of electricity provision and the constitution of 'smart' energy practices
Q3 2012	European Association of Social Anthropologists	Smart grids: evolving relations between suppliers and consumers
January, 2013	Society for Anthropological Sciences	Presentation of DEI Anthropology research
Los Angeles, April, 2013	Association of American Geographers ( <a href="http://www.aag.org/annualmeeting">http://www.aag.org/annualmeeting</a> )	<i>Enrolment and Exclusion – Flexibility Capital and The Politics of Smart Electricity Demand Management</i>
Graz, July 2013	Institute for advanced studies of science, technology and society ( <a href="http://www.sts.tugraz.at/">http://www.sts.tugraz.at/</a> )	Paper 1: <i>Fostering Active Network Management Through SMEs Practices</i>  Paper 2: <i>Smart Grids and the Flexibility of Everyday Life</i>
Copenhagen, June 2013	Nordic Environmental Social Science Conference 2013 ( <a href="http://ness2013.ku.dk/">http://ness2013.ku.dk/</a> )	Paper 1: <i>Prospecting for Flexibility: Findings from a Collaborative Enquiry into Smart Electricity Systems</i>  Paper 2: <i>The Co-evolution of Energy Provision and Everyday Practice: Rigidity, Disruptions and Systemic Challenges in the Installation of Air Source Heat Pumps in the North of England</i>
Durham, June 2013	Smart Urbanism International Workshop and Symposium	<i>The Emergence of Smart Grids from Energy Markets</i>

Full length (circa 7,000 word) academic journal papers are near completion for five of these conference papers and a further two papers are also in development. These will be completed and submitted to journals in quarter four, 2013. After peer review and journal acceptance they will be disseminated openly. In the meantime the social science team will work with partners to communicate the insights in an appropriate manner.

In addition, Professor Harriet Bulkeley who leads the social science team gave evidence to the Houses of Parliament Energy and Climate Change Committee on the Smart Metering Roll Out in which she drew heavily on the social science fieldwork and analysis<sup>4</sup>.

These external activities as well as several internal discussions and analysis meeting have led to the development of the range of insights curated for this report which includes empirical data analysis and some discussion of how the is being interpreted through analytic frameworks which draw on wider energy research in the social sciences.

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<sup>4</sup> <http://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/news/smart-meter-2-3/>

## 3 Emerging Research Findings

This section of the report deals with the emerging analysis, data and findings, and is organised around the learning outcome questions as set out in Section 1.2.

### Learning Outcome 1: Current Loads and Practices

Learning Outcome 1 is concerned with the current loads on UK electricity distribution networks, and this report focusses specifically on domestic loads as reported by participants in test cells 1, 2, 3 and 5. Analysis and illustrative data relating to the LO1 sub-questions are presented in sub-sections as Section 3 proceeds. Before that however, some initial statistical analysis of the first domestic survey is presented.

#### Survey Analysis: Attitudes

The domestic survey received a total of 731 responses from trial participants. We report here on analysis that has been conducted in order to assess the validity of the survey and to explore the ways in which it is possible to cluster or group customers based on either their attitudes toward energy and the grid or their ownership of electrical goods. The following provides a high level summary of this work, and **Appendix 1 – Residential Survey: Preliminary Statistical Analysis**<sup>5</sup> provides more detailed account of the statistical tests and results.

In order to expose underlying structure, all 29 attitudinal questions were entered into a Principal Components Analysis (PCA) which produced four significant factors explaining a total of 41.47% of the whole sample variance in responses to the attitudinal questions. These represent groups of attitudinal questions which are named post-hoc and for which responses tend to cluster, and are suggestive of four ‘meta-attitudes’ that householders report holding to a greater or lesser extent. Each factor is then created as a new variable in the data set, enabling simpler, robust analysis of attitudes. In order to interpret these new variables, their relationship to the original 29 questions was investigated. On the basis of this, the four components appear to relate to:

1. Importance of government action/subsidy
2. Households’ responsibilities in managing infrastructures
3. Everyday practices
4. Confusion relating to accessing energy information.

Further analysis suggests that respondent age correlates negatively with components 3 and 4, suggesting that older respondents are more willing to make changes to their practices, but are more confused about how to obtain trustworthy information about energy efficiency. Furthermore, analysis of variance revealed a significant effect of gender on component 2 suggesting that men place higher importance on the role that households play in infrastructure changes than women. A final observation to report at this stage is that Marital status had a significant relationship with component 3 (Individuals’ Practices). No other component was significantly related to this variable. Specifically, ‘divorced/widowed’ participants report scored less strongly on component 2 than married respondents.

Considering participants ways of thinking about energy use and the home through these attitudinal questions integrates with the practice based approach we have taken to analysis of electrical loads and flexibly.

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<sup>5</sup> Conducted by Dr Jamie F Lawson, Anthropology, Durham University

## **LO 1.1. What are today's Domestic demand (load and generation) profiles and how do they vary?**

LO 1.1 is the top-level question for LO1 which asks a series of questions about current load profiles and their variance. The following sub-sections take each of the sub-questions in turn.

### **LO 1.1.1.a. Which practices are currently giving rise to electricity use in domestic contexts?**

LO1.1.1 is the first sub-question under LO1.1 and asks which practices (activities which make up everyday life) are associated with characteristics of UK electrical loads. In this report, we take a practice based approach to the analysis of electrical loads and flexibility. A practice based approach means that rather than focus on whether people, or groups of people are or are not flexible per se, we focus on the extent to which different practices are giving rise to electricity use and their current and potential flexibility.

This is in line with current research and thinking in the social sciences on the energy consumption and loads associated with everyday life (see Bulkeley et al. 2012; Gram-Hanssen 2010a; Gram-Hanssen 2010b; Halkier et al. 2011; Hinton et al. 2011; Pink 2005; Shove & Pantzar 2005)

In the first interim report produced by DEI's social science team we set out the practices that are of most direct interest to this study – those which are associated with the bulk of energy consumption in the home as; *cooking, heat and hot water, lighting, bathing, chores, entertainment, and standby and 24hour loads*. In considering these household practices, we separate out laundry and dish washing from other chores (such as vacuum cleaning and ironing) and in later sections distinguish dining from cooking. We do not deal directly with heating and hot water in this report as these are delivered almost exclusively by gas for most participants. The exception to this is the section on TC3 – heat pump participants – where we do focus on how heating and hot water practices have co-evolved with the provision of heat pumps. Finally, we do not focus on standby practices in this report in order begin a more detailed consideration of some of the groups of practices<sup>6</sup> we consider to be central to the demand-side management debate in the UK:

- Cooking
- Washing Dishes Laundry
- Other Household Chores (OHCs)
- Electronic Entertainment and Work
- Bathing

### **LO 1.1.1.b. Which of these practices are the most intensive in terms of electricity use?**

This list of practices has emerged as most directly relevant to demand side management debates as a result of the combination of several factors: likelihood of being performed the 4-8 period, electrical load, and technology ownership. We conducted an analysis of these factors using the qualitative data collected as part of CLNR and through reference to the CREST model of domestic electricity consumption. These groups of practices were identified by the social science team as being of potential interest to the DSM community on this basis, which is summarised in Table 3.

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<sup>6</sup> We are not able to report on all practices listed here at this stage but will do so in future work.

**Table 3 - Practices associated with the 4-8 peak period**

Practices	Employed Electrical Appliances	4-8 Peak Likelihood <sup>7</sup>	Group Most likely to use in peak	Typical Electrical Load <sup>8</sup>	Electrical Load Band <sup>9</sup> Mean Duration (mins)*	Proportion of Dwellings with Appliance* <sup>10</sup>	Ownership Band <sup>11</sup>	Peak / Load / Ownership	Rational for possible DSM Contribution
<b>Other Household Chores</b>	Iron	Middle	Busy working couples and families	1.00kW	High 30 min	90%	Very High	M/H/VH	Load intensity, possibly in peak
	Vacuum	Middle		2.00 kW	High 20 min	93.7%	Very High	M/H/VH	
<b>Electronic Entertainment and Work</b>	Personal Computer / Console	High	Almost all Participants. Exceptions are shift workers.	0.14 kW	Low 300 min	70.8%	High	H/L/H	Mass participation in peak
	TV	Very High		0.12 kW	Low 73 min	97.7%	Very High	VH/L/VH	

<sup>7</sup> Likelihood based on CLNR qualitative data analysis

<sup>8</sup> All figures (kW, kWh, minutes and % of dwellings are taken from CREST model of domestic electricity consumption other than Central Heating Pump. See <http://homepages.lboro.ac.uk/~eliwr/>

<sup>9</sup> Load Band Definition: Very Low = <0.99kW, Low = 0.1 – 0.2.99, Middle = 0.3 – 0.99kW, High = 1kw – 2.49kW Very High = >2.5kW

<sup>10</sup> The % of households with an appliance is taken from the CREST model but in future work we will integrate the findings from the social science survey regarding technology ownership.

<sup>11</sup> Ownership Band Definition; Very Low = <10%, Low = 10 - 29%, Middle = 30 – 69%, High = 70 – 89%, Very High = >90% or more

	TV Receiver box	Very High		0.03 kW	Very Low 73 min	93.4%	Very High	VH/VL/VH	
<b>Cooking and Washing Up</b>	Hob	Very High	All participants	2.40 kW	High 16 min	46.3%	Middle	VH/H/M	Load intensity, mass participation in peak
	Oven	Very High		2.13 kW	High 27 min	61.6%	Middle	VH/H/M	
	Microwave	Very High		1.25 kW	High 30 min	85.9%	High	VH/H/H	
	Kettle	Very High		2.00 kW	High 3 min	97.5%	Very High	VH/H/VH	
	Dish washer	Middle		1.13 kW	High 60 min	33.5%	Low	M/H/L	
<b>Laundry</b>	Tumble dryer	Middle	Busy working couples and families	2.50 kW	Very High 60 min	41.6%	Middle	M/VH/M	Load intensity, possibly in peak
	Washing machine	Middle		0.41 kW	Middle 138 min	78.1%	High	M/M/H	
	Washer dryer	Middle		0.79 kW	Middle 198 min	15.3%	Low	M/M	
<b>Bathing</b>	Electric shower	Low	Shift Workers	9.00 kW	Very High 5 min	67%	Middle	L/VH/M	Split: Load intensity for electric showering and mass participation of child bathing
	Central Heating Pump	Middle	Households with small	0.6kW	Middle	90%	Very High	M/M/VH	

			children						
<b>Refrigerati on</b>	Chest freezer	High	All participants	0.19kW	Low	16%	Low	H/L/L	Mass ownership, reliable peak load
	Fridge freezer	High		0.19kW	Low	65%	Middle	H/L/M	

At this stage analysis of the qualitative data suggests that the practices that are of most direct interest in terms of their potential ability to play a part in demand side management of the electricity distribution network are household chores, cooking and dining, laundry and dish washing. Electronic entertainment and showering, although listed in Table 3 either have low electrical intensity (entertainment), or are perceived to be less flexible by respondents (both bathing and entertainment). We do not rule out other practices from further analysis, but this report focusses on these practices and in particular at the ways in which they are reported as being present in the peak period, and the extent to which this is currently fixed or variable.

### **LO 1.1.2      What are the factors that shape the use of electricity for these practices?**

Here we consider what external or common factors are affecting the use of electricity associated with the practices identified under LO1.1.2. The analysis we have conducted across the test cells suggests to us that there at least 5 key factors which determine energy use associated with practices in domestic settings. Importantly, these factors affect electricity use for these practices prior to any trial interventions, i.e., these are LO1 findings rather than LO2 findings. The factors are:

- 1. Ways Of Working**
- 2. The Household**
- 3. Materialities**
- 4. Economies**
- 5. Habits and Norms**

It is not our intention to suggest that these are independent factors – they certainly interact and affect different groups in different ways but they are presented here as a list, leaving open the possibility of analysis which seeks to understand how they combine to affect practices. In future work we will consider how these relate to other theorists' ideas about what are the components of practices but in this report we set out each factor and present data to illustrate some of the ways in which energy use is affected by each.

### **LO 1.1.3      Factor 1: Ways of Working**

Interview data suggests that work regimes significantly influence when and how household practices are carried out, shaping patterns of energy use. Participants work patterns fall into three broad categories: conventional working hours (Monday to Friday); shift working (including weekend working); ad-hoc or flexible working. Those working typically Monday to Friday, 9 to 5:30pm express being squeezed for time, and finding it a challenge to fit domestic duties around their working hours – with dish washing done in the mornings before work, and cooking, cleaning and laundry done mainly in the evenings after coming home from work, although sometimes these are shifted to weekends – but preferring to leave the weekend free for family time or leisure activities. Hard-pressed households employ various technologies and other 'devices' to assist in juggling the different demands, including using automatic timers (for dish washing and laundry), and employing a cleaner.

