# Taking Charge: Perceived control and acceptability of domestic demand-side response

**by**

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# Declaration

I, Michael James Fell, confirm that the work presented in this thesis is my own.

Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:

(February 2016)

# Abstract

If widely adopted, domestic demand-side response (DSR) could help make Great Britain's electricity system more secure, clean and affordable. However, research suggests some people have concerns about participating in DSR programmes, and prominent amongst these is a perceived loss of personal control. This programme of research used a combination of interview and survey methods to explore what such concern might encompass and how it relates to the acceptability of DSR.

Initial focus group findings were drawn on to extend the Technology Acceptance Model (TAM) with perceived control constructs and develop an associated measurement scale. A survey experiment including the new scale was deployed to a representative sample of GB bill-payers (N=2002) to test for the first time the relative acceptability of static/dynamic time of use (TOU) tariffs, with/without automated response, and direct load control (DLC).

DLC was shown to be acceptable in principle to many people, with a tariff permitting limited DLC of heating being significantly more popular than the TOU tariffs. The option of automated response made dynamic TOU (otherwise the least popular tariff) as acceptable as static TOU. This is important because dynamic TOU offers additional network benefits, while automation can improve duration and reliability of response. The tariffs were generally rated highly for giving people control over spending on electricity, but perceived control over general service quality, ease of use and savings potential were more important in overall acceptance and should be prioritized in product development/communication.

Further research in a field trial including automated response by heat pumps to TOU tariffs highlighted various challenges if automated DSR is to be acceptable in reality. These include overheating potential when pre-heating at lower prices, the importance of ease of use, and effective override ability. The implications of these and other findings for policy, industry and research are discussed.

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# Previously published work

This thesis draws (occasionally verbatim) on several of my previous publications. These are listed below, with a brief note on my contribution.

*Fell, M. J., Shipworth, D., Huebner, G. M. and C. A. Elwell (2015). "Public Acceptability of Domestic Demand-Side Response in Great Britain: The Role of Automation and Direct Load Control." Energy Research & Social Science, 9: 72–84.*

➔ I wrote the text for this article in full, revising it on the basis of comments from co-authors and anonymous peer reviewers.

*Fell, M. J., Shipworth, D., Huebner, G. M. and C. A. Elwell (2015). "Knowing Me, Knowing You: The Role of Trust, Locus of Control and Privacy Concern in Acceptance of Domestic Electricity Demand-Side Response." In ECEEE 2015 Summer Study Proceedings, 2153–63. Presqu'île de Giens, France, 2015.*

➔ I wrote the text for this article in full, revising it on the basis of comments from co-authors and anonymous peer reviewers.

*Fell, M. J., Nicolson, M., Huebner, G. M. and D. Shipworth (2015). "Is It Time? Consumers and Time of Use Tariffs." Report to Smart Energy GB. London, UK: UCL Energy Institute, March 10, 2015. http://www.smartenergygb.org/sites/default/files/UCL%20research%20into%20time%20of%20use%20tariffs.pdf.*

➔ This text was written collaboratively by myself and Moira Nicolson, and subsequently revised on the basis of comments from co-authors. I authored those sections of the report which dealt specifically with my research, and only these section are drawn on (on a very limited basis) in this thesis.

*Fell, M. J., Shipworth, D., Huebner, G. M. and C. A. Elwell (2015). "Exploring Perceived Control in Domestic Electricity Demand-Side Response." Technology Analysis & Strategic Management 26, no. 10: 1118–30.*

➔ I wrote the text for this article in full, revising it on the basis of comments from co-authors and anonymous peer reviewers.

# List of acronyms

| | |
|---|---|
| ANOVA | Analysis of variance |
| ASV | Average shared variance |
| AVE | Average variance extracted |
| CLNR | Customer-Led Network Revolution |
| CPP | Critical Peak Pricing |
| DECC | Department of Energy and Climate Change (United Kingdom) |
| DLC | Direct load control |
| DNO | Distribution Network Operator |
| DSR | Demand-side response |
| ENA | Energy Networks Association |
| FCDM | Frequency Control by Demand Management |
| GB | Great Britain |
| IHD | In-home display |
| MANOVA | Multivariate analysis of variance |
| MSV | Maximum shared variance |
| ONS | Office for National Statistics (United Kingdom) |
| PEOU | Perceived ease of use |
| PU | Perceived usefulness |
| RFID | Radio Frequency Identification |
| RSL | Registered social landlord |
| STOR | Short-Term Operating Reserve |
| TOU | Time of use |

| | |
|---|---|
| TPS | Telephone Preference Service |
| UK | United Kingdom |
| US | United States (of America) |
| VIF | Variance inflation factor |

# 1 Introduction

## 1.1 Background

In coming decades the United Kingdom's (UK) energy infrastructure is expected to undergo significant change. On the supply side, more than 20 GW of generating capacity is scheduled to come offline by 2025 as a result of the Large Combustion Plant Directive 2001 and nuclear power stations coming to the end of their operational lives (Energy UK, 2013). In line with the need to meet the UK's carbon reduction commitments under the Climate Change Act 2008, this is expected to be replaced with a combination of low-carbon nuclear, renewable and carbon-abated fossil fuel generation. On the demand side, considerable growth is expected in the use of electric heating and vehicles, again resulting from the need to move away from carbon intensive fuels (DECC, 2011, 2015a). If this happens, the UK in 2050 will have higher demand for electricity than today paired with a less flexible supply.

This is a challenge because, at the moment, the UK electricity system is largely demand-led, with generators being turned up and down to meet mostly uninfluenceable demand cost-effectively and securely. In the developmental trajectory laid out above, there is expected to be an increased role for demand-side response (DSR), or '*change in electricity consumption patterns in response to a signal*' (Element Energy, 2012) (this definition, its implications for the study, and other definitions are further discussed in chapter 2). Alongside energy storage technologies, DSR is expected to be able to help address challenges including how to meet peaks in demand, avoiding congestion on the grid and facilitating the penetration of variable renewables such as wind and solar. It is already quite widely employed in the UK, both in the non-domestic sector through incentives such as critical peak rebates and in homes through 'time of use' (TOU) tariffs such as Economy 7, which charge a lower rate for electricity overnight (discussed in more detail in chapter 2). However, tariffs such as Economy 7 do not provide the flexibility to respond to less predictable factors such as renewable generation and faults on the system. Furthermore, with the exception of the use of simple timers and fairly basic teleswitch systems (see chapter 2), they rely on consumers themselves to adjust their consumption patterns, giving systems operators limited ability to elicit a demand response with the necessary speed, durability and reliability to credibly address the challenges outlined above.

Recent years have seen an increase in research and development focusing on more innovative DSR offerings which better provide the services required above, such as through Ofgem's Low Carbon Networks Fund programme (Ofgem, 2015a). These include 'dynamic' TOU tariffs which vary from day to day to better reflect less predictable factors such as renewable generation or faults. These may be coupled with 'smart' technologies which reliably adjust consumers' electricity use to increase the likelihood of eliciting a sufficient response. Certain offerings propose giving DSR operators themselves the ability to directly influence the action of electricity-using technologies in people's homes – so-called 'direct load control' (DLC). The roll-out of smart meters in Great Britain (GB)[1], scheduled for completion in 2020, is expected to enable the introduction of such offerings. In all cases, what the DSR operator seeks is greater control over patterns of electricity demand in order to provide services to the electricity system.

The problem is that while a clean, reliable and affordable system is in the interest of wider society, it is not clear that individuals' interests would necessarily be enhanced by accepting influence over how and when they use electricity. Indeed, research into the acceptability of DSR suggests that people have a range of concerns (Balta-Ozkan et al., 2013; Balta-Ozkan, Watson, et al., 2014; Goulden et al., 2014; Butler et al., 2013; Darby & Pisica, 2013; Oseni et al., 2013; Paetz et al., 2012; Downing & iCaro Consulting, 2009; Mert, 2008). A key worry is expressed around loss of personal control, both in relation to electricity use and consequently in people's lives in general. This is typified, for example, in the Orwellian allusion by a participant in a study of DSR by Goulden et al. (2014: 25): *'I don't want Big Brother dictating to me the time I get up'*. Such concerns matter because perceived control has been shown to be a factor in technology or service acceptance (Kranz, 2011; Spiekermann, 2008; Venkatesh, 2000), and the effectiveness of DSR programmes is dictated in part by the size of the participating load, which in turn depends on the number of people who choose to participate. For DSR to be effective, it needs first to be viewed as acceptable.

While a range of studies have investigated the acceptability of various approaches to DSR (see chapter 2) none has yet done so with the important issue of people's perceptions of control as its focus. Elaborating on our understanding of control in the context of home energy use is therefore a key theoretical contribution of this thesis. Furthermore, no studies have attempted to estimate actual public demand

[1] The countries of England, Scotland and Wales.

for a range of potentially commercially viable DSR offerings (such as static and dynamic TOU pricing, with or with automated response, and DLC) in Great Britain. Understanding such demand, and exploring hypothesized associations with perceived control and other factors, should provide valuable insights to improve the research, development, targeting, communication and regulation of DSR services.

## 1.2 Aim of research

The overall aim of this programme of research is: to assess how changing where control (or influence) resides over the action of electricity-using technologies affects people's perceptions of control in, and the acceptability of, domestic DSR in Great Britain. In this way it should contribute to the development and deployment of DSR in a way that is acceptable to as many people as possible.

The specific research questions that will be answered are set out chapter 2 following a detailed consideration of the context, drivers and previous relevant research. In terms of scope, the focus of this project was geographically constrained to the domestic sector in Great Britain (for reasons laid out in chapter 3). The DSR options investigated were restricted to those based on TOU pricing (with and without automation) and DLC – other approaches (such as volume/load capping) were not included. This was based on an assessment of the kind of DSR offerings either currently available or which have been trialled in Great Britain and might therefore be expected to be the first to be introduced commercially. This is discussed further in chapter 5.

## 1.3 Structure of thesis

This thesis has eight chapters. Chapter 2 introduces DSR, the principal reasons for employing it and the different ways in which it can be achieved. It summarizes its current and expected future status in Great Britain, and reviews existing research into the acceptability of different approaches to DSR. The concept of control is then examined in detail, and an analysis of relevant literature is used to classify the main motivations, antecedents and agents/means/ends of control in relation to home energy use. Some important terminology is introduced (e.g. 'acceptability' vs 'acceptance', 'consumer') and a range of applicable models of behaviour and behaviour change which may be employed to frame the research are critically discussed. Finally, the research questions for the programme of research are laid out. Chapter 3 presents the methodology. It begins by defining the research population, and then proceeds to set out the rationale for the mixed methods

approach which is employed. A range of possible methods for each stage of the research are critically discussed, and the eventual choices justified.

The programme of research presented in this thesis employed a mixed methods approach proceeding in three main phases, the design of each being informed directly by the findings of the preceding phase(s). For this reason, it is necessary to present the findings of one phase before explaining the method of the next. A chapter is therefore dedicated to each of the phases showing how the method refers back to the findings of the previous phase, and highlighting those findings which are significant for the next. The results of all the phases are then considered together in a 'global' discussion. This section briefly summarizes the main coverage of each chapter.

Chapter 4, entitled 'Exploring control', focuses on the first phase of research which employed a series of focus groups to understand how people understand 'control' in the context of home energy use and DSR. It begins with a detailed description of the focus group sampling, data collection and analysis approach. This is followed by a detailed results section and relatively brief discussion section pulling out the findings which are most relevant to the development of the next phase of research.

Chapter 5, 'Measuring control', covers the second phase of research. This used a between-subjects survey experiment administered online to a representative sample of energy bill-payers in Great Britain to test hypothesized associations between perceived control and acceptability for a range of approaches to DSR, which differed in controlled ways. The chapter begins by describing how the focus group findings informed the development of an extended version of the Technology Acceptance Model (Davis, 1989) and associated attitude scales. It then describes the process of questionnaire design, the selection and development of the DSR offerings, and the data analysis approach. The results of the analysis are then presented and, again, a relatively brief discussion summarizes the key findings necessary to inform the subsequent research.

Chapter 6, 'Experiencing control', presents the third and final phase of research. This took as a case study a trial of an 'intelligent' heating controller capable of cost-optimizing response to DSR signals, with a view to exploring people's experiences of control in DSR. Again, the precise method (drawing on the findings of the previous phases) is described in detail, followed by the results and a brief discussion.

Chapter 7 is a general discussion which integrates the findings of all three phases of research. It considers the extent to which the findings are reconcilable, both within this programme of research and with previous studies, and suggests possible explanations for any divergence. General limitations are discussed with specific suggestions for how they could be addressed in future work. The real-world significance of the findings is developed. Chapter 8 presents the conclusions. The key original contributions are summarized, and specific implications and recommendations are spelled out for research, industry and policy.

# 2 Demand-side response, control and acceptability

This chapter begins by explaining what demand-side response (DSR) is used to accomplish and the various ways in which it can be achieved. Consideration is then given to the role it is expected to play in the UK in the coming decades, and how its development is being promoted. After an initial review of research into the public acceptability of DSR, particular attention is then paid to evidence for concerns around perceived loss of control. The concept of control is discussed in the context of a framework proposed by Skinner (1996), and this framework is used to structure an analysis of a selection of studies into user perceptions of DSR. Finally, the concepts of 'acceptance' and 'acceptability' are defined, leading to a discussion of theories and models which have been used to explain them. Particular focus is put on the Technology Acceptance Model (Davis, 1989), and its justification as the theoretical guide for this study is laid out. The chapter ends with the research questions which directed this research.

## 2.1 Demand-side response

### 2.1.1 Background and function

Demand-side response (DSR) can be defined as '*change in electricity consumption patterns in response to a signal*' (Element Energy, 2012) (alternative definitions are considered later in this section). It is used to provide a range of services to the electricity system, outlined by He et al. (2013) as:

- *Portfolio optimization* (meeting load obligations at minimum cost)
- *Structural congestion management* (managing predictable, geographical stable congestion on the network)
- *Occasional physical congestion management* (managing unpredictable and occasional congestion)
- *Balancing* (ensuring system frequency stays within determined range, which is more challenging when variable sources of supply such as wind increase in proportion)
- *Ancillary services* (other services to guarantee system stability)

Such services have the following benefits (based on Strbac (2008)):

- *Cost.* In the long run, by deferring or avoiding the need to invest in infrastructure upgrades (for example to relieve capacity), the cost of operating the network is lower than it would have been with such investment. In the shorter run, the use of less efficient generating assets may be reduced or avoided. As such assets require more fuel to produce a given output than more efficient counterparts, this also leads to cost savings. DSR can also permit increased load factor of low marginal cost generating assets such as wind and solar power by incentivizing demand when they are generating.
- *Environmental.* The latter two points on cost above also have environmental benefits, as avoiding the use of less efficient fossil fuelled generation reduces carbon and other polluting emissions per unit output, while helping maximize the use of intermittent renewable generation has the same effect.
- *Security.* DSR can be used to avoid overloading on local or larger scale infrastructure, reducing the likelihood of power cuts.

Demand-side response can be achieved through a range of different means. He et al. (2013) propose five distinct classes of contract that, either individually or in hybrid form, may describe any kind of contractual DSR arrangement. They can be classified via the three kinds of signal upon which the response is based:

- *Price-based contracts.* The unit price for electricity varies over time, usually referred to as 'time of use' (TOU) tariffs. Static tariffs are characterized by long notice periods for predefined, relatively extended periods at specified prices. In the UK, the Economy 7 tariff falls into this category. Dynamic tariffs have shorter notice periods and price changes are more volatile and less predictable. Such tariffs are not currently widely used in the UK but have been trialled, for example in the recent Low-Carbon London trial (Carmichael et al., 2014). Critical Peak Pricing (CPP) is a special variant of dynamic pricing where high prices are imposed at certain critical times during the year. No domestic CPP tariffs are available in the UK, but certain industrial contracts deliver a 'critical peak rebate' to users for avoiding demand during 'Triads' (periods of high expected demand) (Pooley et al., 2012).
- *Volume-based contracts.* These impose some cap or constraint on electrical power consumption. Again, these may be static or dynamic over time. No domestic tariffs with this design are commercially available in the UK, but

Short-Term Operating Reserve (STOR) arrangements in the industrial sector are similar in that they reward customers for reducing power demand for a given period at short notice (Pooley et al., 2012). So-called 'demand charges', based on consumers' maximum demand over a given period of time, are becoming increasingly popular in the US (Hledik, 2014).

- *Control-based contracts.* Here, the customer cedes some level of control over specified appliances to the DSR operator. The DSR operator may therefore operate the appliance(s) in such a way as to achieve demand-side response. An example of this in the domestic sector is the use of dynamically switched storage heaters in the UK, which respond to signals encoded in long wave radio transmissions to switch on or off at specified times (McKenna et al., 2011). In this case direct control is used in hybrid with a time of use tariff. In the US there are many examples of tariffs which permit a level of direct control over air conditioning units in return for a rebate on electricity bills[2].

The definition of DSR given above ('*change in electricity consumption patterns in response to a signal*' (Element Energy, 2012)) was selected as being inclusive of this full range of approaches to DSR while also being specific enough to exclude interpretations which are not relevant to the questions posed in this study. Table 2-1 shows a non-comprehensive selection of other definitions which were considered less suitable, for one or more of the following reasons:

- They suggest DSR may include local generation rather than being purely concerned with consumption e.g. Ofgem (2013), Energy Networks Association (2014)
- They exclude certain consumption-oriented approaches to DSR such as time of use pricing e.g. Energy Networks Association (2014)
- They state or suggest that DSR is limited to responses based on price or payments e.g. U.S. Department of Energy (2006), Greening, (2010)
- They include overall energy demand reduction through energy efficiency e.g. broad definition by Greening, (2010)

This study in concerned with consumers[3] (and therefore consumption rather than local generation), is interested in a range of approaches to DSR that may or may

[2] See https://www.clearlyenergy.com/residential-demand-response-programs (accessed 6 July 2015)
[3] The term 'consumers' is discussed in more detail in section 2.3.1.

not be based on price signals, and does not take energy efficiency improvements as its focus.[4]

**Table 2-1: Selected alternative definitions of demand-side response (or, where specified, simply 'demand response').**

| | |
|---|---|
| *'actions by consumers to change the amount of electricity they take off the grid at particular times in response to a signal'* | Ofgem (2013: 3) |
| *'a deliberate and dynamic change in electrical power demand in response to a specific signal (by the user or 3rd party) as seen by the electricity network (at 11kV and above) from the demand that would otherwise have been expected … Under this definition, DSR only occurs because the consumer has pro-actively chosen to take part in a DSR programme and does not include planned load shifting to avoid price differential periods such as those that would normally be associated with Time of Use tariffs'* | Energy Networks Association (2014) |
| *'Demand response is a tariff or program established to motivate changes in electric use by end-use customers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardized.'* | U.S. Department of Energy (2006: v) |
| *'The very broad definition of demand response includes both modifications of electricity consumption by consumers in response to price and the implementation of more energy efficient technologies. … In the short-run, the definition of demand response is limited to modifications in consumption in response to prices.'* | Greening (2010: 1519) |

The volatility of DSR signals (i.e. the extent to which they are static or dynamic) has ramifications for the kind service that DSR can offer. While static tariffs allow regular peaks to be managed, they cannot incentivize demand that follows variable supply (such as from wind generation) or a response to unexpected peaks or faults. Dynamic tariffs, on the other hand, do permit such flexibility and therefore potentially offer added value to networks.

[4] Where overall demand reduction and local generation are being considered as well as demand-side response, this may more properly be referred to as 'demand-side management' (Warren, 2014).

There are a range of ways in which consumers might actuate a response to these different kinds of signal. In the case of control-based signals the need to make any kind of a response is taken out of their hands completely – they have merely to let the supplier carry out operation of their (the customer's) appliances. For price- and volume-based signals, there is the option either of making a manual response to the signal or of introducing some level of automation into the response. At its most basic, such automation would include the use of timers to operate electric heating and appliances at times when either electricity is expected to be cheaper or when it is known that other appliances will not be operating, hence reducing power demand. More sophisticated automation might respond directly to price change notifications or schedule appliances to run in a way that minimizes simultaneous demand for power. Currently the UK lacks the necessary metering infrastructure to allow the commercialization of such devices, but designs have been proposed (Chassin et al., 2015) and international trials are underway[5].

It is necessary to consider the type of signal, its volatility (i.e. the extent to which it is static or dynamic) and the mode of response because this can have a bearing on the speed, duration, magnitude and firmness (reliability) of that response. This is important because DSR operators usually need to commit to meeting certain thresholds on these criteria in order to be rewarded (for example, when bidding in an auction under the Capacity Market (DECC, 2013a)). Direct control signals potentially allow operators to achieve rapid response at short notice. Automating responses to DSR signals has been shown to lead to larger and more sustained shifts in demand than relying on manual responses (Frontier Economics & Sustainability First, 2012a).

A customer on a standard flat-rate electricity tariff is subject to no direct attempt by external entities to influence when they use electricity. What is clear from the preceding discussion is that a defining feature of DSR is that it introduces at least the attempt to exert such influence, with the possibility of a response. The amount of influence a DSR operator wields over the participating load will be a fundamental determinant of the nature of the response (i.e. in size, speed, duration, firmness). The counterpart of the amount of influence is the actual amount of participating load, which is largely determined by the number and type of customers who

[5] E.g. the Advantage Power Pricing scheme in Ontario, Canada, which uses dynamic pricing during the day and provides customers with a thermostat that can respond to price changes, http://www.energateinc.com/advantage-power-pricing/#.VZqYw_lViko (accessed 6 July 2015).

participate (and the loads they open to influence). For this reason the next section considers the potential for uptake of domestic DSR in Great Britain.