*In an ideal world where we didn't have so many time pressures; and we could choose when to do things like the washing or the cooking, and there were cheaper or more efficient times to use energy then we probably would. Not with a family and two jobs at the moment. (EPJ017)*

*I tend to wash and dry on a Saturday. Habit. I'm not working so that's when the washing gets done. ... I don't know how I could change the way I cook. ... No 'cause work. (DL13)*

*I am [cooking a meal] for my wife coming home from work. (GP2702)*

*Friday I would come in from work ... the Hoover would be on. The washer would be going. Right the way through probably 'til 10 o'clock that washer will go. (EPJ014)*

*It would be very awkward for us ... we work days (GDP049)*

*It could be two nights a week that I come home from work and I would put a wash in..... I work in a fish shop so it's a bit smelly. (DL08)*

*[Laundry] is mainly done on my wife's day off. She's off like every Monday and Friday. So tends to do the ironing and washing. (EPJ020)*

*Usually on a Thursday ... that's my day off. And throughout the weekend. ... I get the whole weekend off. ... Big washing gets done on Saturday; bed sheets that sort of stuff. Saturday or Sunday. (GDP051)*

*We don't work Monday to Friday, so it's not that we have to do things during that time [4-8pm] (GDP028)*

*[Dish washing] Every day. Once a day ... It's probably either first thing in the morning or teatime when we're in. It can be during the day though. ... it just depends who's in. My stepdaughter works... she's got mid-week days off so she starts at 5am and finishes at 3pm. ... Predominantly it's in the morning before we go to work or when we come back from work but there are other*

*times it gets middle of the day when it gets used in the as well. (EPJ019)*

*We're out early on a morning. On the days my wife isn't off, we're out the house half past 7- 8 o'clock. ... (EPJ020)*

*Kids' activities, football, daughter's horse riding so Saturdays we're out between 10am and 3pm anyway. (EPJ020)*

Those who work shifts also talk about fitting household routines around their working hours but there is more opportunity to shower, or to accommodate cooking and household chores outside of the morning or evening peak periods.

Although those not in full time paid employment, including those who do casual work, have greater freedom in household management and organising household practices, this may not follow – as practices may be arranged around the needs of others in the household, for example children's activities. This is discussed further in Factor 2: The Household.

Working patterns also relate to the material elements of practices and how certain technologies, such as tumble dryers are used within the home. This is further discussed in Factor 3: Materialities.

#### **LO 1.1.3.a. Factor 2: The Household**

Analysis suggests that practices and how they are performed are linked to household composition and life-stage. From the interview data, three aspects of households are identified with distinct patterns: family structure; employment status; age and health.

#### **Families with young children**

For families with young children, everyday practices such as cooking/eating, cleaning, laundry and bathing are organised around their needs, school and other routines.

*With two kids they have to be fed before they do homework. They tend to be doing homework while I'm cooking. ... If I waited it'd be too late for them ... (DL07)*

*Nearly every day. Especially downstairs. With the little one anyway. Definitely with him, you have the hoover [vacuum cleaner] out every 5 seconds. ... At least once a day downstairs.(EPJ012)*

*She loves to Hoover [vacuum]. ... Probably every other day ... It varies, when these [children] have been tramping mud in ... (EPJ013)*

*Two to three [wash loads] a day. ... Well, if I missed a day I'd probably do 5 loads the next day. (EPJ012)*

*[Ironing] nearly every day. Sometimes I can just do half an hour and then sometimes I could maybe do 2 hours depending. ... Probably about 15 hours a week. ... Between 10 and 15 hours a week. (EPJ012)*

### **Families with teenage children**

In families with older children, routines may be more fluid with events such as mealtimes less structured, and people eating at different times:

*With a 16 and 19 year old ... they're out all the time ... we cook when people are wanting food. (DL13)*

*I don't cook a lot anymore, with being on my own. ... usually use the microwave on the teatime. It got the stage years ago where they all wanted different things but now they just all do their own. And usually it's, if it's a pizza they use the oven, but it's mostly microwave stuff. ... He (son) doesn't eat 'til really late. Sometimes I'll be going to bed at half ten and he might say "I'm going to have a meal now". I think "How can you do it", but that's what he does. (GP021)*

### **Not in Employment or Education**

Retired people or those not in work report being able to exercise greater freedom around when they carry out household practices. Even so, these are often scheduled, such as doing chores at a specific time of day or certain day of the week, or perhaps to fit around other activities, such as going out or watching a favorite TV programme.

*I only watch one soap and that's Emmerdale. I make the dinner, watch Emmerdale then do what I've got to do. If I'm in that's what I do. (GP0026)*

*Well, I'm up at 6 o'clock in the morning so I like to tidy up in the morning so that's me finished for the day. (MJRTL012)*

*[Vacuum] Three times a week ... That would be in the mornings, definitely. (EPJ008)*

*I'll use the Hoover [vacuum] on the morning. I use that every morning. (GP0025)*

*Hoovering [vacuuming] in the morning... normally washing, now that I've got all day (GP042)*

*I plan in advance always. But not today - I was going out shopping today but I won't go out when there's bad weather but yes, I plan my weeks. (MJRTL13)*

For some, mealtimes are often routinised, a practice carried over from family; or previous working patterns:

*Start it [dinner] about 7 o'clock . ... Habit we got into when we were both working. (ML23)*

*I can't see us changing our eating habits – which is what uses most power . ... So firmly ingrained that we have our main meal in the evening. (ML23)*

*As a family, we've always had our meals early evening, and if you go past 8 o'clock at night you're getting late, and I'm starting to want to go to bed earlier, so it's difficult to get out of that of using the oven at that time. (DL0602)*

However, there is evidence of some practices changing following retirement, through having more time to reflect and re-organise:

*I am retired now so time to think about things (DL010)*

*You come in from work and think I have to do the washing, got to do this, got to do that, got to do the other, 'cause you have to do it while you were there. ... I think it's entirely because of being retired. I don't think we would have done some of these things had we had still been at work. (HS001)*

*At one time I used to wash at night coming home from work but not anymore. (GDP042)*

*Hoovering [vacuuming] in the morning. Normally washing, now that I've got all day – at one time I used to wash at night coming home from work but not anymore. (GP042)*

*Most of my meals are cooked before 4 o'clock comes around. It's a case of it's just heating it up ... Mostly it's been done through the day anyway ... (GP0022)*

*Female: I don't think I can wait until 9 o'clock for my dinner. I couldn't eat at 9 o'clock then go to bed.*

*Male: What you'd have to do is have [our]dinner at 4 o'clock.*

*Female: And that's alright for us 'cause we're not working (GP0025)*

## Age and Health

A further aspect of household composition and age is that health and wellbeing are prioritised in some participants' explanations of their energy use, and concerns over poor health in particular lead to increased need for reliable, controllable heat. While this, for now, mostly affects gas consumption, if heating is to be electrified in the coming decades via heat pumps, as per DECC's Carbon Plan (Department for Energy and Climate Change 2011) and Heat Strategy (Department of Energy and Climate Change 2013), and as the population ages, this will become an increasingly powerful driver of domestic electricity consumption.

*I grill things rather than fry them because I've got high blood pressure, and my husband had heart trouble so I was always taught to grill rather than fry. (ML06)*

*Interviewer: Could you cook your tea earlier or later than you do at the minute?*

*Respondent: No. I wouldn't do it. I couldn't do it. Na, Na. Me' grandson comes for his dinner, says I'll be here 5:45 so I couldn't. I'm set in my ways now, I never used to be but since I had all this done (medical treatments) I don't even go out at night." (GPML004)*

*It gets too warm for me you see...Twice while we've had this snow it's been up to 25 but I've had to turn it down. (EPJ009a)*

*The heating is on a lot more now because I've got to keep warm, but that radiator's not on because I get too hot. I've been washing more, I'm washing every day now, and ironing more obviously. The district nurse says she can't believe how well I'm doing. (MRJTL03)*

*If I get too hot I turn it off completely rather than turn the radiators down. And I have the windows open because I like to get some air through the flat. The doctors tell me to try to keep my fingers and toes warm. (MRJTL06)*

### **LO 1.1.3.b. Factor 3: Materialities**

#### **Housing structures**

There is evidence to suggest that spatial constraints within dwellings has an impact on selection of appliances or systems, leading to sustained effects on energy demand:

*[I needed] A cooker that would fit into this station here. I always wanted a range cooker but I couldn't get it in here. I had to do with this one. It's got 4 rings, 2 ovens. (ML07)*

*That one [fridge freezer] is fairly new. ...It's alright - don't think it's top of the range [energy rating]. ... It was a decent size, you know and we had to fit it into that slot. (EPJ013)*

Many of the owner occupiers interviewed have extended their dwellings to create additional space. Commonly, this is to provide a larger kitchen/family area, utility/laundry room, additional bedrooms and bathrooms, with associated new, often larger appliances such as fridges/freezers, cookers as well as dishwashers, tumble dryers, electric showers and additional lighting – which have implications for energy use.

*There was just one [bathroom] but there is one en-suite now. So there's an additional [electric] shower gone in the bathroom. (GDP052)*

*The dryer - that's on more than it should be. But it's just too easy to go from the washer and [into the] dryer in the same room. (EPJ020)*

### Electrical Equipment

As part of the statistical analysis of the survey data a second principal components analysis (PCA) has been conducted on the electrical appliances / technologies that households reported as owning. Counts of all 34 electrical goods prompted in the survey were entered into a PCA. This produced 3 components that accounted for 50.19% of the sample variance in technology ownership. These three components are groups of technology ownership questions which are named post-hoc and for which responses tend to cluster and which. These three components can be thought of as technology ownership tendencies, in which ownership of one or more technologies indicates that ownership of the others is more likely.

1. Common Household Equipment
2. Luxury Items
3. Digital +

The technologies present in each group are shown in Table 4, below.

**Table 4 - Electrical Goods Principal Components Analysis**

	Component		
	1: Common Household Equipment	2: Luxury items	3: Digital +
% Variance explained	31.51	11.93	6.76
Microwave	.90		



Washing Machine	.89		
Tumble Dryer	.77		
WiFi	.74		.42
Electric Kettle (Regular)	.73		
Electric Cooker	.71		
Electric Shower	.70		
Chest Freezer	.61		
Printer	.60		.48
Heated Pool		.90	
Sunbed		.86	
Patio Heater		.80	
Washer / Dryer		.73	
Energy Saving Kettle		.65	
Musical Instrument		.47	
Greenhouse Heaters		.44	
TV			.70
Digital Receiver			.65
Laptop			.61

Phone Chargers			.57
Jacuzzi			
Aquarium			
Dishwasher	.42		
Hair Straighteners			
Games Console			
Desktop Computer			
Garden Tools			.41
Refrigerators	.43		
Fridge / Freezer	.56		
Tablet			
Photocopier		.53	

Further analysis suggests that respondent age was found to correlate positively with the 'scores' in the new variables 'Common Household and 'Luxury Items', suggesting that older respondents possess more of each.

In terms of gender, analysis of variance revealed that gender has a significant relationship with common household items, such that men report owning fewer basic items than women. Neither of the other components had a significant relationship with gender.

Marital status had a significant relationship with component 3 (Digital +). Pairwise comparison revealed that single respondents reported possessing more items in the Digital + group than either cohabiting or married respondents; and that divorced/widowed respondents have fewer of these items than married respondents. No other comparisons were significant.

There was a further significant effect of marital status on the Luxury Items group, which we suspect is the result of the significant interaction between the independent variables for this factor. The interaction can be seen in Figure 1 which shows that married women report owning more luxury goods than any other group.

**Figure 1 - The significant interaction between gender and marital status (1 = single, 2 = cohabiting, 3 = married, 4 = divorced/widowed).**

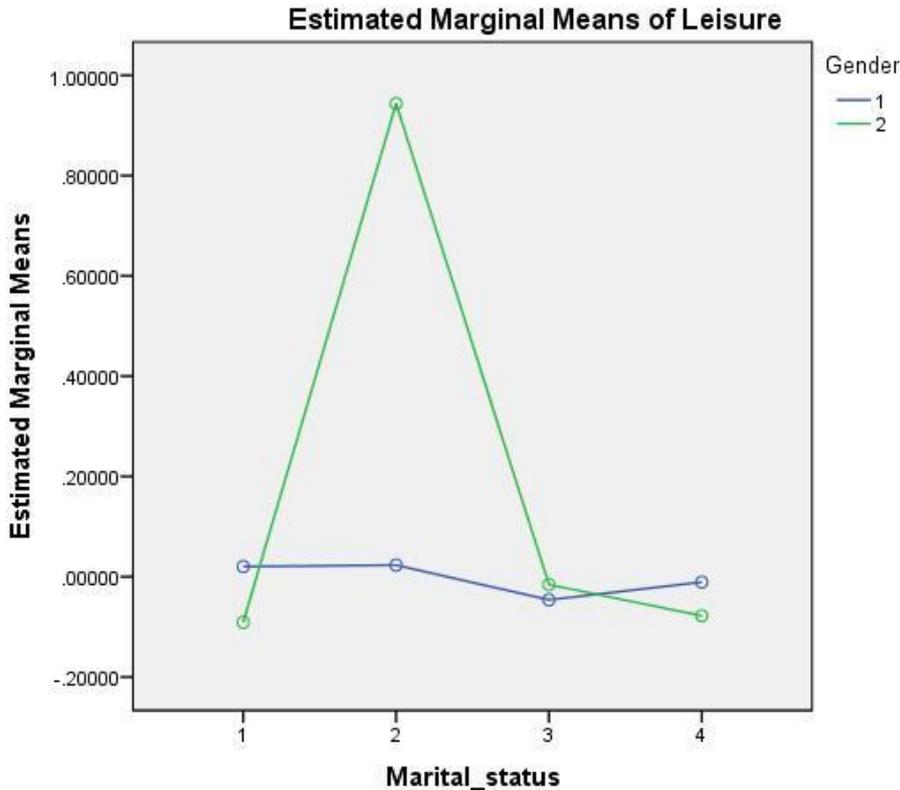


Figure 1 shows that women (green line) who have describe themselves as married (Marital status 2 ) are much more likely to own items in the Luxury Goods group (the vertical axis represents the likelihood of doing so) than any other gender or marital status.

### Qualitative Analysis of Technologies

The relationship between energy-consuming technologies, structural and other factors is evident in the customer responses, for example, the connection between working patterns, use of household appliances and routines.

*When you're at work and you need the uniform for the next day. It's easier ... I do use the tumble dryer a lot. (GP0037)*

*We've always had a big fridge – a relatively big fridge, because we tried to do one big shop a week when we were working so we got used to having a big fridge. (ML23)*

This 'over-sizing' points to 'social loading' (Wilhite & Lutzenhiser 1999) where feedback loops between appliance manufacturers and suppliers of food, detergents and so on create a momentum which leads to appliances getting bigger and more common over time. The data suggest that a large fridge freezer and / or multiple fridges/freezers are commonplace where space permits:

*We've got a chest freezer, an under counter freezer, and an under counter fridge. (GDP049)*

*One of the biggest things we should get rid of is freezers and fridges. We have 3 fridges and 3 freezers. ... Our granddaughter she's vegetarian so all her vegetarian stuff goes out there ... We've got a little bar ... we've got a fridge in there to keep the drinks cool, you know. ... (GP03002)*

Energy efficiency may not be the principal factor in selection of appliances; this is a trade-off against other material factors such as capacity, size and space with multiple fridge freezers often linked to other household practices such as growing food, cooking, managing a household, and catering for visitors:

*That one [fridge freezer] is fairly new. ...It's alright - don't think it's top of the range [energy rating]. ... It was a decent size, you know and we had to fit it into that slot. (EPJ013)*

*When we had the kitchen done, that [fridge freezer] came as part of the kitchen. But I like that one better so we kept that one. I do cook a lot so tend to freeze things a lot. We have a big garden so we freeze vegetables and fruit. ... The one in the garage, someone gave us that. (GDP053)*

*That's the other freezer – which is a chest freezer. [Interviewer: Why do you need a second freezer?] Capacity. Being retired, having an allotment next door, we produce a lot of vegetables which don't last. They go in there. We also produce a lot of our own fruit ... I've got huge surpluses. (DL15)*

*I needed a big one [fridge freezer] cause I do a lot of cooking (ML07)*

*I've got two big bloody fridges, one in there, one in the other room so if we need any meat [for visitors] just pull it out. (GDP045)*

*Nice big size. ... It's not well stocked at the moment. It's very rarely empty! (EPJ012)*

Most households had some low energy light bulbs within the home but adoption was partial; this is because energy efficient bulbs were often deemed not suited to existing fittings, did not 'fit' with a householder's ideas of how lighting should look, or did not provide appropriate quality of light (Crosbie & Baker 2010)

*Most of our [light] fittings don't take them [low energy light bulbs] (GP028)*

*Our bedroom has got the only energy saving lamp in. ( EPJ019)*

#### **LO 1.1.3.c. Factor 4: Economies**

While we do not suggest that households respond in a 'rational', or simple way to prices, we do not pretend that ways of managing the home economy, attempts to re-align practices around new incentive structures (such as tariffs) and various forms of financial calculation do not take place in everyday life. Indeed the analysis suggests that managing the home economy plays an important part in shaping the electricity use associated with the practice we are most interested in. The qualitative data provides a rich set of examples which illustrate the ways in which people think about the home economy and how the day to day performances of cooking, cleaning, bathing, laundry and so on are folded into and in some cases overflow out of such calculations.

#### **Choice of fuel as part of home economy**

*Participant: I think it's cheaper to run an electric cooker than a gas one. ... A gas boiler costs 56p an hour to run, and a gas oven costs about the same. The electric cooker doesn't cost that because it's not on all the time.*

*Interviewer: How do you know?*

*Participant: The smart meter. (ML24)*

*Yesterday my daughter put soup in the microwave; I said what you putting soup in the microwave for!? It takes just as long on the gas and it costs less. (GP023)*

*My washing I definitely do over the weekend when it's cheaper, unless it's absolute necessity. I might have it on twice. (MRJTL06)*

#### **Same-Day Flexibility as part of home economy**

*I had the washing on ... normally I do it on a night time but I had some there that I wanted done so I put it in this morning ... I'll not be drying that until after 8 o'clock tonight. So I put it in the dryer and not switch it on 'til 8 o'clock. ... I wouldn't use it [washing machine] between 6 and 8. ... the tumble dryer is the same. There're expensive to run you know, tumble dryers. (MRJTL12)*

*We do our washing on economy 7, which is midnight or 1 o'clock in the morning or something like that because that's when we get a financial incentive to do it. (DL1502)*

*(The Tumble Drier) It's only used at off peak times. Always weekends and after 8 o'clock at night. ... Always kept it that time. Not for any particular reason before but that's just how it worked out with the washing (MRJTL07)*

#### **Incorporating solar into Daily Routines as part of Home Economy**

*I do tend to use things like the tumble dryer during the day when it's generating. I've stopped doing that at night or in the evening, try to avoid doing it when it's dark. ... that is a change (HS007)*

We see in these responses that managing the home economy is a constantly adaptive socio-technical process in which technologies, tariffs and activities both internal and external to the home are aligned to an attempt to let everyday life continue 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 (cooking) 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. (MRJTL10)*

**LO 1.1.3.d. Factor 5: Habits and Norms****Hygiene related norms**

*Interviewer: How often do you vacuum: Not every day. I think you should, shouldn't you. There's only me here. ... Maybe every other day. (EPJ006a)*

*I've got clean clothes on every day. That [the iron] would be on for about 20 minutes. Every day. (EPJ007)*

*Interviewer: Do you iron very often?*

*No. No, not if I can help it, just my pyjamas. Because them you've got to. (EPJ004)*

**Cooking related norms**

*The point is though, at what time are you going to start making your tea. 8 or 9 o'clock is too late; and 3 or 4 o'clock it's an afternoon snack. It's not your tea for most people's programming.*

*I mean we have to have a dinner, we have a hot dinner every day." (Customer with an in home display only)*

*Microwave? We don't really use it much, I never cook in it, I would never dream. I mean don't get me wrong, I always keep a couple of ready meals in the freezer, sometimes our son will come home, 'I'm hungry mum you got anything?', I bung him one in, or whatever. But I never, I won't make a cake or a casserole in it, or anything like that.*

*Interviewer: Why would you say that I would never use it?*

*Participants: It's not proper cooking is it? It's just not, proper.*

Norms and habits are related but we distinguish between them here to consider the different ways in which social factors shape the contemporary and emerging future performance of practices. Participants often explain their day to day lives by invoking the notion of ‘normality’, and thus making a practice or activity seem self-evident, or not needing explanation. Norms are socially reproduced and come to be more or less widely accepted in social groups. In many interviews respondents present their behaviour as being normal, and therefore beyond analysis or reflection. It is this sense in which practices are beyond reflection that requires analysis of why this has come to be the case and following from this, analysis of the components of practices becomes a way to explain how some things become thought of as being normal and others remain open to reflection. Here we present examples of aspects of daily life which are thought to be self-explanatory in this way, drawing on examples about hot meals and hygiene which seem to be most heavily influenced by norms and received wisdom,

A related explanatory factor is habit which is also often used by participants to explain everyday performances of the practices we are most interested in. Habits can be thought of as personalised ways of performing aspects of daily life – ways of conducting oneself which have become normalised over one’s life rather than reproductions of shared social or group norms. These are habitual performances rather than socially reproduced entities. The social science team has engaged with social theories of habit and routine in other writing but this report does not present a detailed discussion of these debates. Instead, data is presented which illustrates some of the ways in which habitual ways of living have effects on the practices identified above as being of relevance to the demand side management.

### Habits as shaping laundry and cleaning practices

*I tend to wash and dry on a Saturday. Habit. I’m not working so that’s when the washing gets done. (DL13)*

*Oh, I couldn’t stand it. No. Monday is washing when I get up to wash. It’s folded ready to go out or in. I go along to get my pension. ... I go to the paper shop and pay gas, electric, rent, garage, lotto – all on a Monday morning ... all at the paper shop and then back home. ... No, that would knock me to bits. (GPML004)*

*I usually put it [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. (EPJ003)*

*[Interviewer: When do you do your laundry?]*

*“Once a week. All day on a Monday. I go right through the house. I’m in on my own so I can get on with it. Washing and ironing as well. All at the same time. ... Beginning of the week and the end of the week, when there’s enough to go in the washing machine, that’s what I like to do. (EPJ018)*

*I don’t hang it outside (laundry), I just chuck it in the dryer – it’s easier. I have always done that ... since I’ve been divorced. ... It’s convenient, that’s all. (ML12)*

*I have to wash them straight away. If leave these on the bench it makes my kitchen look untidy, it’s so small. So I’m always washing up. ... It’s what I’ve been used to. (EPJ009)*

### **Habits as shaping other practices**

*I can’t see us changing our eating habits (ML23)*

*I have to wash (dishes) straight away. If leave these on the bench it makes my kitchen look untidy, it’s so small. So I’m always washing up. ... It’s what I’ve been used to. (EPJ009)*

## LO 1.2. How are load and generation profiles likely to change?

While LO 1.1 has looked at current loads and practices, LO1.2 considers the emergence of trends in energy consumption and practices

**Context:** According to the latest strategy of the UK government, achieving significant decarbonisation of the UK's energy system requires a significant shift in the ways in which energy is provided domestically for heating and hot water (DECC 2009); this involves incentivising micro-generation technologies and mandating a smart meter roll out to cover all UK properties.

Uptake of PV has increased markedly since the introduction of the Feed-in Tariffs (FITs) and although uptake of heat pump technologies in the UK is considered 'dismal' when compared with the volume of installations reported in mainland Europe and North America with the uptake in ASHP particularly sluggish (Singh et al 2010: 876), this may change in the coming years. By 2010 an estimated 30,000 air source heat pumps were installed in the UK; the majority being located in residential buildings (Fritsch 2011) and in situations where dwellings are without mains gas (EST 2010).

In this context we consider what TC1 (a sample of British Gas's smart meter population), TC3 (a heat pump study group) and TC5 (a PV study group) can reveal about emerging trends associated with these technologies.

**Concepts:** We suggest there is a need to consider how the provision of energy services and the everyday practices within which these are enrolled are related and how they produce one another in order to understand how such interventions are domesticated, either to be embraced, side-lined or contested within the home. Importantly, the insertion, uptake and effect of new technologies will be shaped just as much by the ways in which they are consumed as the way in which they are provided.

### LO 1.2. Insights from smart meter with IHD TC1: What evidence is there that energy use/practice and generation within households or SMEs are currently shifting?

We found that smart meters are viewed positively, with few concerns expressed by participants about security or health. Furthermore, smart meters and IHDs are understood to be the same thing, or at least two parts of a whole. All households who have taken part in our study have both a smart meter and an IHD and for the vast majority the IHD *is* the smart meter – it is the means through which they are provided with information, and it looks 'smart' because of its digital display, its real time information and the way it physically resembles other devices which are associated with domestic ICT devices (smart phones, portable consoles).

We find that people use the IHD in at least three distinct ways; to manage the household economy, to provide oversight on what families are doing, and to challenge themselves to save energy – each of these lead to the identification of energy saving potential and where these fit with a grid intervention such as a tariff, offer opportunities to engage with DSM. These relate directly to two of the five main factors affecting electricity use identified in Section 3; economies, the household.

#### LO 1.2.1.a. Three Modes of IHD Use

**Managing the Home Economy:** The IHD provides feedback and contributes to understanding which devices use energy, how much energy is being used at different times of the day/week, and the overall spend. This is about 'good housekeeping' – knowing what is coming in/going out and managing the household economy and finances in this way. For some people, this feedback is used

to reduce low hanging fruit in terms of expenditure, but for most it is about keeping track of bills/understanding the overall family finances.