### 2.1.2 DSR in the UK domestic sector: status and potential

Recognition of the benefits of DSR is nothing new and, indeed, it has been employed in various ways in Great Britain for decades. In the industrial sector schemes such as Frequency Control by Demand Management (FCDM, in which customers interrupt large demands to support system stability) and Triad (where customers are incentivized to reduce their maximum peak load at times of highest yearly demand) are well established (Pooley et al., 2012). However, the focus of this thesis is on the domestic sector. In 2014 there were 26.7 million households in the UK (Office for National Statistics, 2015), accounting for 29% of UK final energy consumption in 2013, and 35% of final electricity use (DECC, 2014a). The proportion of electricity use accounted for by this sector is estimated to increase to 50% at peak times (in this case between 15.30 and 19.30 on weekdays) (Ofgem, 2010). This sub-section gives an overview of the status of DSR in the domestic sector and looks at estimates of its potential over the coming decades.

A number of domestic DSR tariffs or other products are already in use. Predominant amongst these is the Economy 7 tariff, which offers customers a lower than average unit rate for a period overnight and a higher rate during the day. It is designed to be used in combination with electric night storage heating and water heating. Other so-called 'off-peak' tariffs may be offered depending on the supplier and are usually some variant on the number of hours available at off-peak rates and when these hours occur (e.g. offering them at some point in the day rather than exclusively at night). There is no centralized record of the number of households in the UK currently on a time of use tariff, but 17% of the electricity consumed in the UK in 2013 was reportedly purchased under some form of off-peak pricing structure (DECC, 2014a). As off-peak customers generally use more electricity than those on a flat rate (due to their use of electricity for heating and hot water) (Hesmondhalgh et al., 2014), this means that the proportion of customers on an off-peak tariff is likely much lower than 17%, possibly only a third to a half of this (Owen et al., 2012). In a survey conducted by Ipsos MORI for the consumer organization then known as Consumer Focus, 13% of domestic electricity bill-payers reported being on a time of use tariff (Ipsos MORI, 2012). About 1.8 million customers with off-peak tariffs have their electric storage heaters and hot water switched remotely via the radio teleswitch system cited in the previous section (Spence, 2014).

The potential for an increased role for domestic DSR in Great Britain over coming decades is recognized in a number of policy and regulatory initiatives. Through the Smart Meter Implementation Programme, the Government hopes that every home and small business in Britain will get smart electricity and (where appropriate) gas meters by 2020 (DECC, 2014c). Smart meters are a key enabler of DSR as they allow DSR signals to be sent to customers, and the response to those signals to be accurately recorded. The final impact assessment for the roll-out attributes a present value gross benefit of £869m to load shifting as a result of DSR (DECC, 2014d). Recent electricity market reform has introduced a Capacity Market which allows demand-side response operators to bid in auctions to provide capacity when required (National Grid, 2015a). At the time of writing, Ofgem (the UK energy regulator) are examining the possibility of moving to half-hourly settlement for domestic consumers, a move which would facilitate and incentivize DSR tariffs (as it recognizes consumers' actual consumption at different times) (Ofgem, 2014a). Ofgem also run a Low Carbon Networks Fund of up to £500m to support distribution network operators (DNOs) in conducting research around new technology, commercial and operating arrangements. Various projects have included trialling of DSR (e.g. Low Carbon London[6], Customer-Led Network Revolution[7], Vulnerable Customers and Energy Efficiency[8]). The RIIO-ED1 price control mechanism which governs the outputs DNOs must deliver in the eight years from April 2015 includes a requirement for such innovation to continue (Ofgem, 2015c).

A wide variety of assumptions are used when considering the possible uptake of domestic DSR in Great Britain. DECC's smart metering impact assessment (2014) cited above calculates load shifting benefits on 20% take-up of static time of use tariffs (in addition to those already on Economy 7). This is based on unspecified '*international evidence*' (p59). In a report to the UK Department of Energy and Climate Change (DECC), Redpoint & Element Energy (2012) estimate annual savings attributable to domestic DSR could range from around £50-500m in 2030 depending on factors such as the type of DSR approach employed and the penetration of electric heating and vehicles. The lowest value reflects 31% penetration of static time of use (TOU) pricing, while the highest represents the additional daily use of direct load control (of loads such as heat pumps and electric

[6] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/ (accessed 22 July 2015)
[7] http://www.networkrevolution.co.uk/ (accessed 22 July 2015)
[8] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Vulnerable-Customers-and-Energy-Efficiency/ (accessed 22 July 2015)

vehicles) by 4% of homes by 2020, and 12% by 2030. These assumptions are based on consumers who take up heat pumps, electric vehicles and smart appliances also signing up to DSR tariffs. Hesmondhalgh et al. (2014) model load shifting of 5% on top of electricity demand reduction of 5%, which they consider to '*fall well inside the range of demand that we estimate to be shiftable or reducible*' (p24). They observe that results were very sensitive to dynamic tariff uptake, amongst other factors. IHS Global Insight (2009) estimate that if every residential consumer were to move all of their discretionary demand in response to a signal at peak demand, a response of 1–6 GW could be achieved (6–37% of residential peak demand).

The challenge is that there is little evidence for what possible uptake rates of DSR tariffs in Great Britain might be. While a range of trials have tested customer response to DSR tariffs in Britain (e.g. Bulkeley et al., 2014; Carmichael et al., 2014; Raw & Ross, 2011), their recruitment rates do not provide (nor did they aim to provide) a good indication of likely uptake. This is because they draw on a restricted pool of non-representative participants. In the case of the Customer-Led Network Revolution (CLNR) trial (Bulkeley et al., 2014), only people who already have a British Gas smart meter were invited to participate. Also, incentives were in place both for participation and through bill protection in case people ended up spending more on a TOU tariff than they would have on a standard flat-rate tariff.

Another option is to look to international trials and experience of participation in DSR. For example, the U.S. Department of Energy (2015) recently reported on interim results of 11 trials of time-based rate program in the US, including CPP, critical peak rebates, TOU pricing and variable peak pricing, some with automated response to price changes. Opt-in enrolment rates were 24% on average across the trials (increasing to 93% when participation was the default and customers had to decide to opt out). In Australia, Stenner et al. (2015) used a survey experiment deployed to a nationally representative sample of electricity account holders to measure people's intention to switch to a range of DSR tariffs including static TOU and real-time pricing, CPP critical peak rebates, capacity pricing and a flat rate tariff as a control. Additionally, options were offered with bill protection guarantees and provision of a free automation device to respond to DSR signals. All DSR tariffs were less popular than the flat rate tariff, with real-time and capacity pricing being the least favoured. Participants were asked to rate how likely they would be to switch to the tariff they were shown on a 100-point scale (with 100 the highest) – mean scores for the DSR tariffs ranged from 57 for TOU pricing to 38 for capacity

pricing. The offer of automation had little effect on acceptance of TOU and CPP tariffs, but made real-time and peak rebate options more attractive by approximately ten points each. This trial is discussed further in subsequent chapters. DSR participation rates in other countries are likely to be difficult to translate with any confidence to Great Britain for reasons including differences in heating/cooling requirements and systems, the regulatory frameworks surrounding the energy system and the way the market is structured offering different incentives.

A number of recent studies have set out to assess the potential for load shifting through automated or direct control approaches in the UK. Online surveys conducted by the Electricity Policy Research Group and University of Cambridge in 2010 and 2013 look at potential participation in load shifting (Oseni et al., 2013; Platchkov et al., 2011). Based on a representative sample of 1526 UK residents, Oseni et al. (2013) measured people's stated willingness to accept DSR through load interruption of a range of different appliances. Participants were presented with the following options (p52):

- *Having cold appliances (refrigerators, freezers) interrupt for 1 to 3 minutes intervals*
- *Having wet appliances (dishwasher, washing machine, tumble dryer) preset to operate only between 9 PM and 7AM*
- *Having usage of cooker/oven capped, so household would not be able to use it for 30-minute intervals 10 [or, in another group, 1] times per year during peak demand spikes.*

They found that 32-36% of participants would agree to limited cooker use in return for an annual electricity bill reduction of up to £20, while half would accept cold appliance interruptions for the same reward. Just 30% would accept pre-set operation of wet appliances (such as washing machines) overnight. If participants rejected an option, they would be shown it again but with a larger bill reduction while, conversely, if they accepted it, they would be shown it again but with a smaller bill reduction. In this way the researchers were able to gauge the sort of compensation consumers might expect for accepting different kinds of DSR measure. Increasing the compensation offer to £41-50 led to 42-59% of participants agreeing to controlled cooker use (depending on whether there was one or ten control events per year), 47% to pre-set operation of wet appliances and 61% to interruptions of cold appliances. Participants who had previously expressed

concerns about remote control of technology demanded more compensation, while those who had expressed keenness to try new technology required less.

While this study provides a very useful indication of people's willingness to accept the DSR measures proposed, the way they are presented is rather abstract. For example, no indication is given as to who the party doing the remote control is. Since privacy concern in relation to smart technology is shown elsewhere in that study to depend on with whom data is shared, this might be expected to be a significant factor in acceptance. Also, while the option offering short interruptions of cold appliances is quite plausible, fully constraining operation of wet appliances to the hours of 9pm-7am (without apparent opt-out) appears particularly restrictive and no real-world or trial examples of this sort of measure are cited in the study (or have been found in this review). Similarly, the amounts of compensation involved are not justified by reference to existing or proposed products, and appear to be relatively high. For example, Frontier Economics (2012: 15) suggest the value of direct control of cold appliances is likely to be <£0.20 per year, or £2-4 for wet appliances (cookers are not assessed, but the value for heat pumps – a relatively high power appliance – is £15).

Spence et al. (2015) surveyed online a representative sample of 2441 UK residents and found that just under 30% of people said having their washing machine remotely triggered by a network operator to finish by a particular time would be acceptable, with almost half accepting external control of fridge-freezers. It is striking that the proportions stating acceptance of similar measures are consistent across Spence et al. (2015) and Oseni et al. (2013) which enhances the external validity of these results. However, it is noteworthy that the studies differed in that the latter included financial incentives for accepting load interruptions while the former did not – potentially suggesting that such incentives play a limited or subsidiary role to other factors in acceptance[9], at least in the context of the limited potential size of incentive likely to be on offer in reality (e.g. according to Frontier Economics, 2012). Alternatively, participants in Spence et al. (2015) may simply have assumed some level of recompense.

The ways in which participants' responses were measured also differed between the studies. Participants in Oseni et al. (2013) were required to give a binary response as to whether or not they would accept a given measure at a certain price – which is quite similar to a real-world decision a consumer may be faced with.

[9] The term 'acceptance' is discussed in greater detail in section 2.3.1.

Spence et al. (2015), on the other hand, required participants to *'indicate their view towards the acceptability'* of the options presented, giving a response on a five-point scale ranging from 'acceptable' to 'unacceptable' (p2). It is not clear whether an 'acceptable' response necessarily means that the participant believes they would actually adopt such an option, or if they thought the idea of it was acceptable in principle for them or for society at large. To fully understand such results it is necessary to have greater clarity around the meaning of 'acceptability' – see section 2.3.1 for further discussion of this point. Finally, neither Spence et al. (2015) nor Oseni et al. (2013) deal with electric space heating or vehicles, both of which are expected to play a major role in future low-carbon electricity scenarios (DECC, 2011).

The only UK study to specifically assess potential uptake of TOU tariffs was conducted by Moira Nicolson, David Shipworth and Gesche Huebner of UCL (the latter two authors were also supervisors of the PhD research which is the subject of this thesis). Nicolson et al. (under review – see Fell et al. (2015) 'framing study' for a published overview) used an online survey (N=2020, representative of Great British energy bill-payers) to measure stated willingness to switch to a static TOU tariff and experimentally explored the effect on this of framing of the tariffs (either in terms of loss/gain or with/without environmental and security benefits). They found that 31% of participants were positive towards switching (this was uninfluenced by the framing). This study differed from Spence et al. (2015) and, to a lesser extent, Oseni et al. (2013) in that DSR offerings were presented as actual consumer products with specific tariff detail, which should enhance ecological validity. It did not consider the impact of introducing automation, dynamic tariffs or direct load control.

Earlier in this section it was suggested that the effectiveness of a DSR programme depends on the size of the participating load and the level of influence the DSR operator has over that load. As the preceding paragraphs show, limited evidence is beginning to emerge about possible participation rates for certain approaches to DSR. However, there is also evidence that the introduction of outside influence required for DSR to be effective may lead to concerns about loss of control that could directly impact participation. The remainder of this chapter focuses on this issue. It will examine the different ways in which researchers have conceptualized the idea of control, and how it has been related to product/service acceptance in general and DSR in particular.

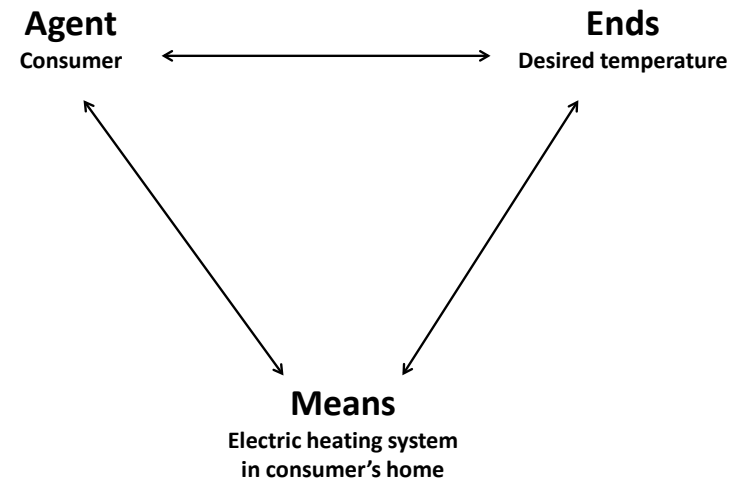
## 2.2 Perceived control and DSR

### 2.2.1 Key concepts in 'control'

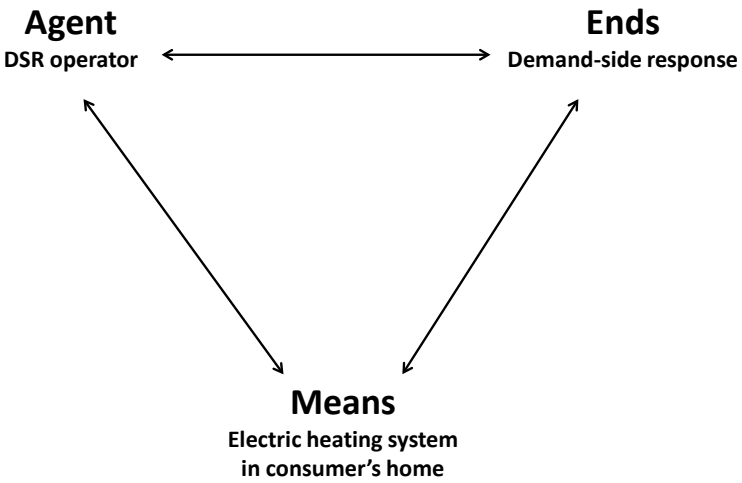
Control is defined by Merriam-Webster (2015c) as '*to direct the actions or function of (something) : to cause (something) to act or function in a certain way*'. The idea of 'control' has been widely studied in both technical and social disciplines. Whether people feel 'in control' or not has been shown to play a role in a range of areas, such as mental and physical wellbeing (e.g. see reviews in Thompson & Spacapan (1991), Strickland (1989) and – most relevant for the current research – product/service acceptance (see section 2.3 below)). This section considers the different ways in which it has been conceptualized, relating this to the context of domestic DSR. In doing so it is largely guided by a framework proposed by Skinner (1996). Although situated largely in social psychology, the framework provides a useful way of classifying different theoretical approaches to the idea of control from a range of disciplines. Skinner argues for the importance of being explicit about construct definitions if there are to be properly operationalized and ultimately '*help investigators make decisions about which control constructs are most likely to predict specific consequences*' (p562). Hers is the only work which assembles and gives order to so many interpretations of control constructs, or attempts to provide a framework for their study, and it is described in a commentary by Hagger (2014: 1) in the journal *Frontiers in Psychology* as follows:

> *As a journal editor, I am frequently asked what constitutes an exceptional research article … I usually respond by recommending Skinner's (1996) seminal guide to constructs of control as a prototypical example. … Skinner's article was extremely influential to my work. It not only helped me make sense of the myriad of constructs and terms used to describe and define the control construct, but also how I approached other constructs in social psychology.*

Skinner's primary distinction is between objective (actual) and subjective (perceived) control. How might objective control be understood in the context of domestic DSR? Firstly, it is important to establish who or what are the agents, means and ends of control. According to Skinner: '*Ends refer to the desired and undesired outcomes over which control is exerted, agents refer to the individuals or groups who exert control, and means refer to the pathways through which control is exerted.*' (p552). There are many possible ways of ascribing each of these in relation to DSR, but for the purposes of this discussion let us consider the two simple models represented in Figure 2-1.




(a)




(b)

**Figure 2-1: A DSR scenario with (a) consumer as agent, and (b) on the introduction of direct load control, the DSR operator as agent.**

In Figure 2-1 (a) the agent of control is a consumer, their end is to attain a desired temperature and the means by which they do this is by directing the action of an electric heating system in their home (this simplified model omits other actions such as window opening). In Figure 2-1 (b) when direct load control (DLC) capability is

introduced, the agent is a DSR operator with the end of achieving a demand-side response with certain characteristics (i.e. magnitude, speed, duration, reliability), and the means by which they aim to achieve this is by directing the action (through DLC signals) of the same electric heating system in the home of the original consumer. In each case the agent affects the means, which in turn affects the end. When the DSR operator is the agent, they could objectively be said to have full control over their 'end' if a certain demand-side response can be achieved at 100% guaranteed reliability with the intended speed, size and duration. Likewise, the consumer could be considered objectively to have full control if they are always able to achieve their desired temperature. However, once DLC has been introduced, both the consumer and DSR operator share the ability to direct the action of (i.e. have some objective control over) the heating system. The situation where both agents have full control over their ends while sharing control of the means is not unattainable – it would be possible to achieve operator's desired response while staying within the bounds of the occupant's desired temperature. However, in reality it is likely that some compromise will have to be reached.

Subjective (or perceived) control is defined by Skinner (1996: 551) as '*an individual's beliefs about how much control is available*'. The same agents/means/ends schema can be usefully applied here as for objective control. Agent-means relationships have been widely studied though the lens of perceived self-efficacy, defined as '*people's beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives*' (Bandura, 1991: 257) – or more simply put, the '*ease or difficulty of performing a behavior*' (Ajzen, 2002: 665). Means-ends relationships '*refer to the [perceived] connection between particular classes of potential causes and desired and undesired outcomes*' (Skinner, 1996: 552) – or the extent to which employing a certain means may lead to a desired end. Finally, the connection between the agent and ends describes the overall perception of control, or '*generalised expectancies about the extent to which an agent (e.g. the self) can produce desired outcomes without explicit reference to the means involved*' (Skinner et al., 1988: 371).

In the context of a study on consumer acceptance of domestic DSR, the primary agent is the consumer. In the example of Figure 2-1 (a), the consumer may form beliefs about their ability to direct the action of the heating system, and of the heating system to achieve their desired temperature. Overall, this may be referred to as their perceived personal control. The consumer may also form perceptions about the ability of others (such as the DSR operator as an agent) to control the

means and achieve its ends. Depending on whether other agents are viewed as acting with benevolent or malign intent, perceived personal control may be augmented or diminished respectively (Skinner, 1996). People's perceptions as to who or what controls events which affect them (i.e. themselves or external entities and circumstances) is sometimes referred to as their perceived locus of control. Early work on the construct by Rotter (1966: 1) outlines it as follows:

> *When a reinforcement is perceived by the subject as following some action of his own but not being entirely contingent upon his action, then in our culture, it is typically perceived as the result of luck, chance, fate, as under the control of powerful others, or as unpredictable because of the great complexity of forces surrounding him. When the event is interpreted in this way by an individual, we have labeled this a belief in external control. If the person perceives that the event is contingent upon his own behaviour or relatively permanent characteristics, we have termed this a belief in internal control.*

Also salient here is the role of automation. Merriam-Webster define automatic as: *'of a machine or device : having controls that allow something to work or happen without being directly controlled by a person'* (Merriam-Webster, 2015a). Automation is desirable because it allows humans to undertake tasks that they otherwise wouldn't be able to do, or do well, or that they don't like doing (Wickens et al., 2015). An example of this would be a thermostat for a heating system – when it detects that the temperature has dropped below a specified point it turns on the heating until such time as a pre-determined temperature threshold is crossed, at which point it turns the heating off again. In this case, is the thermostat to be considered the agent of control, or the person who set it? Or, in the case of a DSR offering with automatic response to price changes, the DSR operator? One way of resolving this is by employing the concept of 'human supervisory control' which, as its name suggests, requires that human operators retain the ability to oversee and affect the operation of automation rather like a manager with their staff (Sheridan, 1992). In such a case the human user may be viewed as the agent even while specific action decisions are delegated to automation.

Aside from the relations between agents, means and ends of control, other constructs need to be considered which are related to, but not part of, perceived control. The first of these is the antecedents of control, or '*conditions that have been hypothesized to have the potential to influence experiences and perceptions of control*' (Skinner, 1996: 555). Examples include '*information, choice, warning signals, regulated administration, help, feedback, and instructions*' (p558).

Secondly, it is useful to consider the possible motivations for control. Skinner (1996) defines this as '*why people form perceptions of control*' (p557). For the purposes of this review this is interpreted as referring to reasons people feel they need control in the context of home energy use. Finally, the concept of self-determination or autonomy ('*desire to experience one's true self as the origin of one's own actions*' [p557]) is proposed by Skinner (1996) as also distinct from perceived control. It is distinct because there is no expectation of contingency between actions and outcomes; rather it refers to the general freedom to initiate behaviour (Deci & Ryan, 1985).