*We've had it (IHD) just over a month about 6 weeks ... since the husband left. It's brilliant. I do check it on a daily basis. Yesterday cost 54p, and 1.11 (Gas), last 7 days 5.84. (DL07)*

**Family management and oversight:**

Especially for families with teenage children, the smart meter provides a means of understanding what other family members are doing at different times of the day.

*When we got it he was like, "What you got on!? What you got on!?" He was in a panic! (DL802)*

*My husband keeps going "Get it off! Get the kettle off!" (GP028)*

*There's nothing to dislike about it. It's quite useful, it tells you what's going on, it changes colour. (ML06)*

**Game-like optimisation:** For a sizeable minority, the SM offers the opportunity for households to try and optimise their energy use in terms of overall consumption, the extent to which energy is being used at different times of the day and so on. This is sometimes related to the home economy but is also often seen as something to do for its own sake with some loose rationalising reference to saving energy, saving money or the inevitability of energy transitions.

*I mean you can see the peaks ... If someone's used summat' you can see it goes it, I mean it's like a skyscraper. On a rare occasion it goes red. There'll be 2 high voltage things on at a time it goes red. If the kettle and deep fat fryer's on together. ... I think they're better than not having anything at all. ... I think we try to use less because they're showing you how much you're using." (DL402)*

**Domestication:** Sociologists (Berker et al. 2005; Mansell 1996) have studied the domestication of technologies in order to understand how they are brought into alignment with specific domestic processes which may or may not match the designer's envisaged optimal usage. IHDs typically find their way onto kitchen benches where they become part of the central electrical hub of the home – adjacent to or at least viewing range of white goods, kettles, toasters, coffee machines. There is a sense in which the kitchen is the cock-pit of the home from where practices, family life and the home economy are managed, with the IHD fitting into this space as an additional source of feedback and information to complement mail, smart phones, and personal interaction which contribute to these management activities.

*It's not caused any bother... I am aware of it because it's in the pantry. I know if I've left something on so I can go back and then the light will go off. So it reminds you that you left something on that shouldn't be on. (ML03)*

*... I look at it daily; it's in the kitchen on the bench so you can see it. (DL802)*

**Ease of Use:** Whilst the majority of participants are positive about their IHDs, a sizeable minority are indifferent with one participant having opted out by unplugging their IHD. The 'traffic light' system is seen as intuitive and easy to understand and little communication/information is needed for people to know that 'green' is a positive level of consumption and that 'red' is a warning about high electricity use/high costs. This is the most widely used feature of the IHDs and is not thought of as complex or difficult to engage with by any of the respondents, even those in demographic groups that might typically be thought to be less likely to engage with IHDs and other smart devices.

*Must admit that I just go by the colours. If I haven't got me glasses on I can't see the rest of it. If the red comes on the alarm bells go. ... I look at it daily; it's in the kitchen on the bench so you can see it. (DL802)*

*I keep a track of it (energy use) by using the graphs because it can go red when the shower's on , or the kettle. But if the washer is on, which is supposed to take the most, it's only orange. But it's about when you use it and for how long (GP2602)*

**Messaging:** Much more could be made of the built in messaging functionality – while this hasn't happened as part of the trial many participants commented that messaging through the meter would be an effective means of communicating DSR messages. In addition however, householders also were open to receiving messages via regular SMS to mobile phones and in a small number of cases suggested messaging to their smart TV or an appliance that is in the living room.

#### **LO 1.2.1.b. Frustrations**

**Confusion:** While the IHD itself is easy to read and understand in the main, with the vast majority of participants choosing to use the price based readings (rather than units of energy or CO<sub>2</sub>), many did comment that it caused them confusion because the readings were hard to explain in reference to their own activities. We suggest that this is both a potential problem (it may lead to disengagement, or reduced trust in the device, if not increased frustration at the 'energy company') and an opportunity to increase awareness and knowledge of the energy consumption associated with different activities and appliances.

*[Interviewer: Do you have faith in the meter?]*

*Well sometimes but not always. Like Sunday I wasn't in at all and it was £1.73, then the next I was in and it more or less the same. Sometimes like it's £3 'summat and other days it's £1 'summat and I don't know why. (DL302)*

**Household engagement:** While the interviewees we spoke to were mostly very positive about the IHDs a common theme in the data is that engaging the entire household or family with the device is a challenge. There are archetypal figures in the accounts narrated by the participants who do not take part in at least two of three major modes of IHD interaction – managing the household economy and family management or oversight – and that for these figures the IHD is at best a toy or folly. Teenage or adult children are least engaged with the IHDs which is perhaps surprising given that this generation is thought to be most attuned to smart / digital devices.

*I 'tek notice. I'll flick up the price and there's about a 10p difference. Me' daughter that's a different story... (DL902)*

*The only other thing is the bloody computer, he's on it all the time. He's got one in his bedroom ... he (son) pays for that, the internet, but he doesn't pay for anything else! No board, or gas or electric and I wonder why he doesn't move out! (ML02)*

#### **LO 1.2.1 Analysis of Heat Pump TC3: What evidence is there that energy use/practice and generation within households or SMEs are currently shifting?**

Discussions with participants reveal the importance of the legacy of existing heating systems in shaping the ways in which they relate to the introduction of the ASHP. Those participants with a communal system of heating and hot water reported that it was 'tip top' (DC031) and they had 'never had no problems' (DC035). In contrast, for participants who had lived with electricity storage heating systems, the ASHPs were regarded as a considerable improvement to a regime in which they depended on various and expensive forms of electrically produced heat:

*You had no heat. They [storage heaters] were supposed to stay warm all day but they were cold by 11 o'clock so you were freezing. I had to use the electric fire all the time... but now I hardly ever use it'... Well, I was putting £35 to 40 a week on with the storage radiators but now I'm putting £20 on now. I couldn't have afforded the other. It was terrible. Female [ST004]*

*You had no control over them ... when I come in in the evening, the place was cold. They only have bricks with a heating element, so once they switch off at 7 o'clock they start cooling down, so by the time I'm getting here in at 7-8 o'clock or whatever, the place was cold and I can't do anything. I can't turn the heating on 'cause they won't switch on again until midnight, and I've got*

*no control.’ ... I mean, there was controls on it, and they said that if you closed the vents when it switched on at 7 o’clock in the morning and kept them shut, then when you came in at night if you opened them that would let the heat out. Then at midnight you close them—but it doesn’t work like that. [ST011]*

Users, and their expectations and practices, are critical in shaping how the system is operated. For some, existing daily routines over-ride the system imperatives, and users are active in reshaping the technology to their needs:

*When I’m working shifts what I normally do when I go out first thing in the morning I’ll switch it off completely. ... so then put it on auto for 5 o’clock, or if it gets too cold, like the last few weeks, I’ll just come in and put it on [ST011]*

#### **LO 1.2.1.a. Degrees of Competence and Confidence**

Yet for many, the demands of participating in the provision of energy services seemed too great. Some had tried and failed to ensure that the ASHP provided the kinds of energy services they required. Several had concerns about whether running the system all day, which technically provides the most efficient service, would in fact incur additional costs (see also Owen et al. 2012). Others sought to distance themselves from the technology, which is regarded as complicated to operate, fearing that their actions may lead to the breakdown of the system:

*I don’t know whether its there’s a fault on the system or what. Sometimes I’ll switch it on the On setting... it doesn’t come on. So if I go and switch it on the All Day setting it’ll come on sometimes. Or if I put it on All Day first and it doesn’t come and I put it on the On, it’ll come on. But sometimes it’ll only come on All Day or On for a couple of hours and it’ll switch itself off and the radiators cool down again. The only time I can get it to work properly is when I put it on Auto. [ST011]*

*That’s the control which I do not touch. I operate it from the thermostat.’ [ST005]*

*I don’t let anybody touch anything. I don’t want to know. As long as it’s working, I don’t want to know. [ST009]*

In these cases, co-provision of energy services is not something celebrated or enjoyed, but rather the emergence of new consumer roles is resisted, ignored or feared. This may very well reflect the social and demographic make-up of the sample of participants, and their position as tenants in social housing over which they may traditionally have held little sway. At the same time, they also reflect the process of installation and instruction that participants experienced. Many participants found the instructions concerning how to operate the system, and the controls through which this was supposed to be achieved, made little sense to them. Recounting the advice received from the social housing provider on re-setting the system, householders remained confused:

*If it goes off and needs reset... Switch it off from the inside, then switch it off from the outside. Give it a couple of minutes then switch it back on from the outside first, then come in and switch it on from the inside. And that should re-set it. ... The people I am asking information off I don't think they are fully aware with it being a new system and that. ... I'm not sure whether they know that much about it. Like I say, I am getting contrasting solutions to the same problems. [ST011]*

However, at the time of the interviews, most householders had reached a point where they were able to operate the system at a basic level (using the up and down arrows on the thermostat), but they stuck to the programme set initially on installation (Figure 2):

*They just put it in and I've left it as it was ... I wouldn't know what to do. That's the only trouble. They didn't really tell you much about anything. [ST004]*

A few more technically literate had changed the programme settings to suit their own preferences or understandings, however, even the more competent had some difficulty with the technical information supplied, as illustrated by the comments from a recently retired electrical engineer:

*I wasn't happy with the times they had set. So I tried to set the timer myself. So eventually I got there eventually. Reading the book over and over and over again. [ST008]*

Others found they had little to go on by way of understanding how the system operated and what they should be doing with it, particularly outside of normal operating conditions:

*The red light stars flashing and I just do not know why. And I think Oh God there's something wrong. Nobody told me that the light would go flashing red, you know. When you don't know, naturally I am the age that I worry. [ST009]*

#### **LO 1.2.1.b. Changes in Heating Practice - Mixed Outcomes**

Householders shifting from storage heaters (with or without supplementary heating) and electric hot water systems make adjustments that sometimes result in a lowered awareness of their energy use and lead to high rates of electricity consumption. *'The booster is brilliant. ... if we've let the water get too cold. It takes less than an hour 'Couple [ST010].* The potential for ASHP to actually increase energy consumption has led some researchers to conclude that depending on context, installation procedures and demographic factors, as well as variations in dwellings and the purposes they serve, a heat pump can be viewed as 'a wolf in sheep's clothing' (Christensen et al 2011). However one

potential counteraction to increased electricity consumption following installation of heat pumps in dwellings previously fitted with electric night storage heating are changes to the use of supplementary heating. Some householders forsook supplementary heating altogether - *'I don't use that [electric fire] now... I used to when I had the storage heaters though'* Male [ST011]. In this case, a once desirable resource is dispensed with and another practice – that of relying on ASHP for thermal comfort is configured. However, this energy saving effect is not universal as others prove more reluctant to depend solely on AHSP *'I was thinking about getting one of those gas ones, just in case ... I used to have a one but got rid of it. I wish I'd never have done now'* Male [0032]. In this case an old resource and associated practice is resurrected out of apprehension about the new technology.

### **LO 1.2.1 Analysis from PV TC5: What evidence is there that energy use/practice and generation within households or SMEs are currently shifting?**

Drawing on interviews with participants in TC5 we are able to make some initial observations about the ways in which generation practices are co-evolving with PV installations. We observe that as householders become familiar with and incorporate generation systems (in this case PV) into their household practices there are indications of changes in the times that some household practices are occurring. This is without there being any other intervention, incentive or other prompt outside of their PV installation. There appears to be a wider range of variability of practices with regard to PV (compared with the time of use tariff), with people talking about moving their cooking, showering, laundry and household chores around in time to incorporate solar energy into their everyday household economy.

*Now that we're producing our own electricity, if it's a sunny day my wife will set the washing machine during the day... 'For everyday cooking we carry on exactly as we always have done. (DL15)*

*It's resulted in more showers being taken during the day. Our normal preference is a shower first thing in the morning. But ... if it happens to be a nice bright sunny day and you haven't had a shower in the morning you can have one in the afternoon knowing you're not going to be short of hot water the next day. (DL1502)*

*I try and I'll even cook things when the sun shines or get a shower when the sun's shining if I can. Obviously if I am at work I'll get a shower in the evenings now. I just try and make full use of the solar panels. (DL17)*

*What I'll do if it's going to be a sunny day tomorrow, I'll fill the washer up tonight and in the morning I'm up at 5 o'clock in the morning and put it on a timer [on the washing machine] ... and it'll be timed to come on later in the day when the sun shines. ... If the forecast is for a bright day that's what I'll do. (DL17)*

*I do tend to use things like the tumble dryer during the day when it's generating. I've stopped doing that at night or in the evening, try to avoid doing it when it's dark. ... that is a change*

Changes to when daily practices are being carried out are often reported as being assisted by technology including timers and delays (where this functionality is built-in to household appliances) to maximise solar generation for domestic practices such as laundry or dish washing:

*If it's going to be a sunny day and I'm out at work I'll put it [washing machine] on a timer, a delay so it comes on half past eleven in the morning. (DL1702)*

*I would normally just at the end of the day when you put in the last dishes set it away in but I don't now. I wait until the next morning when it's sunny or lighter. (HS001)*

*What I do now. Both this and the dishwasher have got a time delay so often I'll load it at night and put the time delay on so it comes on early in the morning when it [PV] starts generating. ... It's only recently, in the last few months I've used it [the timer] on that one [washing machine] and the dishwasher. (HS002)*

These changes are not universal however, with some participants not making significant changes to their practices, as is captured in this remark, *"I am still more or less the same. ... During the winter it doesn't make any difference at all."* (HS009).