The next section reviews the literature as it pertains to perceptions of control – primarily in relation to DSR, but also drawing on related work in the study of smart homes and home energy use. It is structured according to Skinner's (1996) framework. At its core is a thematic analysis of 20 recent research papers or reports which deal with perceptions of control in the context of DSR (see appendix 10.1). The materials were selected based on a review of literature collected during the period of research for this thesis, which has included receiving alerts of any academic publications featuring the terms 'demand-side response', 'demand response' and 'perceived control' (as well as regular literature searches). First the different motivations for control are examined, followed by consideration of the antecedents, aspects pertaining to agents/means/ends relations, and finally other issues relating to control and acceptance of DSR. The aim is to explore the different ways in which concepts related to control are expressed in the literature in this area and to introduce the various control-related concerns that have been shown to exist in the context of DSR.

### 2.2.2 Reviewing perceived control in DSR research

#### *Motivations for control*

In the context of DSR, 'control' as a concept is most commonly introduced when the issue of automated or third-party control of technologies in the home is under investigation. Where this is the case, discussion is often framed in terms of autonomy (Goulden et al., 2014; Murtagh et al., 2014; Butler et al., 2013; Darby & Pisica, 2013; Rodden et al., 2013; Sheldon, 2013). As discussed above, while this concept should be considered outside of the proper domain of 'control', it is related to it and is commonly connected to the idea of control by researchers. In such cases, autonomy or self-determination is treated as a motivation to retain control (however it may be understood). In many cases simply the possibility that an

external actor could have some direct influence over the action of technology within the home – the ultimate private space – is unacceptable. For example, deliberative workshops described in Butler et al. (2013) presented participants with possible future energy system scenarios, including the possibility of direct control of appliances by third parties. They found (p37):

> *… demand management that could lead to more automation, with those outside the home – be it energy companies or another body – able to access 'private' information or manipulate the running of certain appliances, provoked strong negative reactions from most participants. Indeed, participants characterised the type of society that would allow such penetration of the private sphere as being, for example, "draconian", "sinister", "autocratic", "intrusive", a "police state", "nanny state", "1984" or "Big Brother".*

The direct allusion to George Orwell's 'Big Brother' is explicitly made by participants in the same context in a number of other qualitative studies (Balta-Ozkan, Amerighi, et al., 2014; Goulden et al., 2014; Darby & Pisica, 2013; Sheldon, 2013; Strengers, 2010). In *1984* by George Orwell, 'Big Brother' has both an observing and a controlling role, and both privacy and control concerns are invoked by participants and researchers who use this term. For example, Goulden et al. (2014: 25) presents an example of autonomy concern:

> *Suggestions of shifting such practices often generated emotive responses reflecting the degree to which they are woven into the repertoires of performance from which individuals construct notions of self: … 'I don't want Big Brother dictating to me the time I get up'*

Balta-Ozkan, et al. (2014: 10), on the other hand, highlight the privacy aspect of Big Brother:

> *In the UK, the participants were not comfortable with the household monitoring involved in smart home services, some likening this idea to 'Big Brother' watching them. They highlighted a clear distinction between the monitoring of external and internal activities and argued that 'in your own home you expect to be secure and what goes on around these four walls, stays in these four walls' ('Town family' group; UK).*

Because the 'Big Brother' idea is so frequently cited in relation to DSR, it is important to be clear about this distinction when interpreting what research participants mean when they use the term. For example, the term is used in the following passage from Goulden et al., (2014: 27):

> *Discussions of energy use being monitored; cheaper tariffs requiring time shifting; or the purchase of specific remote-operated 'smart' appliances, prompted fears of a loss of autonomy over the ordering of domestic life. These concerns were typically realised in references such as 'Big Brother' and 'Orwellian'.*

The explicit statement is that participants used 'Big Brother' terminology to refer to autonomy concerns, but the mention of '*energy use being monitored*' suggests that privacy may also have been an issue, and without a direct quote it is difficult to know which meaning was intended. Privacy, as an issue related to but separate from control, is discussed in more detail below.

After autonomy, the next most commonly cited motivation for retaining control (however understood) was temporal considerations; that is, concerning the need or ability to perform certain activities at certain times. Often reference is made to household (or other, e.g. work) routines or patterns of activity (Balta-Ozkan, et al., 2014; Bulkeley et al., 2014; Carmichael et al., 2014; Goulden et al., 2014; Murtagh et al., 2014; Balta-Ozkan et al., 2013; Butler et al., 2013; Paetz et al., 2012). Usually the motivation for control is to be able to keep to an existing routine, or alternatively having the ability to vary it as necessary, for example from Paetz et al. (2012: 23):

> *… giving up high levels of flexibility and adapting everyday routines to fit in with electricity tariffs were regarded as difficult.*

The importance of routines is not surprising – the case has previously been made that technology should be designed seamlessly around them as they are:

> *… the very glue of everyday life, encompassing innumerable things we take for granted such that each ordinary enterprise can be undertaken unhesitatingly. This is especially pertinent in the home where the highly disparate priorities of different family members have to be coordinated without the commonality of an orientation to some shared work objective to bind them together. Routines help provide the grounds whereby the business of home life gets done.* (Tolmie et al., 2002:1-2)

At the same time, it has been recognized that while routines do facilitate household functioning, there are many reasons why they might have to change – whether in the short term (e.g. people running late) or seasonally – leading to the need for flexibility (Davidoff et al., 2006). While scheduling was mostly cited as a motivation to retain control in the context of DSR, sometimes the structure that DSR offerings could potentially provide was appreciated. For example, Butler et al. (2013: 37) found that:

> *Indeed, some participants felt further automation (e.g. in relation to turning things on and off) could be helpful in the co-ordination of their everyday lives.*

This was also the case for Carmichael et al. (2014), who found that 77% of participants who responded to a survey said a dynamic time of use tariff helped households in planning and organizing. Often allied to temporal considerations are ideas of convenience, defined by (Merriam-Webster, 2015d) as: '*a quality or situation that makes something easy or useful for someone by reducing the amount of work or time required to do something*'. This concept is highlighted by Costanza et al. (2014), Goulden et al. (2014) and Paetz et al. (2012).

It is not surprising that temporal motivations for control should be prominent in the context of DSR, since much DSR activity is inherently time based, one of its principal aims being to shift electricity consumption from one time to another. However, another motivation for control was the desire to attain certain levels of energy service (e.g. comfort, cleanliness) without an explicit temporal dimension (Broman Toft & Thøgersen, 2015; Goulden et al., 2014; Mert, 2008). For example, participants in a trial of smart grid technology with heat pumps by Broman Toft & Thøgersen (2015) found that (p15):

> *… participants who had adopted Smart Grid technology for a trial period perceived several disadvantages of the technology, including loss of comfort in terms of too low indoor temperature and not enough hot shower water.*

In buildings research (specifically in the non-domestic context), having the ability to avoid discomfort (which requires some level of personal control) has been identified as a key factor in productivity (Leaman & Bordass, 1999) and user satisfaction (Leaman & Bordass, 2007).

Another distinct motivation for control was in relation to spending on electricity. This was evident both in studies that focused on the use of price signals to achieve DSR and those involving direct control signals (Carmichael et al., 2014; Costanza et al., 2014; Goulden et al., 2014; Balta-Ozkan et al., 2013; Rodden et al., 2013; Paetz et al., 2012). This motivation is typified by the observation from Balta-Ozkan et al. (2013): 370), who conducted deliberative workshops to explore people's reactions to smart home technology:

> *Questions were raised as to why costs could not be controlled at source by utility companies or through government regulation rather than responsibility for reducing costs falling squarely on the consumer:*

> *[Participant:] I'm concerned—it looks as though we're getting lots of control but I question how much control we've actually got, even with that information.*

Carmichael et al. (2014) explicitly conceptualize control via this motivation in a survey concerning people's experiences of a dynamic time of use tariff by including an item as follows: '*I/We feel more in control of my electricity bill by being on the Economy Alert tariff*' (p66). Finally, some studies explicitly highlighted control over energy use as a motivation to retain control (Broman Toft & Thøgersen, 2015; Balta-Ozkan et al., 2013; Gangale et al., 2013). For example, Broman Toft & Thøgersen (2015: 17) discuss how some participants with heat pumps including smart grid technology emphasize the benefits of:

> *… gaining control over the heat pump's electricity consumption and control over their electricity consumption in general.*

While these last two motivations were only mentioned in a relatively small proportion of the studies reviewed, it is notable that they are regularly appealed to by companies and other organizations in relation to 'smart' energy offerings more generally. For example, Smart Energy GB, the organization responsible for engaging the British public with the smart meter roll-out, has adopted 'getting gas and electricity under control' as one of its main messages (see, for example, Smart Energy GB (2015)). E.On, the energy supplier partner in the Low-Carbon London trial reported on by Carmichael et al. (2014) used '*Control how much you save*' as its main recruitment message (Carmichael et al., 2014: 25).

To summarize, the review suggested a number of distinct motivations that people may for having control (however understood) in the context of DSR: autonomy; temporal motivations such as routines and flexibility; level of service; spending; and desire to control energy use.

It is important for the purposes of this analysis to attempt to distinguish between motivations for control itself, and motivations to take part in DSR programmes. Sometimes it is clear where this distinction lies, and obvious when it is not correctly drawn. For example, Gangale et al. (2013: 627) cite '*Reduction of/control over electricity bills*' as a motivational factor used by promoters of smart grid projects – but they later specify that this refers only to '*the potential of lower electricity bills for consumers*' (p627), rather to any more general idea of control over bills. However, the line between control over something and the thing itself can be quite fine. In the

example from Broman Toft & Thøgersen, (2015: 15) above, ('*participants who had adopted Smart Grid technology for a trial period perceived several disadvantages of the technology, including loss of comfort*'), that idea that control over comfort would be desired is only inferred (in this review by reference to the buildings literature which connects discomfort alleviation directly with ideas of perceived personal control i.e. Leaman & Bordass (1999), Leaman & Bordass (2007).

### *Antecedents of control*

Antecedents of control are those conditions which influence perceptions of control. Principal among these in the studies reviewed was trust. Trust is important in facilitating relationships of all kinds. For example, where trust exists, in many circumstances parties are less obliged to depend on repeated legal and other formal agreements which are costly in money, time and other resources to administrate. It enables dependence on the abilities and resources of others, rather than having to directly acquire them oneself. However, it involves accepting an element of vulnerability, as the following (widely-used) definition describes: '*[trust is] the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party*' (Mayer et al., 1995: 712).

In the case of DSR, the review highlights issues around trust in two main areas. Firstly, participants often did not trust the DSR operator (e.g. supplier) to act in their (i.e. the customer's) interests (Broman Toft & Thøgersen, 2015; Balta-Ozkan, Watson, et al., 2014; Carmichael et al., 2014; Goulden et al., 2014; Murtagh et al., 2014; Balta-Ozkan et al., 2013; Butler et al., 2013; Darby & Pisica, 2013; Rodden et al., 2013; Sheldon, 2013; Paetz et al., 2012). A typical example of this is the following, from Rodden et al. (2013: 7):

> *Users did not view energy companies with as [sic] particularly trustworthy and felt that these companies were exploitative. …:*
>
> > *[Participant:] … I would feel quite positive about handing out my money to someone I know that is actually not going in their pockets, which is how I feel now half the time. I know some of it is paying for electricity but quite a lot is going in to some extremely rich persons' [sic] big pockets.*

The link between trust and control is clearly illustrated by the following exchange from Butler et al. (2013: 37):

*In part, our participants seemed resistant to ceding responsibility for demand management:*

> *P1: I think we need to be educated about energy levels, electricity levels rather than having to knock them off – you know?*
>
> *P2: I think it's a trust thing.*
>
> *P1: Saying, you'd be educating everybody to be conscious of the amount of electric that they're using in their household, rather than think "ah we needn't bother I'll go to bed and let the company knock it off".*
>
> *M: So you're being more responsible?*
>
> *P1: Yeah you'd feel a better sense of responsibility thinking well no I'm not going to let them do it, I'm going to do it myself and I'm going to make sure it's knocked off… (Cumbria)*

As well as having trust concerns around the DSR operator, consumers may also lack trust in the new automated systems required to respond to DSR signals (Rodden et al., 2013; Sheldon, 2013; Mert, 2008). For example (from Rodden et al. (2013: 7)):

> *If there's a bug, where ya know, it's interpreting the data from the sensor wrong, or its [sic] getting the wrong corpus of available tariffs and choosing them incorrectly, then I'm essentially paying more because of some software bug.*

There is abundant evidence of a positive association between trust and product/service/innovation acceptance across sectors (e.g. see Bhattacherjee 2002 for e-commerce, Ortega Egea & Román González 2011 for healthcare records and Terwel et al. 2011 for carbon capture and storage). In the UK there is a high level of distrust of gas and electricity companies. According to the consumer organization Which?, 40% of the population distrust their supplier compared to figures for other 'essential' services such as 25% for mobile phone services and 15% for water companies (Which?, 2014). Just 28% of people say they trust energy companies to act in their best interests (Which?, 2013a). This is a problematic starting point for DSR. Based on the evidence of a link between trust and acceptance cited above, it suggests that products or services offered by (distrusted) energy companies are at risk of being rejected.

Connected with trust and also, to an extent, with autonomy, was the idea of ownership. Again, in the studies reviewed this was framed both in terms of who ran

the DSR programme (e.g. a corporation or community (Goulden et al., 2014)), and who owned the technology (and software running on it) that facilitated DSR. For example from Rodden et al. (2013: 9):

> *We would suggest that making explicit who owns and controls any embedded agent and the stated aims and limits of the agent will be essential, if users are to develop any trust in these systems. Is an agent acting on behalf of an energy supplier, and are actions limited to monitoring, analysing and reporting behaviour? Is an agent acting on behalf of a user to monitor the activities of the infrastructure and alert them of significant changes?*

Another commonly cited antecedent of control was the importance of having some kind of choice in responding to DSR signals (Butler et al., 2013; Darby & Pisica, 2013; Rodden et al., 2013; Sheldon, 2013; Owen et al., 2012; Downing & iCaro Consulting, 2009; Mert, 2008). Often such choice could be expressed through the availability of an override option for automated responses in in the context of direct load control. Sometimes having such a choice made a difference to the acceptability of automated response (Butler et al., 2013: 37):

> *Important, in this regard, was that householders were afforded autonomy and the ability to override control of the automation – that ultimately they, rather than an 'outside' group, had control.*

And, as this quote from a participant in Darby & Pisica (2013: 2329) indicates, sometimes it did not:

> *That's taking decisions out of your hands. Even though you said it's got an override switch, if you're busy doing something else … there's certain days when we'll stick the washing on and we like to get it done, washed, dried and put away, because we don't have much time.*

This suggests that in order for choice to lead to a perception of being in control, the choice itself must be perceived as real and accessible to user.

Another prominent antecedent of control in the studies reviewed was having information – whether on electricity consumption, pricing, or on how a DSR programme (or the technology that underpins in) actually works (Carmichael et al., 2014; Costanza et al., 2014, 2014; Sheldon, 2013; Owen et al., 2012). Notably, Carmichael et al. (2014: 8) found that:

> *… consumers are likely to engage more with dTOU [dynamic TOU] if the reasons and rationale for the tariff design, rate change events etc. are explained clearly. The*

*absence of any reasons or rationale for rate changes in the LCL dTOU trial was reportedly felt by many trialists and there was a tendency for mistrust and cynicism about profit motives …*

This is an example of how antecedents (in this case information and trust) can work together to build or undermine a sense of control. The 'invisibility' of energy is well-recognized, as is the idea that by giving information to householders on how much they are using they might be able to reduce their usage (e.g. see Darby (2006)). Indeed, a significant proportion of the benefits attributed to smart meters in the impact assessment for the GB roll-out is down to savings resulting from improved feedback via an in-home display (IHD) (DECC, 2014d). For similar reasons, companies have been keen to emphasize the control-giving capabilities of information in relation to smart metering (see Figure 2-2).

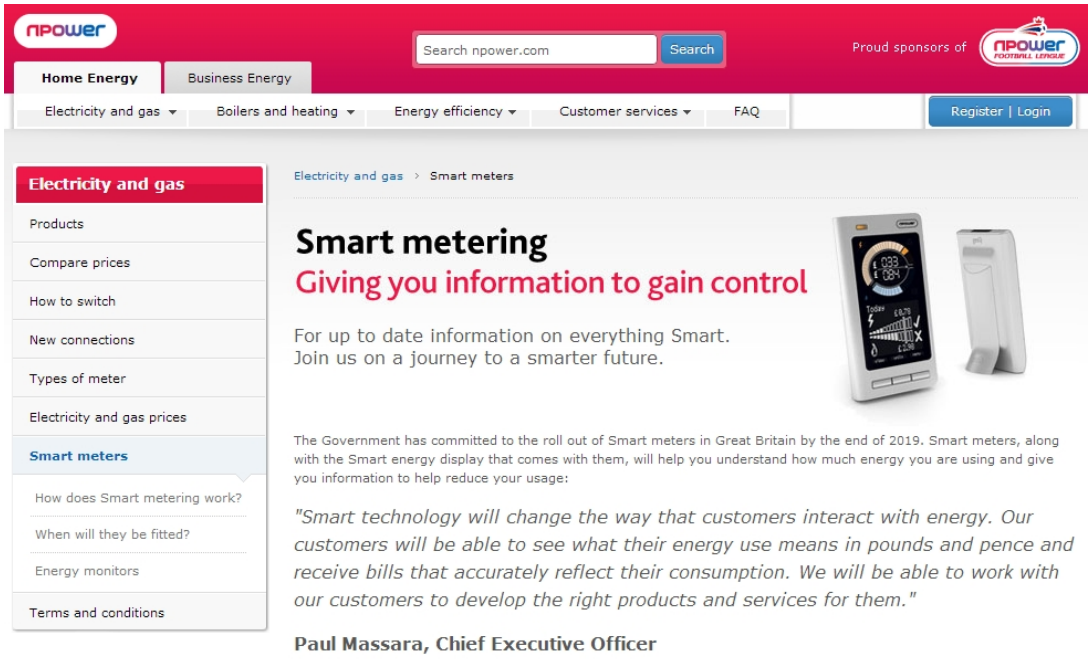



**Figure 2-2: Screenshot of nPower page on smart meters (http://www.npower.com/home/help-and-support/types-of-meter/smart-meters/, accessed 18 March 2013)**

The final antecedent to be identified was predictability, or the extent to which it was possible to anticipate when a response might be required (Carmichael et al., 2014; Costanza et al., 2014; Darby & Pisica, 2013; Sheldon, 2013). This was most often apparent when considering dynamic time of use tariffs. Carmichael et al. (2014) found that 68% of survey respondents said they would be more likely to sign up to a dynamic TOU tariff it were more predictable. Concerns are typified by this exchange on critical peak pricing included in Darby & Pisica (2013: 2326):

*F1: I feel it's not much notice, the day before [i.e., warning of a 'red day' with option 2]. If you plan something for the next day and then you're told that evening [before] …*

*F2: Yes … if you come home late and you're planning for the next day … and then you find when you get back and it's too late to make any change. Whereas that other one [option 1] you know, every single day, that time is our peak time …*

In summary, the main control antecedents identified were trust, ownership, choice, information and predictability.

### *Agent/means/ends relations*

For people to feel in control, they (as the agent) must feel they are able to affect a means of control in the way they want, and they must feel confident that affecting that means will have the desired result (or end). In the studies reviewed, the agent of control was usually a householder, the means an electricity-using technology and the ends some kind of output of such technology such as heat or clean clothes. However, participants also often considered what the ends of a DSR operator (as agent) might be, and how they might achieve this using the shared means of electricity-using technologies in their (the participants') homes. Two main themes were apparent.

One general theme that emerged that applies across agents/means and means/ends relations was that of understanding. Regarding means/ends, people sometimes did not know how changes in the output of technologies would be affected by participating in DSR programmes, or how DSR would be achieved through their participation. For example, Broman Toft & Thøgersen (2015) found that (p22):

*Some of the families in the heat pump-only group did not understand the need to be remotely controlled and they were also uncertain about how that would be done in reality and for how long, about which appliances could be connected to Smart Grid technology, how it worked with fluctuating prices of electricity, and how that was linked to the demand for electricity. Some were also uncertain about how the heat pump's production of hot water would be affected …*

Lack of understanding of how and why technologies are caused to act as they do to achieve DSR could lead to the belief that actions taken by the householders (as agents) would not necessarily have the desired effect (either for themselves or for the electricity system), leading to reduced feelings of control. Mainly, however, concerns were focused on how people (as agents) would use technology (means)

under a DSR programme. Comments on the ease of use of either tariffs or technologies were quite common (Broman Toft & Thøgersen, 2015; Carmichael et al., 2014; Costanza et al., 2014; Darby & Pisica, 2013; Rodden et al., 2013). A well-designed user-interface to book times for appliances to run was welcomed by all participants of Costanza et al. (2014), and contributed to feelings of control in relation to spending (p818):

> *[Participant:] "[The system] helps you save money and do things a bit more economically. Think about how you're washing things and how much money you're spending and how economical you can do things."*

On the other side of the coin, Broman Toft & Thøgersen (2015: 22) found some participants in their trial of heat pumps with external control '*found it difficult to grasp how the setting of the minimum temperature worked*', which may have led to a feeling of inability to control the heat pump as they would like. Such concerns are clearly linked to the idea of information as an antecedent of control, showing how the lack of information which is tailored and communicated appropriately for the user could lead to perceived loss of control.

Another key theme that emerged was the flip-side of the temporal motivation to preserve routine or flexibility. In many cases the need for routine/flexibility was seen as a barrier to being able to use technologies in a way that could give a demand response. Study participants often felt unable to change the way they used technologies because of such a need (Broman Toft & Thøgersen, 2015; Balta-Ozkan, Watson, et al., 2014; Bulkeley et al., 2014; Carmichael et al., 2014; Costanza et al., 2014; Murtagh et al., 2014; Balta-Ozkan et al., 2013; Butler et al., 2013; Darby & Pisica, 2013; Rodden et al., 2013; Sheldon, 2013; Paetz et al., 2012). For example, working routine might mean that an actor is simply unable change when they perform a particular activity (Murtagh et al., 2014: 6):

> *… for some households, shifting their demand from peak time appeared impossible because their routines were subject to external societal temporal patterns:*
>
> > *[Participant:] I can't see that happening. I really can't. I mean, we couldn't have our meal in the middle of the day, for instance, because we're not here – we're both at work. So, we're always going to be eating at that time, aren't we?*

In this case the participant would not be able to use electricity for cooking at a different time because they would not physically be there to do so (even if they

wanted to). One way of responding to DSR signals when the householder is not physically present is through the use of automation. This could be something as simple as a timer switch that can run appliances overnight if electricity is cheaper. Having a timer switch could be seen as objectively increasing the control an agent has over a given means, since instead of only operating it immediately they can do so either immediately or at some point in the future. However, it is also important that the quality of the output is sufficiently good. If the intended output is clean clothes, but running the washing machine overnight means that washed clothes sit in the machine for a long time and get creased and smell damp, the agent may well not feel a sense of control over the ends they were trying to attain (e.g. Carmichael et al. (2014)).

Finally, and separate from these main themes, there was some evidence of concerns that third-party control of appliances would result in poor service quality – that these means would no longer be able to achieve ends. For example, the case given above of the study by Broman Toft & Thøgersen (2015: 15) found that participants with smart grid technology controlling their heat pumps perceived *'too low indoor temperature and not enough hot shower water.*'

### *Other issues*

A number of other issues emerged from the analysis that are related to, but not intrinsic to, control. Firstly, the concerns were related to running appliances at unusual times around noise (Balta-Ozkan, Watson, et al., 2014; Carmichael et al., 2014; Goulden et al., 2014; Darby & Pisica, 2013; Mert, 2008) and the possibility of damage/safety risk (Broman Toft & Thøgersen, 2015; Murtagh et al., 2014; Butler et al., 2013; Darby & Pisica, 2013; Oseni et al., 2013). These may be viewed as incompatible with the motivation for acceptable service quality.

Finally, concerns were often raised around privacy (Balta-Ozkan, Watson, et al., 2014; Goulden et al., 2014; Balta-Ozkan et al., 2013; Butler et al., 2013; Darby & Pisica, 2013; Oseni et al., 2013; Paetz et al., 2012; Downing & iCaro Consulting, 2009; Mert, 2008). Privacy has featured prominently in discussions around the transition to a smart energy system. The principal concerns are around the additional information which technologies such as smart meters allow to be shared and around the security of the infrastructure which permits this sharing (McDaniel & McLaughlin, 2009). Such concerns were exemplified in long delays to the smart meter roll-out in the Netherlands, which were driven largely by the widespread fear of electricity suppliers and network operators keeping track of citizens' electricity

use (Hoenkamp et al., 2011). In the case of DSR, privacy issues are at stake not only in the energy data which may be shared but around control signals and consumers' responses to them. For example, consumers' financial rationality could be deduced from their response to TOU price changes (Li et al., 2014).

It is useful to draw a distinction between different conceptions of privacy. In the sense that it is used above, we may more precisely refer to 'information privacy' – that is, '*the concept of privacy in terms of conditions having to do with access to and control over personal information*' (Tavani 2007: 7). While this is relevant to a discussion of DSR, similarly salient is the concept of 'non-intrusion' – the breach of which may be analogous to '*unwarranted intrusion into one's personal space through someone physically accessing one's personal papers, home, and so forth*' (Tavani 2007: 6). This is because the intention of domestic DSR is to exact some change in a home's electricity use patterns, whether this has perceptible effects in the physical world or not, or is induced directly (as in direct load control) or through price incentives (as in time of use pricing). This echoes the discussion of the two interpretations of 'Big Brother' concerns above.

Privacy is also bound up with trust. As the previous section on antecedents described, trust involves the acceptance of vulnerability by the trustor. In the case of DSR, this vulnerability is likely to involve some compromise in one's previous expectations of privacy. And similarly to trust, privacy concern has also been shown to be associated with product/service acceptance, although in this case negatively (for example in adoption of location-based services (Tao Zhou 2011) and social networking (Fogel & Nehmad 2009)).

### *Remaining questions around control*

The review presented here is based on interpretations of reports of research that are themselves based on researchers' interpretations of what participants said (or responded, in the case of surveys). While these studies all include some consideration of control, as Hargreaves et al. (2015: 1022) find in the case of smart homes, '*the concept of control is often implicit within or treated as a side-issue that emerges from research focussed on different topics*'. None of the work reviewed explicitly set out to elicit participants' own views of what constitutes 'being in control' in the context of energy use and DSR. Because the various dimensions of control were drawn from a range of different studies, it is difficult to say how they might relate to each other or vary according to both the research method employed and the subject of study (e.g. type of DSR). Part of the aim of this study (as stated in the

Introduction and specified in the research questions at the end of this chapter) is to shed light on these points.

As stated at the beginning of this section, Skinner's (1996) framework was largely based around control as conceptualized in the field of social psychology. It is important to recognize, however, that related concepts exist in different disciplines. While in summarizing them here it is impossible to do justice to their full complexity, they are included to show how they relate to the conceptualizations employed, and why the current approach was favoured.

Wilson et al. (2014) conducted a review of user perceptions of smart homes, identifying three main narratives which Hargreaves et al. (2015) subsequently applied to the context of control in smart homes. These are introduced here because it is informative to consider how they map onto the motivations for control presented above. Briefly, the three narratives are as follows:

- *Functional.* Focus on which appliances can actually be controlled.
- *Instrumental.* Focus on interaction between user and technology, with control as a means to some broader end (such as optimizing energy management, (Hargreaves et al., 2015)), usability of interfaces.
- *Sociotechnical.* Focus on smart homes as part of a wider sociotechnical system, '*less on control in and of itself but rather in its impacts on e.g. domestic life and broader sociotechnical trajectories*' (Hargreaves et al., 2015: 1022).

What is clear is that most of the motivations for control identified here align with the 'wider' sociotechnical narrative; the functional and instrumental narratives are more relevant to the discussion of agents/means/ends of control. In a similar way, some of the conceptualizations of control presented in this section find parallels in other fields of the social sciences. The term 'agency' can be used in relation to Skinner's (1996) framework, with 'agency beliefs' being defined as '*Beliefs about the extent to which an agent possesses or has access to potential means*' (Skinner et al., 1988: 371). However, as a central theme in sociology, the term agency has been defined more broadly. At its core it has to do with capacity to act (Barker, 2008), and such capacity may be viewed as constrained or structured to some extent by other factors, and as such has distinct similarities to the idea of autonomy. However, the concept of 'structure' as patterning individual agency has been the subject of enduring and far-ranging debate within sociology, and takes in such diverse

considerations as the role of: '*… class that structures politics, gender that structures employment opportunities, rhetorical conventions that structure texts or utterances, or modes of production that structure social formations*' (Sewell, 1992: 2). The focus of the current work, however, is specifically on people's own perceptions of the control available to them (especially on the introduction of external actors) and how they interpret this, putting more thoroughgoing sociological exploration beyond the scope of study here.

One of the important bodies of theory applied in the context of social studies of energy use centres around the concept of social practices. A practice is summarized by Reckwitz (2002: 249) as:

> *… a routinized type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge.*

Simply put, the way practices are performed can depend on the skills, meanings and material things (e.g. electrical appliances) available to people (Shove et al., 2012). Changes in each of these components may afford or constrain opportunities to act in certain ways, and as such have a clear relationship to the ideas of control explored in previous sub-sections. However, while it does allow for investigation of why people may feel enabled or constrained in the context of energy-related practices, social practice theory does not explicitly set out to provide a framework in which these specific ideas of control can be organized – as is the case for the Skinner (1996) framework employed here.

Finally, the above discussion has not focused on more cognitive interpretations of control. As described by Jackson (2005), people's mental processes themselves have been viewed as having 'automatic' or 'controlled' characteristics, where automatic processes occur without necessarily any explicit intention, control, effort and awareness. Current thinking does not view these processes as discrete, but on a continuum with controlled processes potentially becoming more automatic, and with the use of heuristics (or rules of thumb) to minimize the need for full deliberation (Tversky & Kahneman, 1974). Highly routinized behaviour, or habits, may be viewed as strongly automated and therefore potentially as permitting little conscious control. Consideration of the level of conscious thought given to carrying out certain behaviours (and their potential energy-use implications) is important in understanding how such behaviours may change or be changed. However, except

insofar as people recognize the role of this in affecting their own behaviour, and therefore impacting on their perceived control, this aspect of their cognitive processes fall beyond the scope of the current work.

## 2.3 Control and acceptability of DSR

The focus of the previous section was on control in and of itself. This focus, and the thesis itself, is justified by the important role perceived control has previously been shown to play in the uptake of innovations. While conceptions of control differ from discipline to discipline and between different theories, innovations which preserve or confer some sense of control have consistently been shown to engender acceptance. This section discusses the meaning of 'acceptance' and 'acceptability', presents evidence of the link with control and considers a range of theoretical approaches which can be used to understand it.

### 2.3.1 'Consumers', 'acceptance' and 'acceptability'

So far, this thesis has used the terms 'consumer', 'acceptance' and 'acceptability' in relation to energy and DSR without precise definition. However, it is important to critically discuss these terms to ensure that they are being used correctly and that they are consistent with the wider theoretical grounding of the work. A 'consumer' is defined by Merriam-Webster (2015b) as '*a person who buys goods and services*'. In the context of electricity, this is in-keeping with the established view of energy system, where centralized generators provide electricity for sale to end-users (Hornsby, 2010) – the end-user buys the electricity and is therefore a consumer and, as far as the generator or supplier is concerned, a customer. A system operator is responsible for ensuring the stability of the grid by turning generators off and on to match demand instantaneously. The consumer has no active role in ensuring this stability and is therefore positioned as the passive recipient of a service. However, electricity system developments have started to see a blurring of the role of end-user and generator, and service provider and recipient. Increasingly, UK households or communities are turning into generators through the use of photovoltaic panels or wind turbines (DECC, 2014a). And by participating in DSR programmes, householders can provide services to the grid by choosing to change their consumption patterns. This more active role sometimes sees householders labelled as 'prosumers' or 'pro-savers' (Martiskainen & Nolden, 2015), or more broadly as 'energy citizens' (Goulden et al., 2014).

This section has so far made much use of the word ‘acceptance’, which is defined by OED Online (2013) as, ‘*The action or fact of willingly receiving something offered or given, assenting to a proposal or a state of affairs, or of agreeing to undertake a task or take up a role.*’ The term is directional in that it suggests that there is an ‘offering entity’ and an ‘accepting entity’. In this way it is consistent with the idea of a ‘consumer’, but less so with the idea of an active ‘prosumer’ or energy citizen. In section 2.1.2 above it was claimed that, broadly speaking, ‘the effectiveness of a DSR programme depends on the size of the participating load and the level of influence the DSR operator has over that load’. The size of the available load is a function of the number of participating customers and the power demand of each of those customers. In the industrial sector, a relatively small number of customers each account for a large power demand (e.g. 27 MW peak consumption for a small steel works (Ashok, 2006)). In the domestic sector, on the other hand, average annual electricity consumption per household is comparatively low at just 4192 kWh in 2013 (DECC, 2014b), which equates to an average power demand per household of 0.48 kW. While acknowledging that electricity use can vary substantially from household to household (depending on factors such as heating fuel), the ramification of this is that the only way to bring a large amount of load under the influence of a DSR programme is for many customers to choose to participate in that programme.

Participation could be viewed over two timescales. Usually a one-off decision will be required as to whether or not to be a recipient of DSR signals – for example switching to a TOU tariff. It can be assumed that those who do not receive DSR signals cannot possibly respond to them. Of those who choose to receive signals, there is then the ongoing question of whether and to what extent they respond to those signals. This may also be viewed as a form of participation. This distinction is an important one in that this thesis specifically focuses (as spelled out in section 2.1.2) on the first kind – that is, the choice of whether or not to participate in a DSR programme. However, this view of participation can also be sub-divided. It depends on how the DSR offering is perceived. In one sense the signal recipient may be seen as offering a service for sale – e.g. a reduction in energy use. This is how capacity auctions in the new UK capacity market function. In another sense the signal recipient may be positioned as buying a particular product (e.g. electricity on a TOU tariff). This study focuses on the household level. As has previously been established, individual household contributions to DSR will only ever be very small. While it is certainly plausible that in future individual households will be able to sell

their own DSR services directly to the grid, or to have a similar relationship with aggregators, at the moment and in the short- to medium-term the decision confronting householders is likely to be whether to sign up to a DSR product (such as TOU or DLC tariff) as offered by some other entity. In this case, there is indeed an offering entity (e.g. a supplier) and a receiving entity (e.g. the supplier's customer). This is consistent with the definition of acceptance given above. It logically follows from this that the nomenclature of the acceptor of the DSR product is a consumer. So while this thesis recognizes the loaded connotations of these terms, it argues that using the terms 'consumer' and 'acceptance' in this context is appropriate.

Having argued that the concept of 'acceptance' is appropriate to describe the interest of this research, it is important to draw another distinction between the concepts of 'acceptance' and 'acceptability'. Schade & Schlag (2003: 47) argue that there is a '*lack of conceptual clarity'* in relation to acceptance/acceptability (in their case in relation to road pricing). They suggest that acceptability refers to *'the prospective judgment of measures to be introduced in the future'* (p47), while acceptance *'defines respondents' attitudes including their behavioral reactions after the introduction of a measure'* (p47). This thesis concerns itself with both areas – expectations regarding prospective DSR offerings, and experiences of existing ones. The results will most often be referred to in terms of acceptability since they usually concern DSR offerings which are not yet available to the market, and which therefore cannot be directly experienced. The appropriate term will be used in each case.

### 2.3.2 Understanding acceptance/acceptability

Before discussing further the processes that may lead to acceptance or acceptability, it is also important to be clear on the different levels at which they operate. Wüstenhagen et al. (2007) propose three potentially interconnected levels of acceptance, as shown in Figure 2-3; socio-political, community and market acceptance.


**Figure 2-3: The triangle of social acceptance of renewable energy innovation. Reproduced from (Wüstenhagen et al., 2007)**

Socio-political acceptance is the most general category, describing the acceptance of something (e.g. a technology, issue, etc.) at societal level, relating to general issues rather than specific instances. Community acceptance focuses on the level of acceptance of something within a community, and is less relevant in the case of DSR (as presented in this thesis) than in the context of renewable energy considered by Wüstenhagen et al. (2007), where the role of community is often central. Finally, market acceptance describes whether or not consumers actually decide to adopt and use a product or service. Although not specifically discussed by Wüstenhagen et al. (2007), it is reasonable to think that acceptability can be considered in the same terms (but prospectively rather than on the basis of experience).

The way in which acceptance is construed has important consequences for how it may be assessed. At the socio-political level acceptance is more likely to be concerned with a measure of the unit of study's (e.g. individual or group of individuals) *attitude* towards something (e.g. a technology) – either prospectively (acceptability) or based on experience (acceptance) – although it may encompass behaviour in civil forums (e.g. campaigning, demonstrating). Attitudes are broadly defined as an individual's positive or negative evaluation of some entity:

- '*a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor*' (Eagly & Chaiken, 2007: 598).

- ‘*”attitude” should be measured by a procedure which locates the subject on a bipolar affective or evaluative dimension vis-à-vis a given object*’ (Fishbein & Ajzen, 1975: 11).

Market acceptance may be judged at the market level, for example by measuring the proportion of the intended market for a product or service is using that product or service. At the individual level, it may simply be determined by whether or not an individual is using that product or service. Purchase or use may be viewed as a behaviour, or ‘*observable acts*’ (Fishbein & Ajzen, 1975): 13. In the case of market acceptability, where a product or service is not yet available on the market, acceptability may be judged be somehow assessing individuals’ intention to buy or use that product or service if it were available. Such behavioural intention may be viewed as a probability or likelihood of an individual carrying out a given behaviour (Fishbein & Ajzen, 1975).

The unit of interest (e.g. an individual or the whole of society) is important in determining the most appropriate theoretical basis on which to approach any given process of enquiry into market acceptance. At the societal level, the dominant theory in this area is *Diffusion of Innovations* (Rogers, 1962). An innovation is ‘*an idea, practice, or object that is perceived as new by an individual or other unit of adoption*’ (Rogers, 2003: 12). The theory concerns the way in which an innovation spreads and is taken up within a population. At its heart are four main elements: the innovation; how it is communicated (through certain channels); over a period of time; through a social system (Rogers, 2003).

Understanding the diffusion of an innovation over time requires consideration of the attributes of the adopters and of the diffusion network through which diffusion takes place, as well as the attributes of the innovation itself. While communication about an innovation will very likely be affected by people’s perceptions of control when they are using it, such perceptions are shaped (and are principally of interest) when considering the individual experience of the innovation. Rogers (2003) describes five main attributes of innovations that together have been found to account for about half of variance in rates of adoption: relative advantage; compatibility; complexity; trialability; observability. One way of understanding these attributes is to carry out acceptability research, defined by (Rogers, 2003: 253) as follows:

> *Acceptability research is defined as investigation of the perceived attributes of an ideal innovation in order to guide R&D so as to create such an innovation. If*

*innovations of type X will not be accepted, obviously R&D workers should direct their efforts toward developing type Y innovations.*

As one of the aims of this study is to understand the acceptability of different approaches to DSR so that they might be developed and communicated appropriately, it is therefore necessary to consider what might affect such acceptability and how it might be measured.

As established above, acceptability is a reflection of people's attitudes or intentions towards an innovation that stops short of action – in the case of acceptability research, usually since such action is not yet possible as the innovation is not yet commercially available. A wide range of theories and models have been developed to attempt to explain what factors affect people's attitudes or intentions to act in a particular way (e.g. see review by Jackson (2005)). The following discussion will deal with those theories that either explicitly or implicitly link control to some expression of acceptability or acceptance, or have previously been modified to do so.

### 2.3.3 Theories and models of behaviour including control

Objective control conditions are included in Triandis' *Theory of Interpersonal Behaviour* (Triandis, 1977) where the concept of 'facilitating conditions' may be understood to mean whether an action or event is within someone's control (see Figure 2-4).

**This third party material is available to view at http://www.sustainablelifestyles.ac.uk/sites/default/files/motivating_sc_final.pdf (see p94).**

**Figure 2-4: Diagram of Triandis' Theory of Interpersonal Behaviour (Triandis 1977), reproduced from Jackson (2005).**

Here, facilitating conditions come into play after an individual has formed an intention and determine whether or not that intention can be translated into action. For example, someone may want to switch onto a DSR tariff which involves direct load control, but because of the layout of their building there may not be sufficiently good reception of control signals for them to be able to participate in the programme. Objectively speaking, it would not be within their control to participate. A similar situation may be envisaged in the case of Stern's *Attitude-Behaviour-Context* model (Stern, 2000), where 'context' may equally include factors that are within or outside the control of an individual and affect whether or not action can be taken. For the purposes of this research, the focus is on how perceptions of control are associated with acceptability, rather than objective assessment of individuals' ability to accept (participate in) DSR.

The *Theory of Planned Behaviour* suggests that intention to act results from people's attitudes, norms and perceived behavioural control (Ajzen, 1991). Here, perceived behavioural control is conceptualized as composing both people's perceived self-efficacy (Bandura, 1991) as well as the perceived controllability, or '*beliefs about the extent to which performing the behavior is up to the actor*' (Ajzen, 2002). However, the perceived behavioural control construct refers to people's assessment of their ability to perform actions or achieve goals, rather than their expectations of how much control they would subsequently have if they took an action (e.g. signing up to a DSR tariff). For this reason it would be inappropriate to apply it in the context of this study.

Perceived control has featured quite prominently in the study of user satisfaction with buildings. For example, it has been shown that people who perceive themselves to have control over their environment are more accepting than those who do not, even if employing the available control does not entirely alleviate discomfort (Leaman & Bordass, 2007). In a review of such work, Hellwig (2015) develops a model which includes perceived control as a key determinant of user satisfaction with indoor environment (which may be viewed as a requirement for acceptance). Perceived control forms part of an evaluation system, where people evaluate their state in response to an external stimulus and decide if a response is necessary, and if so, what the response should be and the extent to which it is available to them. However, because it has been developed specifically for use in the indoor environment satisfaction context, it is more concerned with an ongoing sense of satisfaction than with how expectations of control might lead to a decision such as whether or not to participate in a DSR programme.

Because none of the dominant theories of behaviour change explicitly include perceived control as an input factor affecting people's attitude towards and intention to use innovations, researchers working in this area have looked to models that can usefully be adapted to include it. As well as having been shown to be a concern in relation to DSR (see previous section), perceived control has been shown to be statistically significantly associated with acceptance of a number of products and services, such as smart meters (Kranz, 2011), smart appliances (Stragier et al., 2010) and radio-frequency identification (Spiekermann, 2008). To explore the role of perceived control, these studies employed versions of the *Technology Acceptance Model* (TAM) (Davis, 1989) (see Figure 2-5).