## Learning Outcome 2: Flexibility

Learning Outcome 2 is concerned with the ways in which customers may engage with a new system and interventions for the demand side management of the electricity distribution network. While historically the power system has been a demand led system and distribution networks built to serve any foreseeable demand scenario there is increasing interest in and incentives to manage rather than meet certain demand scenarios in order to reduce the costs or defer decisions around network reinforcement. Under LO2 we present emerging analysis from the experimental test cells, (9, 20) and reflect on which practices are most and least flexible and where possible, how this flexibility varies.

### LO 1.3. What does flexibility in energy use mean in a domestic context?

In the first Social Science Interim report we presented a flexibility framework which has been revised in subsequent work and presented again here for completeness. It represents a framework for further analysis and discussion on flexibility as a property of practices that is of value to DSM initiatives.

1. **Time Flexibility:**
  - a. **Same-Day flexibility:** changing the time of day a practice is conducted, moving it within a 24 hour period
  - b. **Inter-Day flexibility:** changing the day on which a practice is conducted, or moving it by more than 24hrs.
2. **Location flexibility:** changing where a practice takes place, such as showering at a family member's home or at work.
3. **Process flexibility:** changing how a practice is performed and as a result changing the electrical characteristic of the practice. For example, cooking on a gas hob rather than a microwave.
4. **Practice abstention or curtailment:** doing a practice less often or for shorter periods of time. For example doing less cooking altogether, or taking shorter showers.

This part of the report now turns to consider the flexibility of dining and cooking practices, laundry and household chores. We will seek to address refrigeration and bathing in future work.

#### LO 1.2.1.a. Dining as a Fixed Peak Practice

For the most part, dining still takes place at conventional meal times, between 4pm and 7pm, and for most households this is firmly fixed in time. It is worth noting however, that this does not cover all situations. Where there are mixed households – with adult children living with parents or grandparents, or where shift patterns vary, some cooking does take place after the evening peak and this tends to be microwave cooking.

*When I was at work I used to come in and have work in the evening, Now, that means if we're using the cooker that's one of the most expensive times ... We did have a situation and we talk about it and we did change a bit and we had our main meal at lunch time but I couldn't get my head around it, I didn't like it. Now we've gone back to having our main meal in the evening, being full aware that that cooker is going to use a bit more electricity. ... I was so used to having my dinner of an evening, and I enjoyed that and it's gone on for years and years. (Customer on a time of use tariff)*

*[Interviewer: Do you use the oven at any time other than the early evening?] No. That's the main meal. I don't use it any other time. (Customer with an in home display only)*

*I probably cook my tea at about 5 o'clock, I know it's probably the wrong time, but I mean, what time are you supposed to have your tea?! You sort of program yourself for it don't you. By tea time I want filling up again.*

*I can't see us changing our eating habits. It's sort of firmly ingrained that we eat our main meal in the evening.*

While the data clearly tells us that dining is fixed for most households, we feel it is worth exploring cooking-dining practices further for two reasons. First, for some households (those not in a typical work or school schedule) cooking, if not dining, is something that participants feel could be experimented with, as is picked up in the LO2 sections of the report, below. Second, there are large loads associated with cooking meaning that there is potential value for DSM.

#### **LO 1.2.1.b. Least Fixed: Dish washing, Laundry and Household Chores**

The analysis suggests that chores are an interesting collection of linked practices in that they are affected by a wide range of factors and they are the practices that large groups of householders feel are least fixed. That is, these activities are not fixed to particular times of day for certain groups but they are activities which participants feel do need to happen in certain time-frames. For example;

- **Dishes:** Having dishes cleaned by a dishwasher appliance is reported as being something which should happen within about a 24 hour time-frame but within this there is flexibility. In short, dishwashers should be activated most days but the timing is not tightly fixed.
  - *"Every day. Once a day ... It's probably either first thing in the morning or teatime when we're in. It can be during the day though. ... it just depends who's in. My stepdaughter works ... she got mid-week days off so she starts at 5am and finishes at 3pm. ... Predominantly it's in the morning before we go to work or when we come back from work but there are other times it gets middle of the day when it gets used in the as well."(EPJ019)*
- **Laundry:** Having clothes cleaned and dried is not always talked about as being fixed to particular hours in the week (although some household do retain the custom of having set days for laundry) and laundry is an activity which some groups of respondents (most typically working families) felt could be moved around within a 24 hour time-frame or even between days driven by convenience, weather and the weekly rhythm of working patterns. People talk about laundry as happening within a weekly time-boundary, which can be contrasted with daily time-frames for practices like dining, entertainment.
  - *"The dryer - that's on more than it should be. But it's just too easy to go from the washer and dryer in the same room. ... We've got no sort of set routine ... but I think over a week you're talking probably about 3 of 4 loads over a week so about an hour and a half each, 6-8 hours a week it'll be on."(EPJ020)*

- **Cleaning:** Having the home dusted, vacuumed is most often thought of as having to happen within either daily or weekly basis but is not always fixed to particular times householder (although this is not the case for all households, as is discussed below). Particularly working couples and families felt that they were open to this being done at a different time, or in the case of an exceptional interruption, reduce these activities (rather than reschedule them).

**Table 5 – Time-Frames and Flexibility of Chores**

	<b>Fixed</b>	<b>Variable</b>
<b>Daily Time Boundary</b>	<p>Set time of day:</p> <p><i>I'll use the hoover on the morning. I use that every morning. I can't change that and use it at night time because the little old lady next door might be in bed.</i></p>	<p>Variable within a daily boundary:</p> <p><i>Daily. Maybe not the whole house but bits and pieces.</i></p> <p><i>Every day. Their (2 cats) hair. Every day. ...</i></p> <p><i>I use the vacuum cleaner every day, for the dog's hairs. I don't have to like, but I do.</i></p> <p><i>I've got clean clothes on every day. That [the iron] would be on for about 20 minutes. Every day.</i></p>
<b>Weekly Time Boundary</b>	<p>Set time and day of week:</p> <p><i>Once a week. All day on a Monday. I go right through the house.</i></p> <p><i>(Ironing) It's usually Sunday afternoon. I know it sounds daft but that's just how we go round.</i></p>	<p>Variable within a weekly boundary:</p> <p><i>"Probably one day a week the iron will be on for a couple of hours.</i></p> <p><i>We're not big ironers ... once a week</i></p> <p><i>About four times a week, with it being solid flooring I generally do that with the mop thing.</i></p>

Having set out the time-frames within which cleaning, laundry and dish washing may be flexible we now develop the analysis by identifying how and for whom they may be flexible. We focus on 2 different ways in which these chores are enrolled in to the management of the household; proactively or reactively.

**LO 1.2.1.c. Proactive and Reactive Laundry and Chores Regimes**

There is evidence to suggest that there are two main approaches to laundry reported by participants. One is the 'when it piles up' approach, which is not set at a particular time in the week and is more flexible. In these *reactive regimes* chores can happen at almost any time of day in working households. Another manifestation of this reactive approach to chores is that laundry in particular is a practice which can be triggered by weather conditions. If there is a particularly sunny or windy day these natural resources are taken advantage of and enrolled into the management of the home by increasing textile washing (clothes, curtains, bed linens, towels etc.) while tumble drying is reduced.

*If there is anything that needs doing you've just got to do it. I can't wait for that. (GDP045)*

*I just do things as they are convenient to me. I do the laundry sometimes in the evening; if the clothes are there I'll do them. (GP0026)*

*I do [laundry] sometimes [in the evening]. If the clothes are there and I think it's going to be a fine day, I'll do it then. (GP0026)*

*[Interviewer: When do you use the washing machine and dishwasher?] Anytime. If we need something doing [washing] we'll do it." (ML28)*

The second type of chores regime is a more proactive, timetabled approach with a particular washing day being a fixture in the week. Counter intuitively this is more typical of retired people or those not in typical (roughly 9am-5pm, Monday to Friday) working arrangements. Although these participants have more time for chores, they tend to create a timetable in which to locate them – in order to 'get them out of the way', or contain them away from the activities of the rest of the week.

*I would never dream of doing me laundry in the evening because I've got all bloomin' day to do it. They did say that if I did me' washing the evening my electricity (bill) would go up but I wouldn't do that anyway so it hasn't changed me' habit at all. ... I do it in the morning so that I can get me' chores over and watch telly for the rest of the day.*

*I tend to wash and dry on a Saturday. Habit. I'm not working so that's when the washing gets done. (DL13)*

*Friday I would come in from work ... the Hoover would be on. The washer would be going. Friday night is my washing night. I don't use the washer though the week. .... [from 5:30-6pm after coming in from work] Right the way through probably 'til 10 o'clock that washer will go. (EPJ014)*

#### **LO 1.4. What are the most effective interventions to deliver this flexibility?**

LO2.2 considers the various interventions used in the CLNR project and assesses the extent to which these have been effective in creating flexibility in domestic electricity use via changes to everyday practices. The interventions we have been able to study at this stage are the three rate time of use tariff in Test Cell 9 and two PV related interventions in Test Cell 20. These are set out in detail in project documents available in the Project's learning library.

For each intervention our interest is in the following three questions:

1. What evidence is there of change per intervention, and how does this vary socio-demographically and socio-technically.
2. What are the factors which have driven the changes
3. Are there daily, weekly, seasonal variations in the nature and types of flexibility that interventions can achieve?

At this stage we are not able to report comprehensively on all of these questions but report our current work with participants in each group and reflect on the flexibilities that have been produced by the interventions.

#### **LO 1.2.2 Responses to a Time of Use Tariff (TC9)**

Six hundred and twenty eight participants in TC9 volunteered to undertake a 12 month trial of a three rate time of use tariff and were equipped with an in-home display which provided instantaneous traffic light system for current loads and retrospective visualisations of gas and electricity consumption. These are the same as the units used in TC1 (in TC1 participants did not have a time of use tariff). The rates and time bands of the tariff are:

<b>Time Period</b>	<b>Description</b>	<b>Rate</b>
07.00 – 16.00	Day	4% below standard rate
16.00 – 20.00	Peak	99% above standard rate
20.00 – 07.00	Night	31% below standard rate

**Notes:**

The Night rate applies all weekend (Saturday / Sunday)

A standing charge is applied in addition to the per-unit costs

Our analysis suggests that participants in TC9 are avoiding laundry, chores, dish washing and in some cases are cooking differently within and around the 4-8 period, suggesting that the tariff is having an effect on these practices:

*I think maybe on a Friday, without thinking ... I'd probably shove them [work clothes] in the washer ... and just start it without thinking. ... Yeah. I would probably avoid that now [using the washing machine]. I can't afford to pay more. (GP0021)*

*The washer, dryer and dishwasher we haven't been putting on between 4 and 8. (GP1802)*

*We're doing after 8 o'clock on a night and over t'weekend. Washing, most of t'laundry gets done on a weekend unless we have something that actually crops up. (DL0602)*

*My washing I definitely do over the weekend when it's cheaper, unless it's absolute necessity. (MJRTL06)*

*She'll do washing after 8 o'clock at night when it goes onto the night time tariff, the lower tariff. (GP2702)*

*The tumble dryer will be used at night time ... Even if I have to stop up later or something. I would rather use it at night time than on the peak [tariff] ... (GP0025)*

*Things like the dryer and the washing we'll put on during the day, then if at 4 o'clock if we haven't finished drying then we stop then and pile it up on usually just put it on the back of the chair and wait 'til 8 o'clock and then we'll finish it then because the dryer's expensive to run... (MJRTL14)*

*We try and do washing on a weekend or after 8. ... The dishwasher doesn't go on 'til after 8 now either ... before we got the [IHD/tariff] we would just put it on when it needed to go on ... Couple (GP1902)*

The results also suggest that the degree of alignment between the tariff and other schedules is important in shaping how flexibility is realised. Although the use of electrical appliances for dish washing, washing and drying laundry is reported as having moved outside the 4-8 mid-week period or to the weekend for many participants, one couple (above) also use the shower any time of day, and within the 4-8 period – which suggests that some practices are non-negotiable. This would appear to be connected to established habits and perceived luxuries, and links with other activities which may connect householders to external practices or social groups making them more difficult to change. Examples would be aspects of work, social and school life. Of particular interest is the way in which flexibility presents difficulty for some groups due to potential misalignment of the tariff time bands and existing timings and schedules around which life is already organised. Our findings suggest that these could be external to the home, such as work hours, or as a result of internal routines around eating times:

*Male: [Shower] me - half past 7 every night.*

*Female: You'll have to change. I told you you're going to have to adapt.*

*Male: I go to the pub at 8 - it can't be after 8.' Couple (DL12)*

*Female: I don't think I can wait until 9 o'clock for my dinner. I couldn't eat at 9 o'clock then go to bed.*

*Male: What you'd have to do is have [our] dinner at 4 o'clock.*

*Female: And that's alright for us 'cause we're not working but what about people that are working? They've got to come home and they're going to do it [cooking] in the busy time, aren't they? Couple (GP0025)*

#### **LO 1.2.2.a. Fixed Dining Routines**

Resonating with the finding reported elsewhere in this report, mealtimes are often fixed and this evidence suggests that the tariff is not effective in moving meals outside the 4-8 period in a sustained or widespread way. This analysis leads to the conclusion that a financial incentive does not lead to a shift in this practice, whereas it does create flexibility in laundry, chores and dish washing:

*Obviously, not our tea ... but [I] wouldn't put the dishwasher on [between 4-8], or the washing machine or dryer. (GP0028)*

*With two kids they have to be fed before they do homework. They tend to be doing homework while I'm cooking. ... If I waited it'd be too late for them ... (DL07)*

*Everything else; or nearly everything we can work around it [tariff] and in a way some of the things we have changed ... putting the dishwasher on - we used to put it on after tea. Now, it will be left 'til the next morning, or after 8 o'clock.*

Of particular interest are those households not working around a 9-5 pattern, where there has been some movement of cooking practices in response to a time of use tariff, which we interpret as same-day flexibility enabled by process flexibility where there are new or different cooking methods used to prepare and cook food.