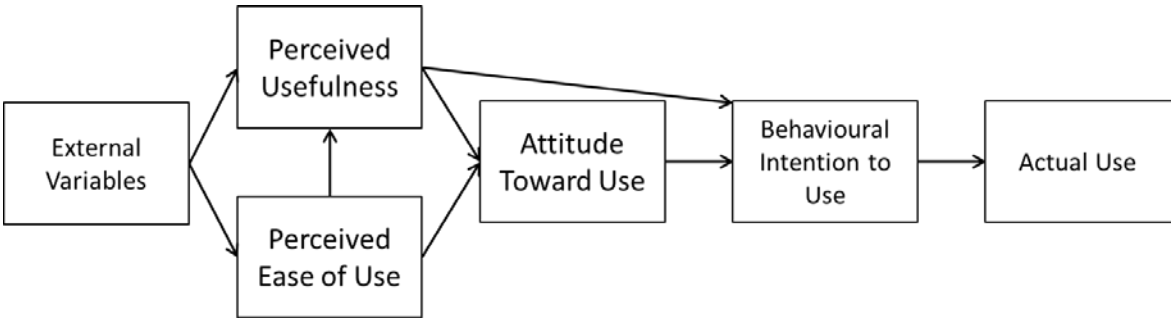



**Figure 2-5: Diagram of the Technology Acceptance Model (based on Davis 1989).**

The TAM has been widely employed to study the uptake of new products and services, as suggested by the almost 25,000 citations the original publication (Davis, 1989) has received on Google Scholar at time of writing (and 5500+ on Web of Science). Examples of subjects of study include: electronic healthcare records (Ortega Egea & Román González, 2011); internet banking (Lee, 2009); e-commerce (Pavlou, 2003); and telemedicine technology (Hu et al., 1999). It applies the *Theory of Reasoned Action* (Ajzen & Fishbein, 1980), which states that people's subjective norm and attitude determines behavioural intention and behaviour. The TAM is more parsimonious, relying on two variables (perceived usefulness [PU] and perceived ease of use [PEOU]) to predict people's attitude towards use, behavioural intention to use and actual use of technology and services. The model is often further simplified so that perceived usefulness and ease of use are related directly to the principal outcome variable of interest (i.e. intention to use or actual use) without the inclusion of the attitude construct (e.g. Burton-Jones & Hubona, 2006; Venkatesh et al., 2003; Adams et al., 1992). Meta-analysis has shown the principal TAM constructs (PU, PEOU and behavioural intention) to be reliable and adaptable to an array of different contexts (King & He, 2006). Originally developed for

organizational settings, the definitions for PU and PEOU used by (Davis, 1989) were as follows (p320):

- Perceived usefulness: *'the degree to which a person believes that using a particular system would enhance his or her job performance.'*
- Perceived ease of use: *'the degree to which a person believes that using a particular system would be free of effort.'*

As the subjects of the previously cited studies suggest (e.g. internet banking, e-commerce), it has commonly been taken out of the workplace and applied to the domestic environment. Subsequent to its original development, the TAM has been extended many times in an attempt to explain more variance in behaviour and capture a wider array of factors which may affect it. These include social influence (Venkatesh et al. 2003), trust and risk in e-commerce (Pavlou 2003) and perceived control in the examples of Kranz (2011) and Spiekermann (2008) above, all of which were shown to increase explanatory power of the model. These final two studies require some elaboration due to their relevance to the current research.

Kranz (2011) describes a study of consumer acceptance of smart metering technology which took place in Germany. It was based on extending the TAM with a construct referred to as 'subjective control' and operationalizing this in an online survey. 351 people were invited to participate, with a response rate of 60%. Subjective control was found to be the second strongest predictor of intention to use smart meters, after perceived usefulness. While this confirms the important role of subjective control in acceptance in this case, it is difficult to generalize the finding to either the case of DSR or to a wider population. The former is because DSR should be expected to involve different control concerns to smart meters (i.e. those suggested in section 2.2.2 above, as compared to smart meters where concerns are more allied to use of data). The latter is because the survey was not administered to a representative sample of the population, but rather emailed to participants (details of selection are not provided) and a link posted on a website.

Spiekermann (2008) conducted a study into the use of radio frequency identification (RFID) tagging in retail environments. Again, the TAM was extended to include perceived control, this time expressed in terms of control over information and in respect of general helplessness. 234 participants were shown one of two videos about an RFID system, presenting different (i.e. automated or manual) options about how personal information on an RFID chip could be accessed by other

devices. The helplessness measure of perceived control was a significant variable in intention to use the chip for both access options, while the information control variable was significant for the manual option. While, again, the sample size is small and non-representative, this finding lends support to the extra explanatory power than including perceived control can bring to the TAM.

Despite its wide usage, TAM has also been subject to critique. Bagozzi (2007) objects on one hand to the simplicity of TAM, disregarding as it does the role of group/social/cultural aspects of acceptance, emotion, and self-regulation. On the other hand, he criticizes the '*patchwork … unintegrated*' (p252) way in which it has been extended, often (he claims) without solid theoretical underpinning for the extensions. Like Bagozzi, Turner et al. (2010) critique the effectiveness with which TAM predicts actual usage (measured objectively), compared to subjective measures of usage or behavioural intention. They conducted a meta-analysis of TAM studies which revealed that PU and PEOU were much better predictors of intention that they were of subjective usage (although not enough studies gave sufficient data on these associations to show statistical significance), which in turn was better predicted than objective measures of actual usage. In particular, the predictive role of PEOU was shown to be low, a finding supported by Liu (2009). These critiques are certainly valid if the aim of applying TAM is to understand as much variance as possible in acceptance and to explain the theoretical underpinning of that variance. However, the focus of many studies (and of the present one) is primarily to understand the role of a particular variable – in this case perceived control. By including an extra variable or variables in TAM, its/their role can be explored while controlling for what have been shown to be two important determinants of acceptance – PU and PEOU.

Another reason to question the use of TAM in this study is the focus on 'technology' and 'acceptance'. The subject of this study – DSR – is not a technology, and as established above, much of the focus is on acceptability rather than acceptance. On the first point, while DSR products and services are not in themselves technology, it makes sense to consider them in the context of technology since it is electricity-using technology which directly gives rise to electricity use in the first place. Since any demand response will ultimately involve a change in the way in which electricity-using technology is operates, DSR offerings cannot exist without technology. DSR products and services attempt to modify the way in which people use such technology, and can do so in ways which will be more or less useful to the user, and more or less easy to use or understand. Where automation or direct

control DSR signals are employed, the actual function of technology in people's homes is indeed modified. For this reason it is argued to be reasonable to use TAM as a basis to explore acceptability of DSR products and services. Regarding acceptance/acceptability, it has already been established that TAM takes into account expectations (in the form of attitudes and behavioural intention) and experience (in the form of actual usage). There is precedent for employing TAM to guide investigation of acceptability when actual use cannot be measured (Kranz, 2011; Lai et al., 2005; Hu et al., 1999).

More broadly, use of the TAM may also be challenged on the basis that it promulgates a technocentric view of solutions to challenges related to energy use. Technocentrism can be defined as '*The tendency to focus on technological artefacts or mechanisms to the exclusion of social, cultural or historical perspectives*' (IGI Global, 2016). Because of this exclusion of wider factors, approaches which are perceived to be technocentric may be viewed as '*a way of providing problems with neat "solutions", whether effective or not*' (Moezzi & Bartiaux, 2007: 149). While the TAM clearly integrates social factors in the form of perceived usefulness and ease of use, and attitude, these are only a tiny proportion of the wide variety of influences likely to affect an individual's decision as to whether or not they use a technology or service.

Approaches which focus on the potential of technology to solve energy challenges have been widely criticized, particularly in the sociology literature. The criticism is perhaps best personified in Strengers' 'Resource Man', '*an efficient and well-informed micro-resource manager who exercises control and choice over his consumption and energy options.*' (Strengers, 2013: 35). This idealized smart energy consumer is largely untroubled by the existence of household dynamics and routines, and responds rationally to information and incentives. Because, as Strengers argues, such factors have been shown to play a vitally important role in the ultimate use (and consequent energy use) of such technologies, such a reductive view is potentially problematic. It is possible that the use of models such as the TAM contribute to perpetuating such a view. However, it is important to stress that the focus in the use of TAM in this research is on the acceptance or acceptability of a range of DSR tariffs, rather than the multiplicity of choices (conscious and unconscious) which determine people's patterns of energy use. It is also used in such a way as to facilitate deeper consideration of the principal factor of interest – perceived control – which as previous discussion has suggested, may indeed capture a wide range of considerations such as comfort and routines.

## 2.4 Summary and research questions

This chapter began by outlining the challenges faced by the UK's energy system and the ways in which DSR could help make it cleaner, more affordable and more secure in future. Different approaches to DSR use different signals (price, volume or direct control), and these signal can elicit different responses which are suitable for different services. To be effective, DSR programmes must have sufficient influence over sufficient electrical load. However, there are concerns that this influence might lead to loss of individual control for consumers, lowering the acceptability of DSR (and hence the participating load). The concept of control was therefore examined through an analysis of 20 relevant studies, according to a framework proposed by Skinner (1996). It identified motivations for control in relation to DSR; its antecedents; agent-means and means-ends relations; and other issues related to control. The final section considered how control has previously been linked to acceptability/acceptance, and identified the Technology Acceptance Model (Davis, 1989) as a suitable framework from which to base investigation of perceived control and acceptability of DSR.

In order to fulfil the aims of this research and to address the gaps raised by the preceding literature review, this study sets out to answer the following research questions:

1. How do domestic energy bill-payers in Britain interpret 'control' in the context of home energy use and demand-side response?
2. How do control expectations in the context of energy use differ with different approaches to DSR, and how does this relate to acceptability/acceptance?
3. How do non-control factors (such as socio-demographics and non-control attitudes) relate to perceived control and acceptability/acceptance of DSR?
4. How do experiences of control in DSR compare to expectations?

The next section presents a methodological discussion of how these questions may be addressed.

# 3 Research methodology

This chapter first defines the research population of interest in the study. The rationale for a mixed methods study is then set out, followed by a discussion and determination of specific research methods that were employed to address the research questions.

## 3.1 Research population

Geographically, the focus of this research is on Great Britain (i.e. England, Scotland and Wales). Other available options would have been to consider a larger region (such as Europe), or a smaller one (such as just England, or a region or city). To justify the choice of scale it is necessary to briefly consider how electricity networks are organized. The traditional centralized model (dominant in Britain since the 1930s (Hornsby, 2010)) is shown in Figure 3-1.


**Figure 3-1: Diagram of a centralized electricity system (reproduced from Institute for Energy Research[10]).**

Electricity from a large central electricity generator (e.g. nuclear power plant or wind farm) is carried across the country by a high voltage transmission network, before being stepped down to a lower voltage distribution network for delivery to the end users. Most (over 96%) of the electricity used in Britain is generated in Britain (DECC, 2014a: 115). The remainder is supplied via international interconnectors (see Figure 3-2).

[10] Available at http://instituteforenergyresearch.org/electricity-transmission/ (accessed 14 September 2015).

**This third party material is available to view at http://www.offshorewind.biz/2015/06/29/uk-govt-includes-interconnectors-in-capacity-market-auction/**

**Figure 3-2: Existing and proposed electricity interconnectors with the UK (reproduced from offshorewind.biz[11]).**

The small proportion supplied via interconnectors is a result of the way the system has evolved over time, constrained by the high cost of international interconnection (e.g. 'around €2bn' for the UK-Norway interconnector (National Grid, 2015b)). Great Britain is the unit at which the electricity network has been regulated in recent decades (currently by Ofgem) and settled/balanced (currently by Elexon) – and therefore the level at which any policy affecting DSR (which this research hopes to inform) would be applicable. Because of the relatively small international connectivity, many of the aims of DSR (such as congestion management and balancing, as set out in section 2.1.1) can only be achieved for Britain if the response itself occurs there (as opposed to internationally). It is also worth highlighting that there is a lot of diversity in fuel and generation mix (and subsequently end-use technology) between countries, even in Europe. For example, Britain is currently highly reliant on gas for heating (DECC, 2015b) (in part due to the local abundance of coal and then natural gas), while in Norway electric heating is prevalent due to the much higher proportion of hydroelectric generation there (Statistics Norway, 2014). In many warmer parts of the world than Britain, the dominant electric load is air-conditioning; such different systems would have different DSR priorities, which might be best achieved in different ways.

[11] Available at http://www.offshorewind.biz/2015/06/29/uk-govt-includes-interconnectors-in-capacity-market-auction/ (accessed 14 September 2015).

Since privatization in the 1990s the various sectors of the electricity system have been less vertically integrated, with different companies (or at least different legal entities) taking responsibility for generation, transmission, distribution and retail. Most direct domestic customer contact is with the electricity retailer, and the vast majority of retail offerings are available throughout (but not beyond) Great Britain. Since one of the stated aims of this research is to inform the design and communication of DSR products, and this is currently the remit of the retailers, then it follows that findings should aim for applicability at the spatial level at which these products would be offered – in this case, of Great Britain.

Having justified the spatial definition of the research population, it is necessary to consider the characteristics of that population and the unit of enquiry. It is important to reemphasize here that the interest of the research is in the acceptability of DSR as broadly indicated by (real or hypothetical) willingness to sign up to DSR programmes. It is not to assess characteristics of the response to DSR signals – although of course people's evaluation of their ability to respond may well inform their initial willingness to participate. It is clear from previous research findings (drawing, for example, on social practice theory) that household energy use is not simply a function of the isolated actions of individuals, but on interdependencies between household members, household and societal rhythms, available technologies and the skills and know-how required to use them, and many other factors (see, for example, Strengers (2010) in relation to DSR). However, the ultimate decision as to which energy tariff to be on has to be taken and acted upon by a bill-payer (either solely or jointly). This person might be expected (to a greater or lesser extent) to take some account of the various factors just suggested to affect energy use – but the act of signing up to a tariff finally comes down to them. For this reason, this study takes as its unit of enquiry individual (sole or joint) energy bill-payers. As such, the research population can be defined as all energy bill-payers in Great Britain.

## 3.2 Research strategy

'Research strategy' is the term used by Bryman (2012: 715) to describe *'a general orientation to the conduct of social research'*, particularly with respect to the use of qualitative or quantitative approaches. To show how the research strategy for this study was determined, this section will consider the characteristics of the answers required by the research questions first set out in section 2.4, and discuss research approaches that are required to furnish appropriate responses.

Research question 1 asks: ‘How do domestic energy bill-payers in Britain interpret “control” in the context of home energy use and demand-side response?’ As noted by Hargreaves et al. (2015: 1022), while control is often a ‘side-issue’ in research in the area of home energy use and automation, it is rarely the primary focus of research. For that reason, while there are many attempts to understand the role played by perception of control in satisfaction and technology acceptance (e.g. see Hellwig (2015)), no systematic attempt has been made to understand what people (in this case energy bill-payers) understand by the term. As such, an inductive approach is required, which identifies data and aggregates them into taxonomies and structures (LeCompte & Schensul, 2010: 18). While the review conducted in section 2.2.2 attempted to identify different motivations, antecedents and understandings of control, the approach taken here is not primarily to test these findings but to generate new data with ‘control’ as the focus of study and then compare these new findings to those of the review. This new data must necessarily be descriptive in nature. The characteristics determined as necessary to answer the question are most consistent with a qualitative approach to research.

Research questions 2, 3, and to an extent 4, focus more on exploring associations (if any), for example between control expectations and acceptability of DSR. As set out in section 2.3, there are theoretical grounds to expect such a link, and the Technology Acceptance Model has been determined as a suitable frame in which to investigate this. Research question 3 calls for similar links to be tested. In this context theory allows predictions (or hypotheses) to be made about possible links between expectations of control (and other factors) and acceptability. As such a deductive approach is required, which begins with general statements (or theory) and, through a process of logical reasoning, comes to a conclusion (Walliman, 2006). The question is put in the context of the research population defined above. As such whatever findings are generated must be to some extent generalizable to this population. The characteristics of deduction and generalizability are primarily consistent with a quantitative approach to research.

The requirement for both qualitative and quantitative approaches in a single programme of study means that, by most definitions, a mixed methods approach is called for (Creswell & Clark, 2011). Such approaches have been criticized for attempting to reconcile incompatible (or ‘incommensurable’) ontological stances (e.g. Sale et al., 2002). For example, the requirement for generalizability reveals an important ontological assumption – that is, that ‘social objects’ exist in reality and could theoretically be known. This is consistent with a positivist, empiricist

epistemology. Conversely, many social researchers hold that we cannot 'find out' knowledge about social objects as separate from us – rather, all knowledge is constructed (or created) by people, including in the process of research. This has led to what some see as fundamental incompatibilities between quantitative and qualitative approaches to research.

According to Hall (2013), researchers have addressed this incompatibility in a number of ways. Firstly these paradigmatic differences can be ignored. Secondly, different paradigms or world views can be held simultaneously and applied to different aspects of the research. Thirdly, researchers can attempt to unify their approach in a single paradigm which is compatible with the various approaches to research that they employ. Two paradigms which explicitly attempt this reconciliation are pragmatism and realism. Pragmatism holds that a proposition can be considered true if it is perceived to 'work' in reality – it *'sidesteps the contentious issues of truth and reality, accepts, philosophically, that there are singular and multiple realities that are open to empirical inquiry'* (Feilzer, 2010: 8). Realism, on the other hand, posits a single knowable reality, but which can be interpreted in multiple ways (Krauss, 2005).

This research is broadly pragmatic in approach in that it starts from the belief that eliciting people's views regarding control and the acceptability of different approaches to DSR can provide useful insights for designing and communicating more acceptable DSR offerings. However, working towards this end, it accepts certain tenets of a realist paradigm. For example, as will become clear through the remainder of this and in subsequent chapters, concepts such as 'perceived control' are treated as if they have some independent existence. Such constructs are treated as latent variables which 'cause' people's responses to, for example, Likert-type items which are used to measure them. Borsboom et al. (2003) have argued that such a treatment implicitly requires a realist approach, although they acknowledge the tension that exists between this and the empirical tradition in disciplines such as psychology (p217):

> *… we would probably like latent variables models to yield conclusions of a causal nature (the model should at the very least allow for the formulation of such relations). But we cannot defend any sort of causal structure invoking latent variables if we are not realists about these latent variables, in the sense that they exist independent of our measurements: One cannot claim that A causes B, and at the same time maintain that A is constructed out of B.*

While realism and pragmatism have themselves often been viewed as incommensurable (Slater, 2008), arguments have been put in support of the usefulness of a 'realist pragmatism' (Lipscomb, 2011; Slater, 2008). Issues connected to the mixed-methods approach taken are discussed further in chapter 7 in light of the findings.

## 3.3 Research methods

The research presented in this thesis was conducted using a mixed methods strategy over three stages. The initial phase employed focus groups to explore how people understand control in the context of energy use. The next phase used a survey experiment to test associations between control (and other variables) and acceptability of different approaches to DSR. Finally, a combination of interviews and surveys in a case study context were used to compare people's experiences of DSR to their expectations. This section justifies these methodological choices and compares them to other plausible options. Detailed explanation of how the research was actually conducted according to these methods, along with discussion of any ethical considerations, is reserved for the relevant chapters.

### 3.3.1 Phase 1: Exploring control

Focus groups were the method of choice to generate a range of understandings of control in the context of home energy use and DSR. Focus groups are a type of group interview which Krueger & Casey (2000: 4) describe as permitting the researcher '*to understand how people feel or think about an issue, product, or service*'. They have previously been used to explore people's views on DSR (e.g. Darby & Pisica, 2013; Rodden et al., 2013; Downing & iCaro Consulting, 2009; Mert, 2008) and sense of agency in relation to energy use (Fell & Chiu, 2014). The other principal options considered for this stage of the research were semi-structured individual/household interviews (e.g. as used to research DSR and smart energy by Hargreaves et al. (2015), Carmichael et al. (2014) and Murtagh et al. (2014), deliberative workshops (as used by Butler et al. (2013)) and online discussions (as used by Sheldon (2013)).

Focus groups were selected over individual or household interviews for a number of reasons. One of the established challenges of conducting any kind of interview is that they are usually arranged and run on the researcher's terms. It is usually the researcher who sets the subject and agenda for the discussion, and the participants who respond to this. While not always the case, this can lead to a power imbalance

between researcher and participant, affecting the type of information which the participant chooses to share (Skinner, 2014: 144). By increasing the number of participants, focus groups have been claimed to reduce this power imbalance, giving participants more ability to influence the course and content of the discussion (Wilkinson, 1999). While this can make the discussion more difficult to manage, it can also lead to more frank discussion where participants are happier to share their views – even if they think the researcher may disagree with them (Wilkinson, 1999). This minimizes the risk that participants are only giving answers they think the researcher wants to hear.

Focus groups have the additional advantage of allowing participants to reflect on and discuss others' views – potentially changing their minds and adding nuance to their own positions (Bryman & Bell, 2015: 514). When well-managed, more 'interactional' discussions can emerge from focus groups, compared to individual interviews which (depending on the participant and interviewer) may end up more stilted (Wilkinson, 1998). This is a concern if one of the aims of the research is to investigate the language people use to express their views and understandings (in this case in relation to control). It is also possible that focus groups allow a better forum for people to discuss subjects on which they may not have ready-formed views, such as home energy use. In many cases participants may not have thought much about energy, and certainly not about DSR. Focus groups allow participants time to reflect and listen to the views of others when they are not talking, which would not be available in the case of individual interviews. Finally, focus groups have the advantage of efficiency, in that they allow a number of people's inputs to be collected in the same time that it would take to conduct a single individual interview.

Focus groups also have several disadvantages compared to individual or household interviews. The benefits that come from harnessing the group dynamic to promote confidence and discussion can also lead to problems. Participants who are unconfident may feel less inclined to share their view in the 'public' forum of a group than in a private interview with the researcher, although this is context specific and focus groups are sometimes viewed as more appropriate for this kind of exchange (Farquhar & Das, 1999). Alternatively, participants may feel inhibited from sharing less socially acceptable points of view, or expressing only those views which they think will be acceptable to the group (Morgan, 1993: 77). Groups can be dominated by talkative individuals, leading to quieter participants being less able to make their views heard (Krueger & Casey, 2000). The gains in time efficiency also mean that

less detail can be collected from each individual participant, potentially decreasing the richness of the data which is collected. Finally, while focus groups take less time to run per participant than individual interviews, they can be more time-consuming to organize since they involve coordination of many participants rather than just one or two. Some of the problems highlighted can be mitigated to an extent by careful moderation – for example in how the ground rules of the group are explained, how the moderator prompts participation and even the surroundings and seating arrangements. While others are inherent to the method, it was considered that the advantages of prompting more realistic and frank discussion outweighed the disadvantages.

Two variants on standard focus groups were considered – online focus groups (as used by Sheldon (2013)) and deliberative workshops, as employed (for example) by Balta-Ozkan et al. (2013) and Butler et al. (2013). Online focus groups involve convening participants in an online forum or chat room, and proceeding as usual except that contributions are typed rather than spoken. Hennink (2013: 10-11) summarizes the advantages and disadvantages of such 'virtual' groups. The advantages are that it can be easier to recruit participants and to arrange the meeting (since participants do not have to be physically present). Potentially, participants can also remain anonymous, which may reduce concerns about discussing sensitive topics. However, the possible downsides are that discussion cannot unfold as reactively and fluently as in person – especially if some participants are not familiar with the online environment or are unable to type quickly. The possibility of anonymity also has ramifications for the credibility of the views expressed. Since the topics covered by this research are not expected to be sensitive, the possible benefits offered by this approach were not considered to be worth the costs.

Deliberative workshops are similar to focus groups in that they involve collecting data through group discussion. However, they tend to be larger in group size, duration and scope. For example, Butler et al. (2013) involved the use of presentations, whole- and sub-group discussions, use of a carbon pathway tool and other scenario discussion, lasting a whole day. This approach has the potential to collect a large amount of rich data and give participants a more active stake in the research. However, it is also resource intensive, requiring much more time both to prepare and run than focus groups, with a requirement for substantial incentive payments for participants and a greater burden on their time. For this reason, such

workshops were considered impractical with the resources available for the current research.

### 3.3.2 Phase 2: Measuring control

While qualitative methods such as focus groups are well suited to understanding participants' attitudes, thoughts and ideas in relation to the subject of research, they are less useful when it comes to investigating how these might be distributed amongst wider research populations. This is mainly due both to the small sample sizes that are usually involved, and the lack of representativeness in the sample of the characteristics of the research population[12]. Generalizability of the results can be enhanced by selecting a method which allows for the inclusion of larger and more representative samples. The most common approach employed, and that which is employed here, is the social survey. In a social survey, multiple participants are asked to provide information on the same variables, usually with the aim of finding associations between variables (Vaus, 2013). For example, they may be asked to respond to a questionnaire consisting of specific questions, the answer to which is often constrained in some way (e.g. through selection from certain options, or a certain length of open text response). Because all participants respond to the same questions (or at least a sub-set of them depending on their response to other questions), the results obtained from different participants are directly comparable. Furthermore, because the results are easily rendered into quantitative data, statistical approaches can be used to explore associations between sets of responses and sets of participants. So long as the sample has been selected in the appropriate way, these can be generalized with a specified degree of confidence to the research population.

The survey approach in itself only refers to the structured method of data collection across participants. What is perhaps more important is the mode of data collection. One drawback of many questionnaire-based surveys as alluded to above, especially in the context of the acceptance on new technology and services, is that participants are being asked to report on their behaviours and behavioural intentions. There is evidence that such reports are not highly predictive of actual behaviours (Kormos & Gifford, 2014). One potentially preferable alternative would therefore be to systematically observe or otherwise measure actual behaviour. In the case of DSR offerings, for example, this could be achieved by tracking the

[12] NB There are circumstances where focus group research can be more generalizable, such as to more specific research populations and where sampling is done in such a way as to approach representativeness.

number of people from an appropriately selected sample who sign up to different tariffs. From this it would be possible to tell the relative popularity of the offerings and also (assuming information was also collected about the participants) whether there were any demographic or other differences associated with acceptance. However, as was made clear in chapter 2, the kinds of DSR offering of interest in this research are not currently available on the market in Great Britain. Offering them for trial purposes in the context of this research would not be possible due to lack of resources. Collaboration in existing trials was a possibility, and this is addressed later in this chapter. Even if it were possible to run a trial of actual product offerings, some form of questionnaire-based survey would still be required to explore perceived control and other factors that may lead to participants deciding whether or not to sign up to any given DSR offering.

Questionnaires may be delivered face to face, on the telephone, in paper format, online, or by some other means. The mode selected for this study was to deliver the survey online. This approach is now commonly employed in social research, due mainly to the ease and relatively low cost with which surveys can be administered to large sample sizes (Tourangeau et al., 2013). There are many previous examples of online surveys being used to investigate acceptance of new energy products, services and scenarios (e.g. Spence et al., 2015; Kranz, 2011; Stragier et al., 2010; Downing & iCaro Consulting, 2009). As well as being quicker and cheaper to deploy, online surveys also yield data which is already in digital form as input directly by the participants themselves, minimizing the probability of coding and other data processing errors. The participation burden is also relatively low – participants can complete the survey when they like (within a specified period), do not have to make appointments and can submit their response with the click of a button. Using online surveys have also been shown to reduce social desirability response bias compared to oral survey methods (Chang & Krosnick, 2010). For many people, the online environment is now more comfortable than, for example, being on the telephone or filling out a form by hand (Tourangeau et al., 2013).

Where criticisms are made of the use of online surveys as compared to other forms of survey, these largely focus on the sampling approaches which accompany them – particular with respect to online panel surveys. A panel consists of individuals who are recruited and retained by research organizations in order to complete surveys. Firstly, a pre-requisite of being eligible to complete an online survey is that the participant has access to the Internet. This has been a greater problem in the past – it is now estimated that 84% of households in Great Britain have access to the

Internet, compared to 57% in 2006 (Office for National Statistics, 2014). However, it should be noted that penetration varies depending on the household make-up. For example, while 96% of households with children have Internet access, just 41% of households with a single adult over the age of 65 do (Office for National Statistics, 2014). While it is possible that people without Internet access at home could still have access elsewhere (such as in the workplace or at a public library), it is likely that Internet access introduces some bias into the sample that is suitable for participation in an online survey.

There are also known to be systematic differences between people who belong to online research panels and the general population. Fulgoni (2014) reports evidence that panel members tend to be heavier Internet users than people who are not survey panel members. This means that the results of such surveys may be more representative of people with relatively high Internet usage compared to the general population. However, these data were collected in 2006, and as the Internet access figures shown above demonstrate, much has changed since then. Response bias may also be an issue, which can occur when the people who respond to a call to participate in a survey differ in important ways from those who do not. However, the polling company YouGov now report higher response rates for online panel surveys than telephone surveys (Eastbury, 2014), suggesting this is now less of a problem for this mode of delivery. Overall, it is considered that online panel surveys can provide a cost effective means of data collection suitable to contribute to answering the research questions posed here. Nevertheless, limitations have been highlighted and the results must be considered in this context.

Having established the online survey as the mode of data collection, it is important to address another aspect of the research questions – that is, the relative control expectations in, and acceptability of, different approaches to DSR. In particular, the interest is in how differences in specific characteristics of DSR offerings (e.g. whether the response is manual or can be automated) affects acceptability. To explore this, an experimental design was required, involving random allocation of participants to different groups which are exposed to conditions which vary in controlled ways (adapted from Vaus & Vaus (2001: 48)). The use of an experimental approach in survey methodology is known as a survey experiment, or *'a study that manipulates some feature of a survey protocol'* (Marsden & Wright, 2010: 860). Survey experiments are usually run by assigning participants into groups and asking each group to complete surveys that differ from each other in controlled ways. This often takes the form of variations in information which is

provided to participants on which they are later asked to base their responses. For example, Walter (2014) tested the acceptability of wind power projects in Switzerland by describing them in different ways to different experimental groups. One of the variations was as follows:

> *Level 1: A citizens' vote showed that a majority of citizens in your municipality opposes the wind energy project.*
>
> *Level 2: A citizens' vote regarding the wind energy project has not been held.*
>
> *Level 3: A citizens' vote showed that a majority of citizens in your municipality supports the wind energy project.*

By comparing the responses of the different groups, so long as they have been appropriately sampled and all other factors are held constant, it is possible to attribute significant differences in results to the change in information provided between groups. It is this ability to allow statements about causation, rather than simply association, that makes the experimental approach powerful. In the current research different experimental groups were exposed to descriptions of tariffs with characteristics of interest to the study that differed in controlled ways. Specifically this included static and dynamic time of use tariffs, with and without the option of automated response, and direct load control. The precise tariff details and the rationale by which they were arrived at are set out in chapter 5. The Australian study by Stenner et al. (2015) described in chapter 2 applied a very similar approach in the context of DSR tariffs, using a 3x6 experimental design which showed participants one DSR tariff from a choice of six at random, with the additional random inclusion of either a bill protection option of provision of an automated device to response to DSR signals.

While survey experiments are increasingly widely employed by researchers, there are also a number of questions over their use. The main challenge is in assessing their external validity, or the extent to which the results would be relevant in a real-world (rather than survey) setting. Barabas & Jerit (2010) compared the effect of giving different information about government announcements in the context of a survey experiment to the effect of actual announcements, as also measured by surveys. They found that the effects observed in the real-world setting, while not fundamentally different, were smaller than those garnered in the survey experiment. In this case they attribute the difference to the level of coverage the announcements received in the media, hypothesizing that exposure in the natural experiment was

not as large as where people where specifically asked to read the information in the survey experiment. In the context of the current research this is considered to be less of an issue since it is not testing knowledge and how this relates to attitudes, but explicitly sets out to measure acceptability based on presented information about a subject which participants are likely unfamiliar.

Gaines et al. (2007) highlight a number of other critiques of the survey experiment method. Firstly, because survey experiments present information and ask participants to respond in a short period of time, the responses received may be based on little reflection and may not endure for very long. For example, a political advertisement worded in one way rather than another may prompt a survey participant to say they would vote one way rather than another – but would this effect endure long enough to actually affect voting behaviour if they were to see that advertisement in the real world? Both Druckman & Nelson (2003) and Mutz & Reeves (2005) found in follow-up studies that effects observed in original survey experiments did not last more than a few days to weeks. However, in the case of product or service purchase such as signing up to a DSR tariff, it is not unreasonable to expect that the decision would be made in close temporal proximity to being exposed to information about the tariff (e.g. through reading information on a website description), thereby minimizing this problem.

Another issue with survey experiments highlighted by Gaines et al. (2007) is that they often fail to include a true control group. For example, Kinder & Sanders (1996) studied the effect of how two different framings of affirmative action affected participants' attitudes towards it. However, they did not include a control group where attitudes were measured without any framing. While significant differences were found between both the framings, the researchers could not say whether the individual framings had any effect simply on existing attitudes (i.e. where there no framing). There is a trade-off to be made here between the extra insight that including a control group may bring, and the cost of either increasing the sample size or reducing the statistical power of the comparison by dividing the sample into smaller groups. The current research did not include a non-DSR (i.e. standard flat rate) electricity tariff as a control. The reason for this is that the technical and economic drivers for moving to wider use of DSR are clear, and policy is expected to make this likely (see chapter 2). The primary interest is therefore between different DSR options, rather than in comparing DSR to the current situation. While including a flat-rate control group would be expected to provide an useful comparison (as indeed it did in the case of Stenner et al. (2015)), the value of this

was considered to be outweighed by being able to test five different DSR tariffs as opposed to just four.

### 3.3.3 Phase 3: Experiencing control

So far, the approaches discussed are concerned with people's attitudes and preferences in relation to DSR based on hypothetical products and scenarios. The focus of research question 4 is on people's actual experience of DSR, and how this might compare to their expectations. Collecting data based on people's experiences of innovative DSR offerings is challenging because such offerings are not yet available on the market in Great Britain. As such, undertaking study on a representative sample of the population would be impractical. Furthermore, because experience of such tariffs is extremely limited in Great Britain, an approach which allows exploratory research as well as testing the findings of the previous phases of work presented here is appropriate. This situation lends itself to a case study approach. Swanborn (2010: 13) defines case studies as usually possessing the following characteristics (summarized):

- '*carried out within the boundaries of one social system (the case), or within the boundaries of a few social systems (the cases)*'
- '*in the case's natural context*'
- '*by monitoring the phenomenon during a certain period or … by collecting information afterwards*'
- '*in which the researcher focuses on process-tracing*'
- '*using several data sources*'

It is first necessary to determine the criteria for case (or cases) selection. At the most basic level, for the case to be relevant to the research population as defined above it must be located within Great Britain and involve people who are wholly or partly responsible for paying energy bills. Temporally, research access must span the introduction of an innovative DSR programme such that participants will be able to share views on both their expectations and subsequent experiences of DSR. For the purposes of this stage of the research, 'innovative DSR' is understood quite broadly and could involve either a novel DSR tariff, new approaches to automating response to DSR signals, or direct load control programmes. Finally it must be possible to undertake the research within the constraints of a PhD schedule and resources. On the basis of the latter point it was not feasible to implement a bespoke DSR trial for the purposes of this project. Rather, it was decided to seek a partner with existing trial plans and collaborate with them to address the research

question. A number of possible collaborators were identified through professional and personal networks:

1. A trial involving the installation of modern electric storage heaters with direct load control in social housing in an island location in the north of Scotland.
2. A trial of energy efficiency interventions and time of use pricing focused on fuel poor customers in south-eastern England.
3. A trial of an 'intelligent' heat pump control system able to respond to time of use pricing and direct load control signals, focused mainly on older social tenants in the south-west of England.

Discussions with coordinators of the first two projects revealed that either other social research was already planned for the project (project 1), or the project timescale did not fit with that required for the current research (project 2). Project 3 had only very limited plans to include a social research element and was scheduled to take place with the timescale of the current research. It therefore fit the basic criteria for case study selection. More information about the trial is provided in chapter 6.

The research conducted as part of the case study consisted of pre- and post-trial surveys and interviews. The research question specifically focuses on a comparison between people's expectations and experiences of DSR. As such, data collection before and after exposure to DSR was necessary. A quantitative approach was required as it would facilitate statistical comparison between these two conditions, which would be a powerful way to demonstrate difference (or lack of it) before and after exposure to DSR. This could involve either observation of actual behaviour or self-reporting of behaviour and/or attitudes via a survey procedure. While physical monitoring conducted as part of the trial did allow some direct observation of participant response to DSR activity, that work falls beyond the scope of this thesis[13]. To provide context to this physical monitoring and to measure subjective responses to the control system being trialled, a survey was therefore considered necessary. Pre- and post-trial postal surveys were already part of the project work plan – the existing focus was on household composition and general experience of the new control system. The opportunity was available to add a limited number of additional questions to the survey with a focus on DSR – these are discussed in detail in chapter 6. The intention was also to allow direct comparison with the

[13] A paper is currently being co-authored which draws on the results of both physical monitoring and the social research described here.

results of the survey experiment described above. A postal survey was selected by the trial coordinators rather than other format (e.g. online, as above) principally because the majority of participants were expected to be older people and therefore less likely to have access to an Internet-enabled device (Ofcom, 2014).

The aim of the qualitative part of the research was to understand the reasons underlying participants' attitudes towards DSR before and after the trial. It employed a combination of individual pre-trial interviews and household post-trial interviews. As for the initial stage of qualitative research described above, the main method options available were either individual or group interviews (the latter including focus groups). Whereas the previous stage of research principally aimed to generate a range of subjects for further study (i.e. different aspects of control), this stage was very much focused on understanding individuals' own expectations and experiences. The benefits that focus groups allow, such as allowing group members to complement and challenge each other's viewpoints, are not as prominent here. Individual or household interviews would give participants the time and space to share their own frank views on motivations and concerns around DSR without fear of being challenged by others. Practically speaking, while the trial homes were all located in the south-west of England , they were dispersed over a number of locations and even within these the distance between individual homes was sometimes quite high (e.g. tens of miles). Combined with the consideration that some older residents might not still drive regularly, individual or household interviews were viewed as the more practical solution over focus groups which would require participants to travel to a central location.

The pre-trial interviews were conducted over the telephone. This medium of data collection was considered optimal for a number of reasons. The pre-trial interviews were intentionally kept quite brief – long enough to record information on people's experience of their current system and expectations of the new one, but short enough to minimize inconvenience and avoid deterring participants from taking part in the (longer) post-trial interviews. Irvine et al. (2013), who conducted a comparative study of telephone and face-to-face interviews, found that telephone interviews tended to be shorter because participants went into less detail in their responses. However, studies have consistently found that there are not major differences in the content of data collected between telephone interviews and the variety of other interview modes (e.g. Brustad et al., 2003; Pettigrew et al., 2003; Block & Erskine, 2012). It was also anticipated that face-to-face interviews would be more of an imposition on participants and should only be undertaken once in the

study. Because the study homes were quite widely geographically spaced, the cost and time required to visit them all for a relatively short interview was not considered justified. Finally, because it was intended to visit a selection of participants for face-to-face post-trial interviews (see below), this later visit was expected to provide an opportunity to observe and explore in person points which the participants had made in pre-trial interviews.

Post-trial interviews were conducted face-to-face in participants' homes, with a request that as many household members be present as possible. As suggested above, conducting in-home interviews would provide an opportunity to observe participants using the control system and pointing out other characteristics of their home that they considered relevant to the interview. Face-to-face interviews also allow the inverse of the point suggested for telephone interviews (i.e. by Irvine et al. (2013)) – that is, participants may go into greater detail in their responses. They also improve the possibility of building a rapport between interviewer and interviewee, and allow extra cues (e.g. intonation, body language) to be picked up that might be missed in other modes of interview (Opdenakker, 2006) – these can act as prompts to explore subject further or to avoid them. Household interviews have been shown to be useful in reducing participant concerns and increasing their confidence, while also helping to shed some light on the household dynamics that can influence choices that impact or are otherwise related to home energy use (Valentine, 1999). The interviews were led by the author, but attended by a representative of the company coordinating the trial who took notes and also participated in the discussion at times. While it was recognised that having a representative of the company present may risk inhibiting participants from sharing their frank views, it was considered necessary from the point of view of risk assessment (both for researchers and participants), to provide expert input of the system where necessary, and to assist in note-taking.

## 3.4 Summary

The selection of the research population of energy bill-payers in Great Britain was justified on the basis of the physical composition of the electricity network and that people who are in a position to decide on and initiate tariff switching are of principal interest in this study. The rationale for a mixed methods research strategy was then set out, with a pragmatic approach requiring both qualitative and quantitative approaches. The selection of specific methods was then discussed and determined. The initial exploratory phase of research involved focus groups to explore people's

understandings of control in the context of energy use. These allow participants to reflect and comment on each other's views and help minimize power imbalances between researcher and participants. The next phase used a social survey approach delivered online to provide quantitative data suitable to demonstrate associations between variables and to generalize findings from a sample to the research population. An experimental design was employed to attribute different results to differences in DSR approach. The final phase of research used a combination of surveys and interviews before and after a trial of DSR technology in order to help compare people's experiences and expectations. A case study approach was employed because the innovative tariffs of interest in this study are not yet available at the national scale, and to facilitate in-depth qualitative research.

# 4 Exploring control

This chapter presents the methods, results and a brief discussion of the focus group stage of the study – a fuller discussion in the context of other stages of research is presented in chapter 7. It starts out by explaining the choice of sample characteristics and sampling approach. The focus group procedure is then laid out. Content analysis was used to identify motivations for and antecedents of control. The findings are briefly discussed, with a focus on those results which are required to inform the subsequent stage of research.

## 4.1 Focus group method

### 4.1.1 Sample

The intention of focus groups is not usually to produce findings that are generalizable to a population (i.e. in terms of prevalence of a given opinion), so probability sampling is not necessary (or appropriate). However, if they are to successfully help '*understand how people feel or think about an issue, product, or service*' (Krueger & Casey, 2000: 4), it is important that the participants can represent to some extent the diversity of views that may be expressed by the '*people*' in whom the study is ultimately interested. As such, purposive sampling was employed. Purposive sampling involves '*applying expert knowledge of the population to select in a non-random manner a sample of elements that represents a cross-section of the population*' (Battaglia, 2008). As has been defined in the previous section, the research population for this study is quite broad, including individuals in Great Britain who are wholly or partly responsible for household energy bills. When choosing a sample and sampling technique, it is important to consider the basis on which that sample may be able to represent the research population. Because the focus of this study is 'control' in the context of home energy use and demand-side response, the intention in selecting the participants was that they have diverse experience in these contexts.

The first clear consequence of this is that the sample should include people who have different experience of DSR. This could be achieved by intentionally including participants who are currently on a DSR tariff (in this case Economy 7) and those who are not. Secondly, and more problematically, it was important to include people who were likely to have different experiences of control in relation to home energy use. Heating is the most important driver of home energy use in the UK (Palmer &

Cooper, 2013). It is also very important to the way in which people live their lives, having been shown to be related to use of space in homes (Wilhite et al., 1996), having large variation in the amount of automation involved in its operation (Peffer et al., 2011), as well as having demonstrated challenges with how people directly engage with the technology through heating controls (Peffer et al., 2011). It was therefore decided to draw on people with experiences of different kinds of heating system. The most widely used heating fuel in the UK is natural gas (Palmer & Cooper, 2013), followed by electricity. Because these types of primary heating system differ substantially in the way in which they operate (with gas usually being burned to provide heating when needed, while most electrically generated heat is stored to be released when needed), representatives of people using gas or electric heating were included in the sample. Finally, district heating has been projected to play an important role in the UK energy system in future (DECC, 2011). For this reason, and because it involves elements of external control similar to that which are at play in the case of DSR, people currently living with district heating were also included in the sample.