#### **Inflexibilities for those with conventional work or school hours**

*[Interviewer: Is there much flexibility with when you cook?] Not really. We're quite traditional, lunch is at 12, tea is 5...it's based around work. There will be times when you get in late but it's not that often"*

*I'll still be eating at around 5. [Despite the time of use tariff]*

*(Cooking habits won't change because) When the wife cooks she usually cooks enough for 2 days each time, so we're only using the cooker 3 or 4 times a week... she's clever that way.*

### Cooking Flexibility in Households not in 9-5 Work or School Patterns

*I've started it already. I cook everything together now. I've tried to keep economy you know ...I put more in the cooker now, instead of putting one thing in then another thing I put both together now, things like that,... at one time if I had fish and chips I would put them in separate but now I would put them in together with her pizza instead. I wait for her to come in and we eat together now, we all just sit in the dining room when at one time we didn't. It's really good, and it's easier. I have my tea with them rather than have mine early then cook for them.*

*I am thinking about how I'm using it now. Otherwise I would have just fried it and not thought about it. Like I made a casserole yesterday and I just put the veg in there with it whereas before I would have put the veg in the mic'. It's spurred me into getting a new microwave too, more energy efficient.*

*You could get people to cook meals then freeze them, then just heat them up if they've got gas. You know, take them out, defrost them, which I did with my soup. I just tip it out, let it defrost and then heat it up on gas.*

### Same Day Cooking Flexibility for this group

*Most of the cooking, well some of it is done before 4 in the afternoon, well most if it. .. Because I'm retired and because of the tariff we find ourselves dining a little bit earlier ... all because of the tariff, yeah.*

*Meal times, I usually make a meal before I go to work and that's when he comes in. ... it's just before 4pm now.*

*My wife would really like to change our main meal to a lunch time and I keep saying let's do it, but we, I, never get round to it, But if it got to the point where it was more economical to do the main meal of a lunch time than an evening then we would do it.*

### LO 1.2.2.b. Peak Laundry Flexibility

Feedback from IHDs fed by smart meter data are talked about as having changed the way people achieve certain washing practices – particularly water temperature and cycle duration are mentioned as being ways to reduce power consumption as a result of seeing the IHD change to red, in the case of tumble dryers, or seeing the sustained peak created by some white good programs. There is also some evidence to suggest that chores have moved more than other practices out of the 4-8 period; for those on a TOU tariff, and for those with PV there is evidence of some efforts to use the PV power for laundry, although this is not always the case.

### Same-Day Flexibilities

*Washing, I mean unless it's absolutely necessary, it never goes on before 8 o'clock, well or early mornings. Or between 8 and 7, or Weekends, which is low tariff anyway. It never goes on other times ... not very often... Before the tariff it would go on anytime. Things like ironing things like that my wife does on a weekend or before 4 o'clock on an afternoon. Before it was just any time... my wife's a dinner lady so it was around that. (Customer with Time of use tariff)*

*Now that we got that (tariff) my wife's been putting a wash in after 8 o'clock at night, and before she goes to work she'll hang it out. (Customer with Time of use tariff)*

*Things like laundry, putting the dishwasher on. We used put it on after tea, now it'll get left 'til the next morning, or after 8. (Customer with Time of use tariff)*

*(My wife) has put a sticker on the washing machine, Do not use between 4 and 8".*

*With laundry we'll put that after 8 now. We had the old one, which was cold fill and quicker but now (we'll use it later) (Customer with smart white good and time of use tariff)*

*It's a small little bungalow and you can't get things on dry on the radiators. We pay for it, it gets accounted for. But when we start that thing you know (tariff) the tumble drier will go on after 8, or at night, not during the ...even if I have to stop up late I'd rather do that than use it on the peak.*

While this timing flexibility is apparent, there is less reported flexibility when participants were asked about changing the days of the week associated with laundry. This is in part explained by the 24hr rhythm of the tariff in the mid-week period, and the constraints of timers on white goods which were found to be commonly used to facilitate the flexibility and which often have a maximum delay of 9 or 12 hours. It is notable however that there is little evidence to suggest that laundry or dish washing will have inter-day flexibility.

As well as studying how TC9 participants have responded to the tariff, we have also asked members of other test cells about how they might relate to a time of use tariff. Although many participants are amenable to the idea of moving some practices outside the 4-8 period, there are some ways in which household practices are not perceived to be flexible in response to a the price signal in the 4-8 period:

*I couldn't alter things really. I just do things as they are convenient for me... I could put the dishwasher on I suppose after 8 o'clock instead of before. That would be the only thing I could alter. (GP0026)*

*You could put the washer on before you went out could put the dishwasher on before I walked out the door to go to work in the morning. Yeah there would be things ... (GDP050)*

However, this family could not envisage changing their cooking practice of using the electric oven to cook the evening meal:

*It'd be hard. Even though I do put the oven on its not on for a great amount of time, I'd say it were only on for no more than an hour a night and some nights you're talking probably 20 minutes. (GP050)*

*At the moment it [TOU tariff] probably wouldn't make much of a difference – not while we have a 4 year old and a 6 year old. Because time is scarce and precious and the washing machine goes on when you've got the opportunity. (EPJ017)*

Clearly, some practices are seen as essential and non-negotiable, while others appear to be more flexible:

*When you want a cup of tea you'll put it [kettle] on. You can't avoid that ... If there is anything that needs doing then I will do it. I can't wait for that [tariff]. Like I say if I've got to use my drill for something ... I've got to do it that way ... We'll put that [washing machine] on after 8 o'clock anyway or a weekend ... (GDP045)*

### **LO 1.2.3 Responses to Within Premises Balancing Intervention (TC20)**

Test Cell 20 included two different interventions. First a group of 99 participants who already had a PV installation agreed to have a system fitted which would divert up to 5kWh of solar energy into an immersion tank to provide hot water. Second, 141 participants who also already had a PV installation agreed to have an in home display system fitted which provides a green or red digital display to communicate whether they are exporting their PV generated power back to the grid (and in doing so collecting the feed-in tariff) or using it in the home to power electrical goods or appliances. These trials are being conducted because the use of the power on-site use is of interest to network designers as it could reduce potential voltage problems associated with increased penetration of micro-PV in the future.

#### **LO 1.2.3.a. The effect of PV alone**

The data contain several reports of moving white good usage to take advantage of PV generation, reinforcing the emerging conclusions made elsewhere in the report that laundry and dish washing are the most readily flexible practices because of the way in which is easy to move the load in time without substantially changing the user's performance of the practice. Much of the emphasis in this

data is on the effect of PV itself rather than the CLNR intervention. Some examples of these reports include:

*I never put the washing machine on overnight anyway... I used to. ... Although I do washing on a weekend, obviously I have to do some through the week, I never do it overnight. I try not to do anything overnight anymore ... When I went to bed was putting a wash on and dishwasher on and then obviously realised that that wasn't generating any power at that point. (DL13)*

*I would normally just at the end of the day when you put in the last dishes set it away in but I don't now. I wait until the next morning when it's sunny or lighter. If it's not particularly nice then it doesn't matter when it goes on. (HS001)*

There is also evidence that PV can be aligned with other factors which influence practices such as ways of working and ownership of technology. This is not specific to the TC20 IHD, but indicates a wider fit between PV generation and domestic practices.

*[PV is convenient because] I'm very lazy. I don't have a washing line. ... I use the dryer – all the time. ... Lazy! I suppose 'cause I work full time and can't be bothered to putting washing out and coming back to wet washing on a line." DL13*

*I think it's entirely because of being retired. I don't think we would have done some of these things had we had still been at work. I don't know. (HS001)*

*You charge the ipad through the day ... and the laptop. (HS001)*

#### **LO 1.2.3.b. Automatic Hot Water**

Participants in TC20a (with automatic water heating from PV) reported only modest changes to practices as a result of the automated hot water system intervention and not all participants in this group attributed changes to the intervention. The small changes reported were mostly related to when showers were taken.

*It has resulted in more showers being taken during the day. Our normal preference is a shower first thing in the morning. But with the [PV]... if it happens to be a nice bright sunny day and you haven't had a shower in the morning you can have one in the afternoon knowing you're not going to be short of hot water the next day (DL1502)*

*In summer I'll shower during the day, but in winter it won't provide enough power to let me have a shower and do everything else so I shower at night before bed, just on normal electricity. I prefer to have a shower before bed but like I say, in summer I'll do it in the afternoon. (DL17)*

However, for more households the incentive to use the power for domestic appliances which is associated with PV in general rather than the intervention still dominates their thinking. In other words, the analysis of the data suggests that participants are motivated to use the power for use of appliances more than they are motivated to use it to fill the hot water tank with hot water:

*If it's a sunny day my wife will set the washing machine during the day. Before the solar panel 'were installed all the washing was done at night on Economy 7 ... (DL15)*

Respondents also reported that the tanks are unable absorb all the surplus energy, and that they were both positive and negative about system. This extended quotation provides a detailed account of how the system is interacting with showering and how the details of system design, specification and installation affect both the householder's experience and the eventual impact on energy demand.

*The tank will only accept 4 – 6 kWh of energy and on a decent day I'm getting 10 - 15, so there's still about 5kWh going back into the grid. Of course I'm getting paid at about three and half pence per unit, which is neither here nor there. So the system does work, I'm getting additional hot water. I used to have two immersion heaters now I've only got one. ... but that has a downside, ... I've got one immersion heater on the E7 circuit. I've got another one on the solar panel circuit and that does not heat water if there's no sunshine, so I'm only getting one immersion heater operational in dull weather and that has a consequence, in that (my wife) and myself couldn't both have a shower without putting day time electricity into the system. We look at the weather forecasts and look at the weather on the day and I've got the solar panel immersion heater set at 70 degrees which is very hot, so if we don't use it, it will still be available the next day, if that was dull. But it's something we have to be careful of. We have to take into consideration the weather conditions. I'm anticipating that once it comes to the beginning of April until the beginning of October there's no problem at all. ...It's strange; it's resulted in more showers being taken in the day. (DL1502)*

### **LO 1.2.3.c. TC20 In-Home Display**

When looking more specifically at evidence of changing practices to take advantage of the TC20 IHD we find that households are responding to the traffic light system of the TC20 IHDs, as the quotations below testify and that households report that the device is easy to understand and has prompted them to make further changes to their practices. Often changes had been made as a result of the original PV installation but the IHD is associated with going further with changes that participants were aware would be beneficial but which had not been fully realised, while for others the IHD identified new optimal alignments of PV and their practices.

*We don't want to export. We want to use. ... We are better off using it. That's why we then changed to that habit (using on site) because we're using what we generate. We could change our habits more really, if we thought about it. Probably.*

*[Asked by the interviewer when they started to change their habits] We were generating and not really thinking about it - It was after we got that box [TC20 IHD] that identified green, amber, and red that literally the next day changed our habits. It was quite drastic ...." (DL13)*

*I'm in green which means I'm generating more than I'm using. ... So whenever it's on green we stick a big appliance on and you are more or less getting that electricity free 'cause we're generating it. Then obviously at night ... it's all red because we're not generating any power. (HS001)*

*Washing machine goes on a Monday morning. We use it on a timer so it's done ... when it's sunny. The dishwasher is on a timer so it comes on when we're at work usually. (Customer with PV Panels and a device which provides a traffic light signal to communicate generating status )*

Other respondents were less positive about the IHD, with one not using it at all. Another respondent complained that it was difficult to re-start the system after having previously disengaged it. Other sentiments were that householders in this group were already quite knowledgeable or already had meters which they had worked into their home management regimes so felt that the IHD offered little additional information:

*I think the reason I don't use it is that I know how much a kettle uses, how much a TV uses. I'm quite knowledgeable about what I actually use. ... I've got a meter which measures total power generated, which is in the garage not from the inverter. So that's good information.(DL1502)*

This suggests that the information provided by the IHD needs to be able to be tailored to householders requirements to continue to be relevant.