While it would have been possible to attempt to select a random probability sample from a frame including the characteristics described above, this was not necessary because no attempt would be made to extrapolate from the sample to the wider population. Furthermore, the practical considerations involved in organizing focus groups meant that it would be beneficial from the point of view of communication and timetabling to have participants who were connected to each other in some way (within groups). For this reason, snowball sampling was used to recruit a range of participants meeting the diversity requirements described above. Snowball sampling is '*a technique for gathering research subjects through the identification of an initial subject who is used to provide the names of other actors*' (Atkinson & Flint, 2004). This method of recruitment is suggested to be suitable '*as an informal method to reach a target population where the aim of a study may be exploratory*' (Atkinson & Flint, 2004), as is the case with this study. Other purposive sampling options available would have been convenience sampling ('*a type of nonprobability sampling in which people are sampled simply because they are "convenient" sources of data for researchers*' (Battaglia, 2008)), or alternatively identifying places (physical, online, etc.) where people fitting the sample characteristics could be identified and advertising for participants. Convenience sampling was not an option because there were not 'convenient' representatives of all of the characteristics available. While both snowball sampling and advertising for participants risked

introducing biases, snowball sampling was considered to be more likely to yield sufficient numbers of participants in the necessary timeframe.

Sampling was undertaken by identifying a different ‘seed’ person with one of the three selection characteristics and asking them to invite other people sharing that characteristic to participate in the study (Bailey, 2008). Where possible they were asked to invite people with a range of ages and a mix of genders. Recruitment yielded the following groups:

- District heating group (n=5)
- Gas central heating group (n=8)
- Economy 7/10 time of use tariff group (n=3)

An initial pilot group convenience sample consisting of energy experts (researchers and students at the author’s institution) was also recruited (n=6), yielding a total sample of N=22. The pilot group provided an opportunity to trial the discussion schedule while also collecting the views of people with special interest and expertise in the subject of energy use. Table 4-1 gives more information about the participants.

**Table 4-1: Focus group participant details. In participant code, PIL = pilot group, DH = district heating, GCH = gas central heating, TOU = time of use tariff.**

| Participant code | Sex | Age | Tenure | How pay electricity? | Heating | TOU tariff | Switch in last year |
|---|---|---|---|---|---|---|---|
| PIL1 | M | 25-34 | Rent | Other | Gas | N | N |
| PIL2 | F | 25-34 | Rent | Direct deb | Elec (storage) | N | Y |
| PIL3 | M | 25-34 | Own | Direct deb | Gas | N | Y |
| PIL4 | F | 35-44 | Rent | Direct deb | Gas | N | Y |
| PIL5 | F | 25-34 | Rent | Direct deb | Gas | N | Y |
| PIL6 | F | 25-34 | Rent | Direct deb | Gas | DK | N |
| DH1 | F | 55-64 | Own | Direct deb | District | N | Y |
| DH2 | F | 35-44 | Rent | Direct deb | District | N | N |
| DH3 | M | DK | Own | Quarterly | District | N | N |
| DH4 | M | 45-54 | Own | Direct deb | District | N | N |
| DH5 | M | 45-54 | Own | Direct deb | District | N | Y |
| GCH1 | M | 55-64 | Own | Direct deb | Gas | N | Y |
| GCH2 | F | 55-64 | Own | Direct deb | Gas | N | Y |
| GCH3 | M | 65-74 | Own | Direct deb | Gas | N | Y |
| GCH4 | F | 45-54 | Own | Direct deb | Gas | N | N |
| GCH5 | F | 55-64 | Own | Direct deb | Gas | N | Y |
| GCH6 | F | 65-74 | Own | Direct deb | Gas | N | N |
| GCH7 | M | 55-64 | Own | Direct deb | Gas | N | N |
| GCH8 | F | 55-64 | Own | Direct deb | Gas | N | N |
| TOU1 | M | 35-44 | Rent | Quarterly | Elec (storage) | Y | N |
| TOU2 | F | 55-64 | Rent | Prepay | Elec (storage) | Y | N |
| TOU3 | F | 45-54 | Rent | Direct deb | Elec (storage | Y | Y |

A number of limitations were apparent in the sampling approach. These are mentioned here so that they can be borne in mind when reading to the results, but are discussed in more detail in section 4.3 below. One of the outcomes of using snowball sampling is that participants will be personally known to the 'seed' person, and possibly to each other. They may also be connected in ways other than according to the main recruitment criterion. In the case of the district heating group, participants were all members of the estate's 'sustainability group' – although at least one was new to that group and had not previously attended their discussions. The result was that they had actually given quite a lot of previous thought to their own (and the estate in general's) energy use, so were able to offer well-considered views. However, they were likely to be more motivated than the average resident by sustainability concerns, and perhaps also (through their membership of a community organization) by community concerns. Participants in the time of use group were connected only by having consented to take part in another research

project and therefore being known to the researcher, while participants in the gas central heating group were friends of the seed person. Participants in the expert group were mostly known to each other (as colleagues), and to the author. Levels of interest in energy and environment issues in the non-specialist groups varied with some people's work fairly directly related to home energy use (e.g. plumber, house builder), and were highest in the district heating group. Finally, the relatively low number of participants in the time of use tariff group limited the opportunity to get a fully diverse range of opinions.

### 4.1.2 Data collection and analysis

Focus groups were scheduled in discussion with the seed person, who passed on details on timing and venue to the participants. Venues were arranged by the lead author and included an office meeting room (expert group), participant home (gas central heating group), estate community space (district heating group) and rented meeting space in a local community building (time of use group). All groups were scheduled for weekday evenings when participants were available, with the exception of the expert group which took place during the working day. Each 'seed' person was provided with an information and consent form (see appendix 10.2) to pass on to potential participants before the group took place. Arriving participants were given printed copies of this sheet on arrival and asked to sign and return it before the commencement of the group (and offered a copy to take away).

Groups were facilitated by the author and followed a consistent structure, each lasting about an hour. The discussion schedule is provided in appendix 10.3. The discussion opened with a re-statement of the aims of the research and conditions to which participants had consented (e.g. recording of discussion), along with ground rules for focus groups (such as keeping participants anonymous outside the group, letting everyone speak, no right or wrong answers) (as recommended by Krueger & Casey (2000)). The first substantive part of the session was used to discuss people's views on control over energy use in general, the extent to which it was something that could be controlled, and what people wanted control over. The facilitator then gave a brief overview of the rationale for DSR (outlining in basic terms the main benefits highlighted here in chapter 2). Participants were handed short descriptions of the following customer offerings: flat unit price for electricity; fixed time of use tariff; dynamic time of use tariff with smart appliances; and direct load control (DLC) with the specific example of space and water heating (see appendix 10.4 for materials). The offerings represent a range of different DSR

signals and are based on actual programmes. General pricing indications were provided so as to avoid heavily influencing people's views with cost considerations at an early stage in the discussion.

Each participant was then asked to mark on a scale their response to the question, '*All things considered, how much control would you have, compared to now?*' for each tariff option (see appendix 10.4 for scale). This instruction was intentionally non-specific to allow people to interpret 'control' as they chose. Participants were asked to do this without consulting with each other, the aim being to obtain individual viewpoints before they could be directly influenced by the group. Each participant was then asked to explain the reasons for positioning different options on the scale, and the results for the group noted together on a single chart by the facilitator. Participants were then invited to comment on the group results. Subsequent discussion was guided towards what people thought they would gain or lose control over in DSR scenarios and what affects this. The extent to which this would relate to their acceptance of DSR was also discussed. Finally participants were asked to complete a short questionnaire which provided the information contained in Table 4-1. All groups were recorded for audio and subsequently transcribed. A technical problem meant that the end of the district heating group discussion was not recorded. This was apparent immediately after the discussion and detailed notes were made to supplement those taken during the session.

Content analysis was conducted by the author in NVivo 10. Hsieh & Shannon (2005) describe three approaches to qualitative content analysis – conventional, directed and summative. Conventional analysis involves generating codes only from the data itself, while directed analysis uses previous findings or theory to dictate codes which are then applied to the data. The current analysis combined these two approaches in that, while the codes themselves were purely based on interpretation of the data, the codes were collected under themes including (but not limited to) those outlined in section 2.2.2 as relating to Skinner's (1996) framework of different aspects of control (e.g. motivations, antecedents, agents, means, ends). Results from the scale exercise were transposed into Excel by measuring the distance of participants' marks from the centre point, and a repeated-measures analysis of variance (ANOVA) conducted to detect any significant differences between expectations of control in the tariffs presented. Caveats connected with performing these quantitative analyses are discussed in section 4.2.1 below.

### 4.1.3 Ethical considerations

The research was judged to be exempt from the need to secure approval via University College London's institutional research ethics on the basis that it consisted of an interview procedure which did not touch on sensitive topics or include vulnerable individuals. Nevertheless, any research which involves human participants necessarily requires consideration of the ethical implications of that work. The key concerns identified here were the potential for inconvenience incurred by the participants, and the possibility of concerns around the confidentiality of any views expressed.

Concerns about inconvenience were addressed in two main ways. Firstly, discussions were scheduled at times and in places that were thought to be convenient for the participants to attend (described in section 4.1.2 above). All efforts were made to ensure that sessions began and ended promptly, and refreshments were provided for all groups. Secondly, an information and consent form (see appendix 10.2) was given to all participants informing them what was involved in the research and what the intended benefits were. Making the reasons for undertaking the research clear to participants (as well as any potential risks) is important if they are to think it is worthy of their time and effort and is a key part of assuring informed consent (Israel & Hay, 2006). Potential confidentiality and anonymity concerns were addressed by following best practice guidance in the moderation of focus groups. Mainly this involved giving a reminder in the initial preamble about the ways in which participants' contributions would be used, along with a reminder to keep the discussion confidential outside the group (Krueger & Casey, 2000). The assurances that there are no right or wrong answers, and the reminder to give everyone a chance to speak, were given with the aim of ensuring no-one felt marginalized or belittled during the course of the research.

Once the results had been analysed a brief summary of the results was prepared and sent to the original snowball 'seed' person, with the request that they circulate it to members of the group (see appendix 10.5). It was not possible to send it to individual participants because their contact details were not recorded – a decision which was taken to minimize the chances of accidental breaches in confidentiality. A brief summary of the research was considered likely to be of greater interest to the participants than a detailed academic discussion (such as a journal paper or this report). The authors contact details were provided on the original information sheets

(of which participants were able to take an additional copy) and they remain free to request copies of outputs.

## 4.2 Results

In the following section participants are identified by a two- or three-letter group code (PIL = pilot group, DH = district heating, GCH = gas central heating, TOU = time of use tariff) followed by a number for each participant in the group (e.g. TOU2 is participant 2 in the time of use tariff group). The main focus is on the discussion around the specific DSR tariffs as it is here that the idea of control was dealt with most explicitly.

### 4.2.1 Perceived control and DSR

Figure 4-1 charts participants' written responses to the question, '*All things considered, how much control would you have, compared to now?*' for each tariff option. To create the chart, participants' marks on a scale were transposed into Excel by measuring the positions of the marks. The question phrasing was deliberately vague so as to allow participants to interpret it as they chose (the interpretation being a focus of subsequent discussion). Strong caveats are required – this chart compares on the same axes people's subjective judgments in relation to different concepts (e.g. some people were considering control over spending, others over time). These data are presented here as they suggest something of the direction and extremeness of people's first reactions to the DSR offerings.

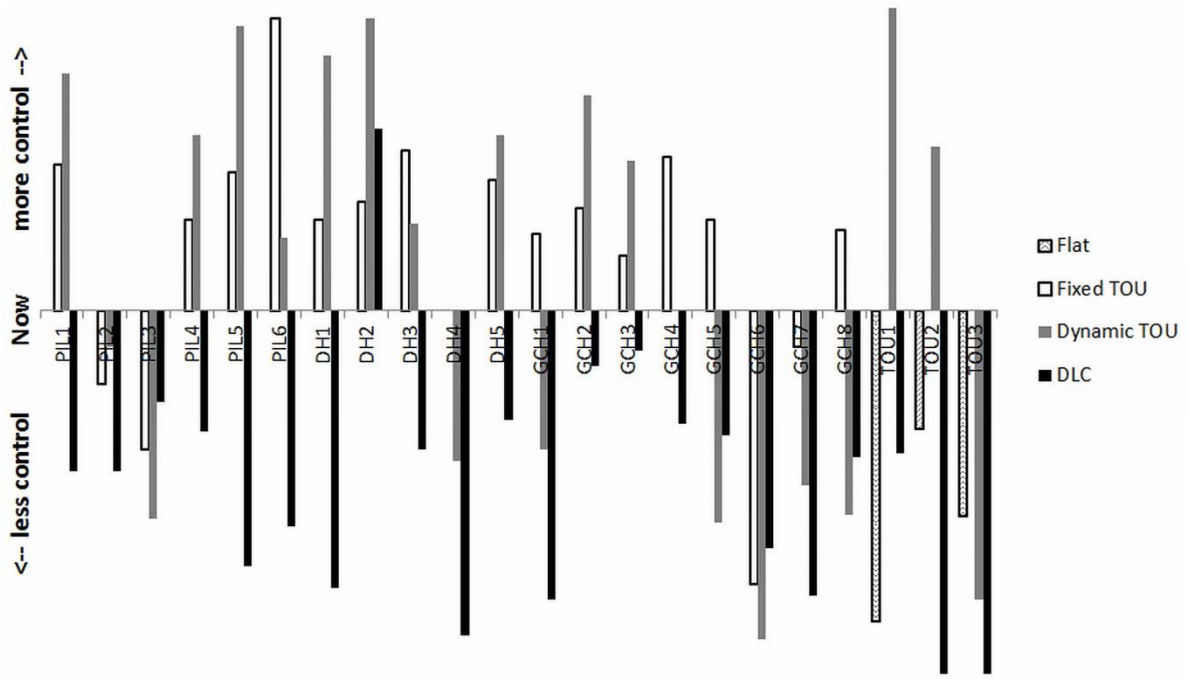



**Figure 4-1: Participants' self-reported perceived control expectations under different DSR offerings. Bar lengths were calculated by measuring the position of participants' marks on the scale.**

A repeated measures ANOVA with Greenhouse–Geisser correction showed that mean perceived control differed statistically significantly between tariff options ($F(2.05, 40.97) = 14.15$, $p < .0005$). *Post hoc* tests with the Bonferroni correction revealed that people's control expectations were significantly lower for DLC than for flat rate ($p < .0005$), fixed TOU ($p < .0005$) and dynamic TOU ($p = .001$) tariffs. There were no other significant differences between the tariffs, although people's control expectations for the fixed TOU tariff approached significance in exceeding those for the flat rate tariff ($p = .072$). A clear majority of people (white bars in Figure 4-1) considered fixed time of use tariffs to increase their level of control over fixed rate tariffs (or in the case of those already on TOU tariffs, flat rates were associated with loss of control). The picture was more varied in relation to dynamic time of use tariffs, where there was a relatively even spread of people who thought these would give them more or less control. Almost everyone associated DLC with loss of control. The following sections consider in more detail participants' understandings of 'control'.

### 4.2.2 Motivations for control

Participants introduced a range of motivations for control in the larger context of home energy use and in relation to DSR in particular. During the initial discussion around control and home energy use in general, there was considerable talk of control of temperature, both in terms of direct control over heating systems and

more generally of homes. People discussed what they did in order to obtain a desired temperature, and in such cases people's motivation to have control was to achieve comfort in their homes. For example, from a participant in the district heating group:

> *Similarly we have a small amount of fans and in the winter we're using those to top up the heat, so when I said the place is comfortable, it's comfortable most of the time and if it's not we'll turn on, if it's too cold we'll turn on one of these fan heaters, it's seldom too warm.* [DH5]

The theme of comfort was less prominent in discussion of the various DSR offerings. Here, three main motivations were prevalent – connected to timing of activity, autonomy and spending on energy. Throughout the discussion two types of temporal motivation were evident. One was directly linked to the provision of the particular energy service under discussion – for example in the quote above, the home is described as being comfortable 'most of the time', but supplementary heating is available to top it up at the times when it is not comfortable. This was particularly evident amongst the time of use tariff participants, all whom either had night storage heaters or had done until recently. These were typically described as being unsatisfactory, especially with regard to being able to provide the right amount of heat at the desired time:

> *… in the morning I get up, something like early morning my throat's dry cause the flat's so warm and by the time I need to leave for work I'm used to it and by the time I get home I'm back to when I need a jumper on* [TOU2]

There was concern, especially in the case of the DLC tariff, that services such as heat would not be available when desired:

> *… they can see through my house and they can see that, right, I've been using so much energy, I go away for the weekend and it says, "Wow this person's not using this energy so I will cut it off", you come back in and … you think you're coming to a warm house but it's cold now …* [TOU3]

This was also apparent for the dynamic time of use tariff:

> *… I'm sitting there, you know, I want to cook I want to do this and I can't do it so, I'd want some sort of control …* [TOU2]

The other kind of temporal motivation was around generally feeling able to do things when people wanted to do them, independent from the running of any particular appliance. For example from the gas central heating group:

> *… I think we would just probably to wanting to do things when we want to do them because that's the way that our life works* [GCH1]

Again, this was especially prevalent in the case of the dynamic time of use tariff (which the above comment refers to), and to a lesser degree the static:

> *… the economy 7 one [i.e. static TOU tariff] is wonderful … if you want to get up at 2 o'clock in the morning, unless you got a clock on everything …* [GCH7]

This latter temporal motivation was not far removed from expressions of desire for a general sense of autonomy or self-determination. Sometimes people felt that energy would take on an undue prominence in their lives, such as in the time of use group:

> *… you are programming yourself at the same time you are programming your furniture [appliances]* [TOU1]

> *… our lives would be determined by energy rather than freedom.* [TOU3]

Other autonomy concerns were more related to the involvement of a third party in affairs of the home, especially in relation to the DLC tariff:

> *… it sounds very Soviet system kind of like having someone turning your electricity off, I know you've got the override, but there's just something about that when you pay for a service that somebody can knock it off that doesn't seem right …* [GCH4]

> *… I just find it a little bit off-putting when someone else is in control, so someone is remotely controlling my electricity, it's almost like I'm not in control …* [TOU3]

References were made to '*Big Brother telling you what to and what not to…*' [TOU2], in this case clearly referring to the intrusion rather than the monitoring interpretation of the Orwellian idea. In the district heating group, participants were already well aware that their heating system was controlled elsewhere, and were frustrated by this:

> *… it's not on a prediction basis it's actually the actual temperature at a certain point in the night will trip the grid and it's completely automatic … just doing it on a night-time temperature isn't very efficient because generally speaking if you have a very*

> *cold, you know it's usually clear, next day is very sunny and there's a lot of insulation and temperatures actually in the flats become incredibly high …* [DH1]

This was in line with other more general concerns about too many aspects of life becoming subject to automation:

> *… you have a house and it's going to run by computer and … your computer is kind of in a sense programmed to cook the chicken for you to have for dinner without you putting the chicken in the oven … We're not robots!* [TOU3]

> *… you've got to have everything on one of those timers … you'd have to have a timer in almost every socket … you haven't got time to keep thinking about all these timers, you know?* [GCH5]

The above motivations were generally discussed in the context of diminished control. Where people thought they would gain control in DLC, or lose only a little, this was generally motivated by consideration of convenience – either of managing costs or of managing appliances themselves:

> *If it's … something that happens in the background and doesn't actually affect your usage … for me personally I don't think I have an issue with them controlling it.* [PIL3]

Connected to this, the final main motivation was to have control over spending on energy, and where it arose in was mainly in respect of an increase in feelings of control. This was mainly applicable to the static and dynamic TOU tariffs, where people saw the opportunity to schedule activities in order to save money:

> *I was looking mainly at my control over how much the energy is going to cost me, so, that sort of gives me different levels of control over the cost.* [PIL4]

> *… you have got some more control cause you can look at the, "Oh right OK let's put the washing machine on now"'* [GCH4]

The participants in the time of use tariff group all thought that they would lose control on a flat rate tariff, and said that this was motivated by concerns around control over spending:

> *… if I'm not at home there's certain things that you leave on like your fridge freezer or whatever, and you know it's, paying the same amount of money all the time … Even though it's on low [period] you're still paying same tariff so you might as well be on [static TOU]* [TOU2]

There was little reference to a desire for control over electricity or energy in and of itself, as distinct from the costs or services associated with it.

There were differences in motivations between the groups. It was noteworthy that concerns around loss of autonomy resulting from third-party control did not arise spontaneously in the expert and district heating groups, and discussion of these issues had to be prompted. It was acknowledged by participants in the district heating group that they would probably be more accepting of external control since they were already accustomed to it through their heating system. Conversely, autonomy was a main spontaneous subject of discussion in the gas central heating and time of use tariff groups. For example, even while the DLC tariff was being described by the moderator, a participant interjected, *'That means they're controlling your life basically'* [TOU2], to agreement from other participants. Control over spending emerged less strongly as a theme in the gas central heating group, where it was hardly discussed, compared to the other groups where it was often cited a main motivation (particularly in relation to the time of use tariffs).