## 4 Future Work

The social science team is continuing with analysis and further fieldwork, which will focus on trial participants with electric vehicles, smart heat pumps and micro CHP units.

Areas of focus in our next phase of analysis will include:

1. We identify four trends in the data which suggest longitudinal changes to electrical loads associated with practices:
  - a. **Impact of recession:** the combination of recession and rising energy costs is reported as having an impact on energy consumption which respondents feel is a long term to permanent feature of their energy use.
  - b. **Ways of working:** The data suggest that the ways in which people work, including their hours, use of technology and mobility, is changing meaning that there is more work done in different places and different times and through different devices, many of which use batteries rather than mains connections
  - c. **Lighting:** We observe a widespread but partial adoption of low energy lighting.
  - d. **Increased household dynamism:** The research has detected an increase in the degree to which households, or 'domestic customers' are changing their composition with more mobility between homes, informal living arrangements and a splintering of family units.

We will seek to study these in more detail and through work with related public data sets in order assess their importance for the electricity system and markets.

2. In both our qualitative and quantitative analysis we find that gender roles appear as not insignificant and are of potential interest to the on-going development of grid politics, markets and customer propositions. We will seek to explore these issues in the coming period.
3. More broadly we will build on the integration of qualitative and quantitative analyses which has so far revealed that there is considerable overlap between the principal components analysis of the survey data and the qualitative analysis of face to face research visits. When we consider that these two data sets come from samples which are at least potentially very different it is of some interest that the findings of analyses conducted entirely independently show so much potential for integration. A feature of this integrated analysis will be to conduct more detailed analysis of socio-demographic and socio-technical variations in consumption, attitudes and practices using sub-test cell attributes and other clustering, grouping and categorisation techniques.

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## Appendix 1: Residential Survey

### Preliminary Statistical Analysis

#### CLNR Residential Survey: Preliminary Statistical Analysis

Jamie F. Lawson, 9th July 2013

#### Attitude survey

All 29 attitudinal items were entered into a Principal Components Analysis, with varimax rotation. 4 components were retained which had eigenvalues >1, and fell before the point of inflexion on the scree plot (Figure 1.). These components which explained a total of 41.47% of the variance. Inspection of factor loadings (Table 1.) suggests that these factors represent 1: government action; 2: household action; 3: personal action and 4: confusion about options. Components were named accordingly.

Components were saved as variables using regression extraction and used as dependent variables in the following analyses.

#### Respondent Attributes

Respondents who did not report a gender or marital status were excluded from analysis (this included the solitary respondent who identified as being in a civil partnership). The sample for the following is therefore  $n = 730$  (see table 2 for descriptives).

Respondent age was found to correlate negatively with components 3 (personal action,  $r = -.14$ ,  $p < .001$ ) and 4 (confusion about options,  $r = -.23$ ,  $p < .001$ ), suggesting that older respondents are more willing to take personal actions, but are more confused about how to obtain trustworthy information about energy efficiency.

All 4 principal components were entered as dependent variables into a 2x4 MANOVA, with participant gender (2 levels: man; woman) and marital status (4 levels; single; cohabiting; married; divorced or separated) as independent variables. Respondent age was entered as a covariate.

As expected, there was a significant main effect of age,  $F(4,718) = 18.03$ ,  $p < 0.001$ . Controlling for this, there was a significant main effects of marital status,  $F(12,2160) = 2.15$ ,  $p < 0.05$  and a borderline effect of gender,  $F(4,718) = 2.43$ ,  $p = 0.05$ . There was no significant interaction between the IV's. These effects were investigated using univariate analysis.

ANOVA revealed a significant effect of gender on component 2 (household action, such that men (mean = 0.07, sd = 0.97) scored higher on this variable than women (mean = -0.13, sd = 1.03,

$F(1,721) = 4.66, p < 0.05$ ); men place higher importance on household level changes than women. No other component related to gender ( $p > 0.05$ ).

Marital status had a significant relationship with component 3 (personal action),  $F(3,721) = 5.49, p = 0.01$ ). No other component was significantly related to this variable ( $p > 0.05$ ). Pairwise comparisons with Bonferonni adjustment revealed that respondents identifying as 'Divorced/widowed' (mean = -0.45, sd = 0.72) report taking less personal action than married (mean = 0.08, st = 0.98,  $p < 0.05$ ) respondents. No other comparisons were significant ( $p > 0.05$ ).

### House Attributes

Before proceeding with this analysis, the 12 individuals who reported living in a flat or maisonette were excluded and "end terrace" and "mid terrace" were collapsed into a single category "terraced". Final sample size for the following was ( $n = 694$ ). See Table 3 for frequencies.

All four attitudinal components were entered as DVs in a 2x4 MANOVA. The two IV's were ownership type (2 levels, owned; rented) and property type (4 levels, detached house; semidetached house; terraced house; bungalow). House period could not be included in this analysis since 601 individuals failed to answer this question. House period is analysed separately, below.

Results from the MANOVA revealed no significant effect of either house or ownership type on any of the 4 components (all  $p > 0.05$ ).

A separate one way MANOVA was run for house period. Again, no significant effects were detected (all  $p > 0.05$ ).

### Electrical goods inventory

Counts of all 34 electrical goods were entered into a Principal Components analysis with varimax rotation. 3 components were retained which had eigenvalues  $> 1$ , and fell before the point of inflexion on the scree plot (Figure 2.). These components accounted for 50.19% of the sample variance. Inspection of the rotated factor loadings (see Table 4) suggest that these components can be named 1) Basic household items; 2) Luxury items and 3) Technological items. Variables were extracted using regression technique.

### Respondent Attributes

Respondents who did not report a gender or marital status were excluded from analysis (this included the solitary respondent who identified as being in a civil partnership). The sample for the following is therefore  $n = 730$  (see Table 2 for descriptives).

Respondent age was found to correlate positively with components 1 (basic items,  $r=-0.09$ ,  $p<0.05$ ) and 2 (luxury items,  $r = -0.19$ ,  $p<0.05$ ), suggesting that older respondents possess more basic and luxury electrical items.

All 4 principal components were entered as dependent variables into a 2x4 MANOVA, with participant gender (2 levels: man; woman) and marital status (4 levels; single; cohabiting; married; divorced or separated) as independent variables. Respondent age was entered as a covariate.

As expected, there was a significant main effect of age,  $F(3,719)=16.20$ ,  $p<0.001$ . Controlling for this, there was a significant main effects of marital status,  $F(9,2163) = 6.99$ ,  $p < 0.05$  and a significant main effect of gender,  $F(3,719)= 3.56$ ,  $p < 0.05$ . There was also a significant interaction between the IV's,  $F(9,2163) = 2.30$ ,  $p<0.05$ . These effects were investigated using univariate analysis.

ANOVA revealed that gender has a significant relationship with component 1 (basic items), such that men (mean = - 0.05,  $sd =0.75$ ) report owning fewer basic items than women (mean = 0.09,  $sd = 1.30$  ,  $F(1,721)=6.96$ ,  $p <0.05$ ). Neither of the other components had a significant relationship with gender ( $p >0.05$ ).

Marital status had a significant relationship with component 3,  $F(3,721) = 14.83$ ,  $p<0.001$ . Pairwise comparison revealed that single respondents (mean = -0.53,  $sd =.63$ ) reported possessing more technological items than either cohabiting (mean = -0.004,  $sd = 0.81$ ) or married (mean = 0.14,  $sd = 1.06$ ) respondents; and that divorced/widowed (mean = -0.32,  $sd = 0.87$ ) respondents have fewer technological items than married respondents (all  $p<0.05$ ). No other comparisons were significant ( $p>0.05$ ).

There was a further significant effect of marital status on component 2 (luxury items,  $F(3,721) = 5.15$ ,  $p<0.05$ ) which is presumably the result of the significant interaction between the IVs for this factor, (interaction effect:  $F(3,721) = 4.46$ ,  $p<0.001$ ). The interaction can be seen in figure 1: married women appear to report owning more luxury goods than any other group.

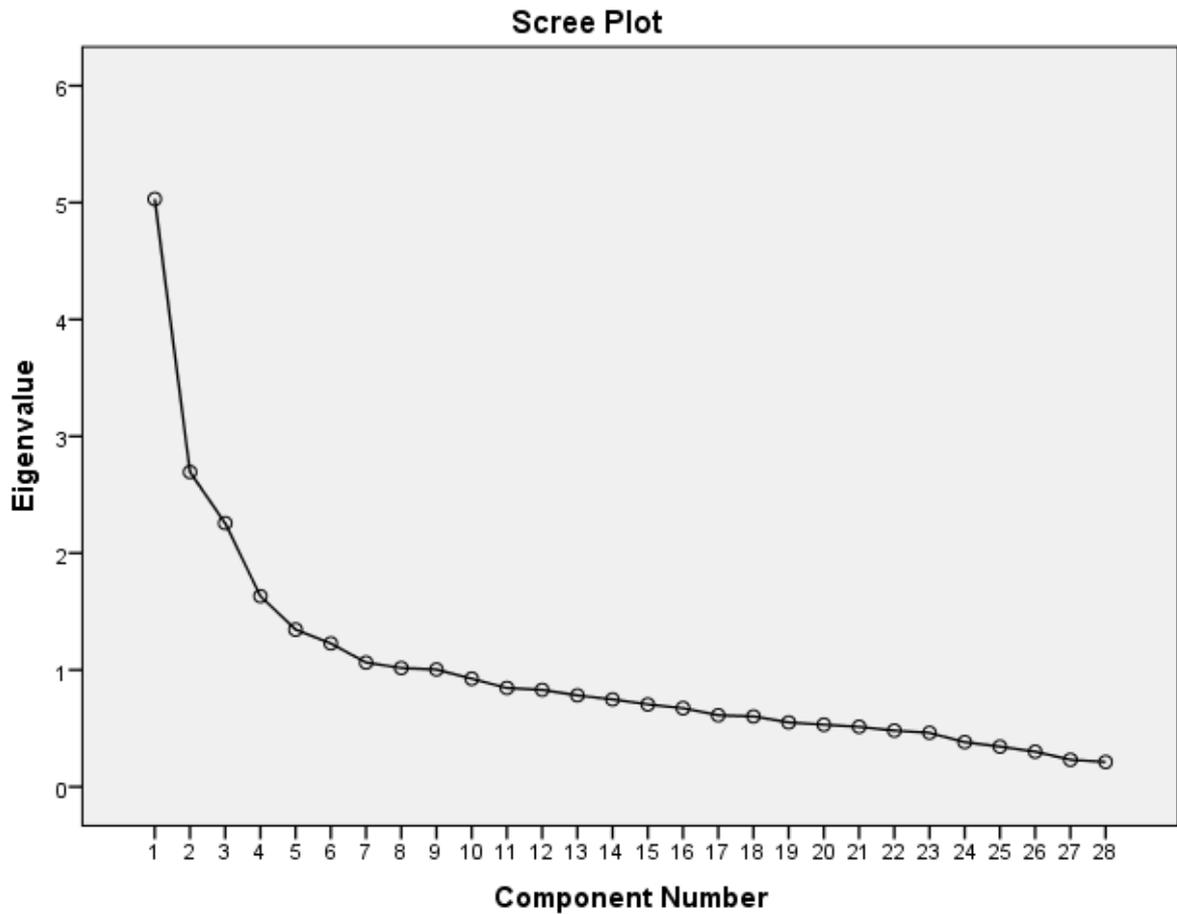


Figure 1: Scree plot for PCA 1 (attitudes).

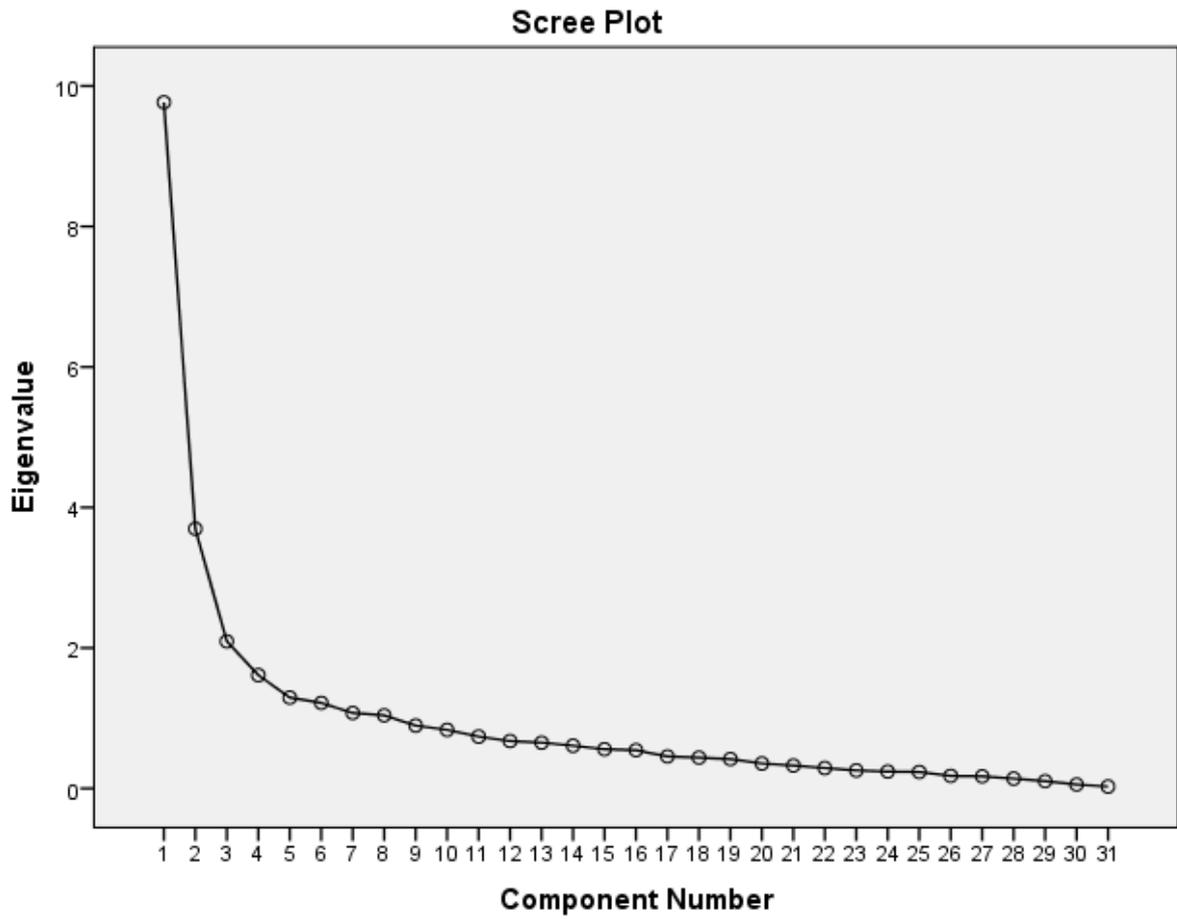


Figure 2: Scree plot for PCA 2 (Technologies)



	Component 1: Government action	Component 2: Household action	Component 3: Personal action	Component 4: Confusion
% Variance explained	17.97	9.62	8.06	5.88
<i>If the government is going to take a lead in order to improve energy efficiency in UK households how do you feel about them using the following measures?</i>				
Q23.3 Providing financing at low or no interest for energy efficiency improvements	.782			
Q23.5 Granting direct subsidies so that the cost of energy efficient technologies is shared	.776			
Q23.2 Providing customised energy advice: free or low cost information about energy efficiency improvements	.740			
Q23.1 Applying energy standards that require minimum levels of energy efficiency on most appliances	.657			
Q23.4 Banning inefficient technologies, such as incandescent light bulbs, where more energy efficient options exist	.513			
<i>How important do you think it is for households like yours to:</i>				
Q24.2 Reduce the amount of water used at home		.885		
Q24.1 Reduce the amount energy used at home		.860		
Q24.3 Be more environmentally friendly in your day to day activities		.854		
<i>Please read the following list of possible energy saving behaviours. Please indicate how often you do each of the following actions:</i>				
Q25.7 Keep household heating low to save energy (below 18 °C)			.753	
Q25.6 Put on more clothing before turning up heating			.731	
Q25.9 Taking shorter showers			.533	
Q25.3 Reduce heating in unoccupied rooms			.531	
Q25.8 Line drying of laundry			.461	
Q25.1 Turning appliances off at the wall (not just leaving on standby)			.431	
<i>To what extent do you agree or disagree with each of the following statements?</i>				
Q22.5 It's difficult to know what information to trust in regards to energy efficiency				.843
Q22.6 Making choices about energy efficiency in the home is complex				.803
Q22.4 I find it hard to find information about being energy efficient around the home				.772
Q22.8 I am confident that I have the right skills to make informed decisions in energy efficiency				
Q22.7 I am confident I can invest the time and effort to make changes towards being energy efficient				
Q22.9 I know where to find the right information about energy efficiency				-.515
<i>Items which load &lt; 0.4 on all factors</i>				
Q22.3 I don't pay much attention to what my energy bill is each month				
Q22.2 I don't think very much about ways of saving energy in my own home				
Q25.11 Pulling curtains at night				
Q25.2 Rinsing the dishes with cold water				
Q25.5 Wait for a full load before using washing machine				
Q25.4 Switching off lights in unused rooms				
Q25.10 Doing dishes by hand				
Q22.1 I only buy appliances with high energy efficiency ratings even if they cost more				

		Component 1: Government Action			Component 2: Household Action		Component 3: Personal Action		Component 4: Confused by energy efficiency information	
		n	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Men	Single	47	.18	1.04	.30	.95	.03	1.10	.01	1.02
	Cohabiting	42	-.32	.98	-.03	.88	.11	1.06	.11	.93
	Married	337	-.04	.99	.04	.99	.17	1.01	.05	1.04
	Divorced/widowed	20	-.16	.80	.24	.81	-.69	.68	.02	.93

Table 1: Component loadings for PCA 1, loadings <0.4 suppressed.

	All men	446	-.05	.99	.07	.97	.11	1.03	.05	1.02
Women	Single	50	.16	.93	.05	1.21	-.30	1.07	-.03	.86
	Cohabiting	26	.07	.87	.05	1.08	-.11	1.02	.44	1.05
	Married	173	.02	1.01	-.17	1.01	-.09	.91	-.14	.93
	Divorced/widowed	35	.12	.97	-.31	.80	-.30	.71	-.19	1.04
	All women	284	.06	.97	-.13	1.03	-.15	.93	-.07	.95
Men and Women	Single	97	.17	.98	.17	1.09	-.14	1.09	-.01	.94
	Cohabiting	68	-.17	.95	.00	.96	.03	1.04	.24	.98
	Married	510	-.02	1.00	-.03	1.00	.08	.98	-.02	1.01
	Divorced/widowed	55	.02	.91	-.11	.84	-.45	.72	-.11	1.00
	Whole sample	730	-.01	.98	-.01	1.00	.01	1.00	.00	1.00

Table 2: Descriptive statistics for Analysis 1.1, attitude factors by respondent attributes

		Component 1: Government Action			Component 2: Household Action		Component 3: Personal Action		Component 4: Confused by energy efficiency information	
		N	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Detached house	Owned	206	.09	1.04	-.01	1.00	.24	1.04	.08	.94
	Rented	4	1.14	.24	-.36	.78	.20	1.11	.08	.74
	All	210	.11	1.04	-.02	.99	.24	1.04	.08	.94
Semi detached house	Owned	232	.05	.98	-.01	.96	-.10	.92	-.02	.97
	Rented	31	-.16	.96	-.19	.89	-.28	1.14	-.36	1.20
	All	263	.02	.98	-.03	.95	-.12	.94	-.06	1.00
Terraced house	Owned	131	-.16	.96	-.04	1.02	-.17	.95	.14	1.08
	Rented	26	-.04	1.08	.19	1.25	.00	1.10	-.06	1.08
	All	157	-.14	.98	.00	1.06	-.14	.97	.11	1.08
Bungalow	Owned	55	-.10	.96	.10	.93	.06	.83	-.21	1.05
	Rented	9	-.16	.94	-.06	.73	.12	1.36	-.71	.65
	All	64	-.11	.95	.07	.90	.07	.91	-.28	1.02
All houses	Owned	624	.00	1.00	-.01	.98	.01	.97	.03	1.00
	Rented	70	-.04	1.01	-.04	1.02	-.10	1.14	-.27	1.08
	Whole sample	694	.00	1.00	-.01	.98	.00	.99	.00	1.01

Table 3: Descriptive statistics for Analysis 1.2, attitude factors by house attributes

	Component		
	1: Basic items	2: Luxury items	3: Technological items
% Variance explained	31.51	11.93	6.76
microwave	.90		
washing machine	.89		
tumble dryer	.77		
wifi	.74		.42
electric kettle regular	.73		
electric cooker	.71		
electric shower	.70		
chest freezer	.61		
printer	.60		.48
heated pool		.90	
sunbed		.86	
patio heater		.80	
washerdryer		.73	
energy saving kettle		.65	
musical instrument		.47	
greenhouse heaters		.44	
TV			.70
digital receiver			.65
laptop			.61
phone chargers			.57
Jacuzzi			
aquarium			

dishwasher	.42
hair straighteners	
games console	
desktop computer	
garden tools	.41
Refrigerators	.43
fridge-freezer	.56
tablet	
photocopier	.53

Table 4: PCA 2, Electrical Items

		Component 1: Basic Items			Component 2: Luxury items		Component 3: Technological items	
		N	Mean	Sd	Mean	Sd	Mean	Sd
Men	Single	47	-.12	.26	.04	.32	-.43	.60
	Cohabiting	42	-.18	.36	-.15	.24	.07	.64
	Married	337	-.03	.85	.01	.47	.14	1.03
	Divorced/widowed	20	-.05	.28	.00	.30	-.52	.81
	All men	446	-.05	.75	.00	.44	.04	.97
Women	Single	50	.08	1.26	-.06	.48	-.62	.65
	Cohabiting	26	.50	2.31	.78	4.88	-.12	1.03
	Married	173	.02	1.10	-.07	.40	.15	1.11
	Divorced/widowed	35	.10	1.28	-.11	.31	-.20	.89
	All women	284	.09	1.30	.01	1.52	-.06	1.05

Men and Women	Single	97	-.02	.93	-.01	.41	-.53	.63
	Cohabiting	68	.08	1.48	.21	3.02	.00	.81
	Married	510	-.01	.94	-.02	.45	.14	1.06
	Divorced/widowed	55	.05	1.03	-.07	.31	-.32	.87
	Whole sample	730	.00	1.01	.00	1.01	.00	1.00

Table 5: Descriptives for Analysis 2.1

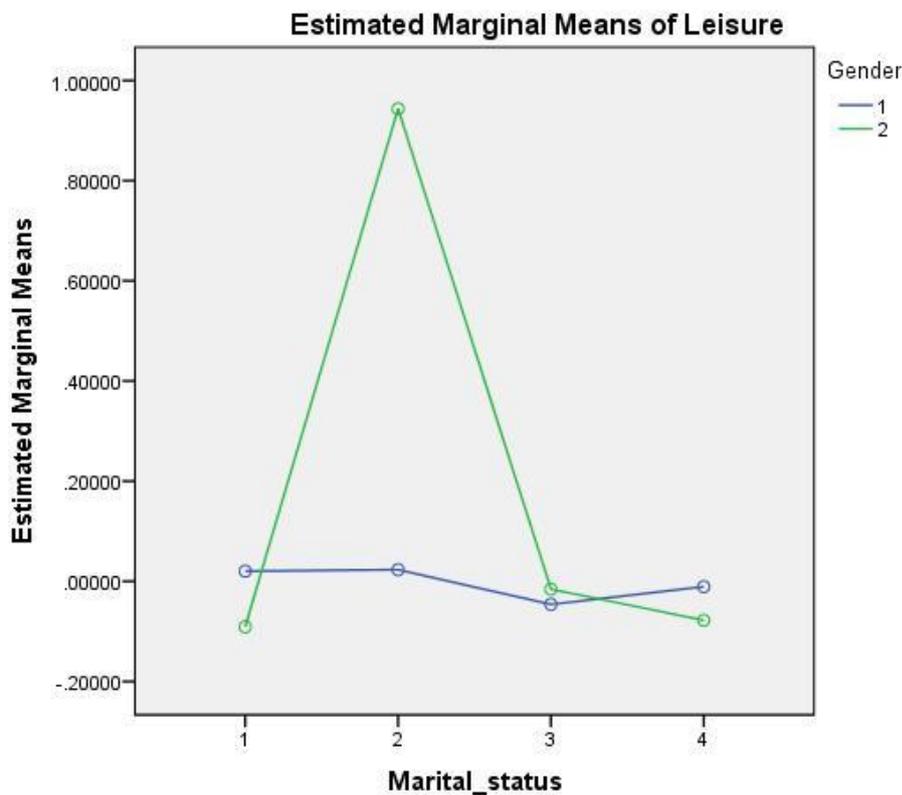


Figure 3: The significant interaction between gender (1= male) and marital status (1 = single, 2 = cohabiting, 3 = married, 4 = divorced/widowed).