### 4.2.3 Antecedents of control

Lack of information was a notable antecedent for people feeling a lack of control over certain appliances. For example, participants on Economy 7/10 tariffs were not confident of the times between which the night-time tariff was in operation or of the difference in price between peak and off-peak rates.

> *… it's direct debit but I was trying to get into my bill online today and it just wouldn't let me so that I could have a comparison but … they did tell us that it's a cheaper rate in the evenings and if the water tank, the immersion heater is heated between a specific period then during the day you'll have enough and you don't have to switch anything on and so far it's been OK …* [TOU3]

One participant had requested a prepay meter so as to more easily track their expenditure on energy ('*with a key [prepayment meter] I now know how much I'm spending every month'* [TOU2]), and others expressed interest in using energy monitors to find out how much electricity they were using.

While information was not discussed as a main antecedent when the groups focussed on the DSR offerings, related concepts such as familiarity and predictability were. The static TOU tariff was seen as very similar to existing products which people were familiar with, such as in the time of use tariff group:

*I think I'm on that sort of system … when I compared it with the other three that's what I think, it's still the best.* [TOU3]

Participants who were not on Economy 7 were also familiar with it and therefore recognised the concept of the static TOU, as demonstrated by the following exchange in the gas central heating group:

*It's based on economy 7 basically...* [GCH7]

*Exactly, and I suppose because we know about that system, you know what I mean and I think that does [give more control]* [GCH5]

Familiarity was not expressed in relation to the dynamic tariff, and concerns were raised about the unpredictable nature of price changes making it difficult to plan:

*… would you want your electricity switched off half way because you misjudged half an hour here and there …* [GCH6]

*And this one [dynamic TOU], the prices change so often it's difficult to predict I just thought I'd never understand it.* [GCH7]

Where people were concerned about losing control in DSR scenarios (especially DLC and dynamic TOU) this was often associated with lack of trust in either third parties or technology. Participants related stories of energy companies and other comparable organizations (e.g. phone companies) acting without their interests at heart as a basis for this concern (‘*wait till you get over the limit and they charge you whatever they want*’, PIL4). People recognised a misalignment between their own ends (e.g. energy services) and those of energy companies (e.g. profit) being sought through the same means (electricity-using technologies in the home), causing them to be doubtful as to which the energy company would prioritize:

*I think at the moment because of the perception of the way that the big energy companies manipulate prices and so on there's a real cynicism about it, so in that scenario I don't think people would really believe it.* [GCH1]

However, there were mixed views as to whether other bodies (for example government or community groups) would be more trusted to take on roles in DSR. There was also quite a sense of scepticism that either the technology or the tariffs themselves could be trusted to achieve their desired ends:

*… no-one would be sure that the guarantee was actually going to work, so if you get up in the morning at 7 o’clock and you've got to rush off to work and your car's still*

*flat everyone's going to go "Well that don't work", it's not going to last very long at all.* [GCH7]

Part of this scepticism arose in connection with another expressed antecedent of control – choice. For example, the option of a limited override in DLC was not widely viewed as a sufficient choice as compared to the greater freedom that was perceived to be afforded by other DSR approaches:

*I know you've got the override, but there's just something about that when you pay for a service that somebody can knock it off that doesn't seem right so that's less [control].* [GCH5]

It was also suggested that a lot of people would be likely to override (or choose to use appliances) at the same times, rendering the system ineffective:

*… how do you stop there being a mass of overrides 'cause we all want to go and watch Manchester Utd and Man City?* [GCH7]

*… you are going to probably be using your appliance when everyone is using them … everyone is getting home at a certain time and everyone wants dinner at the same time …* [TOU2]

### 4.2.4 Agents/means/ends of control

#### *Agent-means relations*

The perception across the groups was that energy use was not something people have many choices around, and as such was hard to control. There was a strong feeling that certain energy services, such as heating, were non-negotiable (e.g. '*I try and work with it with what I've got, the heat I can't live without'*, TOU2). This effect was increased when other occupants such as housemates or children were mentioned:

*… my partner doesn't [think about saving energy] at all and, because he's a computer person and he's got like six computers in his office now, he's running them 24 hours a day constantly, and I keep telling him that is using huge amounts of energy and he just keeps doing it all the time …* [PIL4]

*… if you had a baby it'd be different … that baby determines the timing rather than you determine the timing*. [TOU3]

In such cases other people are perceived as a barrier to the agent (the participant) taking action to achieve the ends of saving energy (in the first case) or using it at certain times (in the second).

People differed in the options they had available to them to reduce energy use. The most marked difference was between people who owned their own homes (houses) and people who rented, or owned in blocks. The former group spoke more about possibilities for installing insulation or replacing boilers themselves, for example:

> *We've been wanting to get a new gas boiler, a new gas combiboiler because ours is very old and it's, I think it's G rating but the price was just ridiculous.* [GCH4]

> *We had the [cavity wall insulation] … on a kind of a when the government were giving some money, weren't they, for that so we had that done on that basis.* [GCH2]

Tenants did not mention having taken such actions, but spoke more about behavioural measures, or even unsuccessful attempts to get landlords to take more permanent measures:

> *I asked our landlord about the boiler replacement scheme because where we live they do boiler replacement scheme for G rated boilers and ours is blatantly G rated, it's horrible, and they do it for free at no cost to the landlord or tenant and I suggested it to him and he was basically like, "No, they'll come and they'll ruin the kitchen, they're not coming in and doing that so, so you can live with your horribly expensive energy bills".* [PIL5]

This reflects a difference in legal access to different means of control over energy use. In the case of the district heating group, participants did not have any way to affect the output temperature except by asking an engineer to come and adjust it:

> *… there is no fine control … people open windows, that's the control.* [DH1]

While these examples of agent-means relations are drawn from general discussion in the context of energy use, they may affect people's ability to respond to DSR signals. When DSR tariffs were being explicitly discussed, the main agent-ends issue related to the ease with which tariffs could be understood and accommodated in people's lives. In general, the dynamic TOU tariff was seen as rather complicated, while the static tariff was more simple:

> *This [dynamic tariff] is the one where the price changes so often that no-one knows what they're doing!* [GCH7]

> *… it's [static tariff] quite a simple system that probably would, you've got a bit more control.* [GCH5]

> *I think the principle is that if it's simple, and Economy 7 was simple, then you have more control, you might not like it but it's very very simple, I think the more complex that systems get the less people are likely to understand them and therefore use them …* [GCH1]

It was evident from the discussion that while the static tariff was quite understandable to most people, the dynamic tariff (and its automated element) especially was sometimes confusing:

> *… so how do you actually go and regulate that because, how do they know because it's two days gone or five days gone you haven't returned, six days you return, how will they know when to put, you know, the energy on?* [TOU3]

If people do not understand how a DSR product works, they may not use it correctly. Indeed, there were also cases of people exercising control with possible unintended consequences. For example, one participant in the time of use group explained how they adjusted their water heater to come on later (thereby providing hot water later) – with the likely result that they were paying for peak rate electricity to heat water. However, there was some recognition of the convenience that could come with an automated response to the dynamic tariff:

> *I think this [dynamic tariff] can work so integrated system will kind of take the responsibility of choosing, so in a sense you release the control to these program or to the supplier in a sense, I mean probably you don't think too much about it …* [TOU1]

Routines were not widely discussed as a reason not to engage in DSR, perhaps because a lot of the focus of discussion was on heating, which happens while people are performing other activities. When routine was mentioned, it was in relation to activities which require instantaneous personal engagement with electricity-using appliances, such as cooking:

> *… if we have to cook and do all the other stuff between 12 and 6 in the morning your whole lifestyle has changed hasn't it, so what will you do when you return at 6, from 6 to 12, practically you will eat at midnight …* [TOU3]

There was some recognition of the difficulty of responding to signals if (for example) work routines mean the home is unoccupied:

*… if you know you're not going to be there in the day most people are out at work that's an issue. And you've got to have everything on one of those timers.* [GCH5]

### *Means-ends relations*

There were examples of people not having confidence in the means of control over various factors to achieve their intended aims. For example, participants with storage heaters described how when they took action to use them to provide heat later in the day, the heaters didn't work as intended:

*… you come back and there's a chill, and it's all just like, open up the vents but there's nothing there to give.* TOU2

Such concerns were also expressed in the context of the DSR offerings which were discussed. Participants were worried that technology would not be able to perform its intended function, for example (regarding the DLC tariff):

*… no-one would be sure that the guarantee was actually going to work, so if you get up in the morning at 7 o'clock and you've got to rush off to work and your [electric] car's still flat everyone's going to go "well that don't work" it's not going to last very long at all.* [GCH7]

*… I can come in and my supplier's decided that that's the hour they want to cut down and I'm sitting there, you know, I want to cook I want to do this and I can't do it so, I'd want some sort of control, I'm paying for it so I want some sort of control when I use it …* [TOU2]

As was mentioned in section 4.2.3 on antecedents, there was also scepticism that the tariffs could actually successfully achieve their intended ends (e.g. reducing peaks in demand), either because people would have to use electricity at certain times (e.g. for cooking or watching television), or because peaks would just be shifted to different periods.

In the expert group, and to an extent the district heating group, there was some consideration as to the suitability of existing technologies to adapt to the various DSR offerings:

*It would work well with heat pumps though, really well with heat pumps and well insulated buildings but with my current electric heating I'd refuse to have it I think.* [PIL2]

However, these considerations were not prominent in the other groups.

## 4.3 Discussion

This section presents a brief discussion of the results described above insofar as is necessary to inform the research presented in subsequent chapters. A more detailed and integrative discussion which takes in all three main stages of research is presented in chapter 7.

The focus group results presented in section 4.2 highlight multiple dimensions of perceived control in relation to home energy use, and DSR in particular. When people spoke about their motivations for control, the main topics were time/flexibility, service level (e.g. comfort), spending and a sense of autonomy (although as outlined in section 2, Skinner (1996) regards this as a concept outside the boundaries of control proper). The principal antecedents of perceived control (or lack of it) were information, familiarity, predictability, trust and choice. Trust was especially important where DSR introduced additional agents, such as in DLC or through the introduction of automation. Overall expected perceived control was consistently highest for fixed TOU tariffs, more varied for dynamic TOU tariffs with automation, and consistently lowest with DLC.

While it is impossible to generalize from the groups to a more general population, background factors which appear to be associated with people's perceived control in relation to energy use included tenure (renting vs owning) and existing technology usage (e.g. district heating vs gas central heating). People with gas central heating (the most common form of heating system in the UK) tended to expect greater loss of control under automated and DLC DSR conditions than other groups. This is, perhaps, unsurprising as gas central heating provides a responsive service with no external control over its operation. Along with the TOU group, these participants were also more likely to highlight loss of autonomy as an issue than other groups. This appeared to be more of a non-negotiable concern than other motivations such as comfort level and flexibility – that is, people who expressed this concern did so strongly and appeared less likely to be willing to negotiate on its acceptability. For example, being assured that DLC would operate unnoticeably in the background or that they have the option to override it did not necessarily make it acceptable to someone with autonomy concerns, while it may for someone who is only worried about the level of service they receive.

As summarized above, the findings point to a substantial degree of variability in how control is perceived in the context of DSR. Static time of use tariffs were perceived as enhancing people's control over costs, whereas there were highly mixed

reactions with respect to dynamic time of use tariffs in this regard, and DLC was perceived as reducing people's control. That static time of use tariffs were perceived as increasing control is of particular importance in the context of consumer acceptance of smart metering programmes such as that currently being undertaken in the UK. This is one of the subjects of work presented in chapter 5 determining if this finding holds in the wider population, and on determining the conditions and specific pricing structure of such tariff offerings.

Several limitations specific to this study should be highlighted. In common with much qualitative research, the small sample size means generalizations cannot be made about the likely prominence and distribution of the issues raised in a wider population. For example, the group participants were all drawn from urban or sub-urban contexts. It is possible that people living in certain rural areas (with different security of supply issues) may have raised different issues or concerns (this issue is addressed further in subsequent chapters). Some participants experienced difficulty in understanding the different DSR offerings, especially DLC. This may be due to the clarity of the explanation provided (which could have been more explicit on points such as the bounds within which third parties were able to turn appliances off and on) and partly a reflection of the complete novelty of DSR to many participants. Only a short time was available to cover the approaches so the data should be seen as very general first reactions rather than indicative of what might be expected if people were genuinely considering signing up to a DSR programme. However, this does suggest the importance of clear and ongoing communication by DSR operators if they expect people to understand their offerings. It is also noted that at the time the focus groups were being held (September/October 2013), debates around energy prices were especially prominent in UK news coverage with price rises taking effect at the beginning of a new heating season.

The discussions which took place during this study focused on DSR offerings as largely independent of wider smart grid and smart home initiatives (e.g. controlling heating systems via smartphones). Such affordances as the smart grid might offer should be expected to affect people's overall sense of control in relation to energy. This reflects a wider challenge for work that asks people to reflect on hypothetical scenarios rather than focusing on their actions in real-life situations – indeed, some participants mentioned products such as Tesco Clubcard which might appear controversial in terms of the amount of data they allow companies to collect but which many people opt in to all the same. These themes are taken up further in chapter 6.

## 4.4 Chapter summary

This study used a series of focus groups to explore bill-payers' perceptions of control in relation to home energy use in general, and DSR in particular. Content analysis revealed four main motivations for control – over service level (e.g. comfort), timing/flexibility, spending on energy, and autonomy. The main antecedents of control were information, familiarity, predictability, trust and choice. The results add detail to previous findings discussed in chapter 2 which identify loss of control in DSR in a general sense as an important concern for some consumers. It is noteworthy that all of the motivations and antecedents of control raised in that discussion were also apparent here, and that no major new motivations or antecedents were raised. Taken together with the review in section 2.2.2, this lends confidence to the view that these therefore describe the main motivations and antecedents of perceived control in relation to home energy use and DSR. However, it does not reveal the extent to which these motivations and antecedents are discrete and independent from each other. This paves the way to a systematic examination of the different motivations and antecedents of control and consideration of how any concerns around them can be addressed through design, targeting and communication of DSR offerings. In conclusion, the current study has highlighted multiple dimensions of, motivations for and antecedents of perceived control in relation to energy use and DSR.

# 5 Measuring control

The second phase of research used a survey experiment to explore associations between perceived control (and other factors) and acceptance of different approaches to DSR. This chapter describes the extension of the Technology Acceptance Model used to structure this phase of the research and sets out the hypotheses to be tested. The process of attitude scale development is then explained. The sampling procedure is outlined, as is the rest of the questionnaire development process. The selection of DSR offerings is justified, along with their mode of presentation. The results section covers analysis involving one- and two-way analysis of variance to look for differences between the experimental conditions, and multiple regression to test the hypotheses set out in the extended TAM. The key findings are then discussed.

## 5.1 Model development and hypotheses

Chapter 2 established that using an extended version of the Technology Acceptance Model (Davis, 1989) would be a viable way of exploring the role of perceived control in acceptability of DSR. The results of the focus group study presented in chapter 4 provide a basis on which to proceed with development of this extended model, and subsequently its operationalization through a social survey. Chapter 2 cited two studies which previously extended the TAM with perceived control constructs – Kranz (2011) and Spiekermann (2008). While both demonstrated an increase in explanatory power through extending the model in this way, the specific control constructs (as reflected in the items used to measure them) employed in these studies were not considered directly transferrable to the context of a study on DSR. They both focus on a specific information and communications technologies (smart meters in the case of Kranz (2011) and radio-frequency identification in the case of Spiekermann, (2008)), and as such conceptualize control principally in relation to the sharing of information (which is the primary role of these technologies). The results of the focus group research conducted here showed that this would not be appropriate for the current study.

Focus group research and the review presented in chapter 4 identified four key motivations for control in relation to home energy use and DSR: service level (e.g. comfort), timing/flexibility, spending on energy, and autonomy. These subjective control expectations are hereafter referred to as the constructs ‘comfort control’,

'timing control', 'spending control' and 'autonomy'. It was not known to what extent the constructs were independent of each other – this was viewed as an empirical question. As such they were treated as independent but related (due to their conceptual similarity), without suggesting a direction for the relationship. For the same reason, they were not hypothesized to contribute to an overall subjective control construct, but to separately influence the 'behavioural intention to use' construct in the TAM.

The first stage of model development is to decide on the version of the original model which is to be extended. As was shown in Figure 2-5, TAM relies on two variables (perceived usefulness [PU] and perceived ease of use [PEOU]) to predict people's attitude towards use, behavioural intention to use and actual use of technology and services. Because the DSR offerings that were investigated in this research are not currently available on the market in Great Britain, it was not possible to measure actual use. Necessarily, therefore, this could not be included in the model, with implications for the interpretation of the results (discussed further in section 5.4).

As introduced in section 2.3.3, the attitude construct is also often omitted from TAM. Indeed, as early in the development of the model as 1989, Davis et al. (1989) found the attitude towards use construct to have only a partial mediating effect on intentions. Venkatesh et al. (2003) found that attitude did not have a direct effect on intention. Therefore, the pursuit of parsimony has led to it being regularly omitted from the model. However, Kim et al. (2009) argue that this approach lacks sufficient theoretical justification, and is solely based on empirical findings. In a study that also measured the strength with which people hold attitudes towards use of technology, they found attitude to fully mediate the effects of PU and PEOU on intention amongst those with a strong attitude, and still to have a greater effect on behavioural intention than PU where attitudes were weakly held. They also found that attitude strength was correlated with amount of experience of a technology. Due to the hypothetical nature of the products tested in the current work, participants' can have no direct experience of them, or may have experience of related products only (such as existing time of use tariffs like Economy 7). For this reason the balance of evidence suggested that attitude should not be included in the extended model. It was, however, still measured because having an assessment of whether consumers think a product/service offering is a good idea or not (i.e. their attitude) – separately from their individual intention to use it – was

expected to provide useful insights (for example into socio-political acceptability – see section 2.3.2).

The basic model to be extended therefore consisted of three constructs – perceived usefulness, perceived ease of use and behavioural intention to use. To this were added the four new subjective control constructs. The extended model is presented in Figure 5-1.

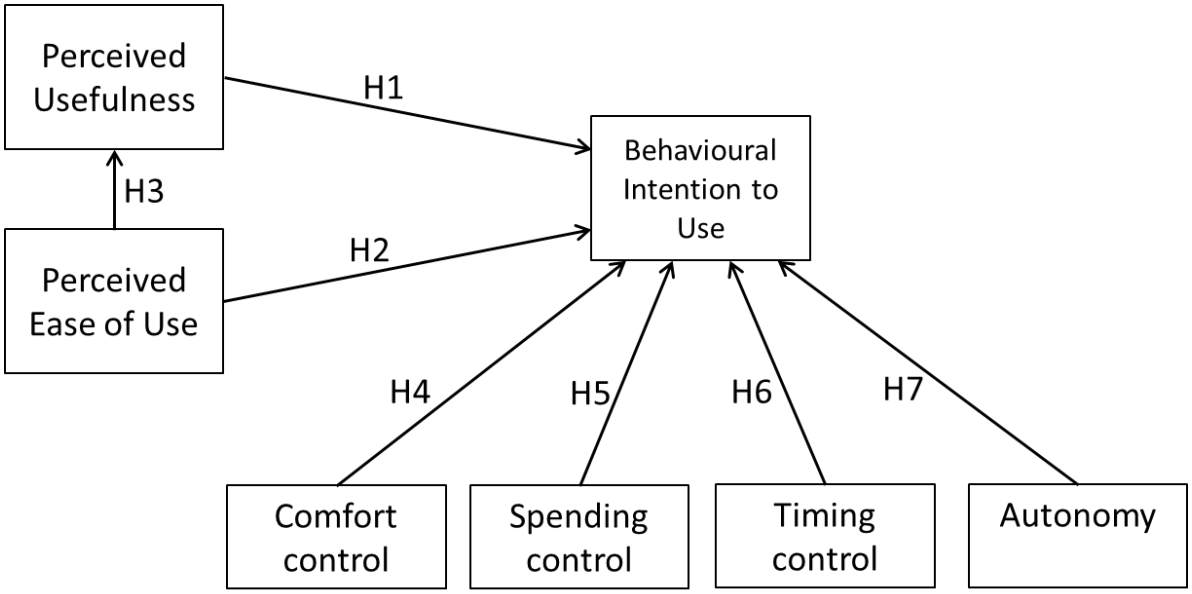



**Figure 5-1: The extended TAM.**

The model reflects the following hypotheses:

- H1: Perceived usefulness positively influences behavioural intention to use (original TAM)
- H2: Perceived ease of use positively influences behavioural intention to use (original TAM)
- H3: Perceived ease of use positively influences perceived usefulness (original TAM)
- H4: Comfort control positively influences behavioural intention to use (extended TAM)
- H5: Spending control positively influences behavioural intention to use (extended TAM)
- H6: Timing control positively influences behavioural intention to use (extended TAM)
- H7: Autonomy positively influences behavioural intention to use (extended TAM)

Before the above hypotheses can be tested it was necessary to identify a valid way of measuring the constructs they refer to. The next section describes the process of scale development by which this was achieved.

## 5.2 Method

### 5.2.1 Scale development

#### *Item generation*

Attitude scales can be used to divide people into broad groups with respect to particular attitudes, usually by asking people to agree or disagree with a number of statements known as items (Oppenheim, 1992). An initial review was completed of general TAM studies and those which included a perceived control construct (Kranz, 2011; Ortega Egea & Román González, 2011; Stragier et al., 2010; Lee, 2009; Spiekermann, 2005, 2008; Burton-Jones & Hubona, 2006; Pavlou, 2003; Venkatesh, 2000; Hu et al., 1999; Davis, 1989). Where the items used were provided, those items which could potentially be adapted to the context of DSR were noted for each of the constructs. The wording was then altered to refer to a general DSR 'plan' (e.g. 'I would find CHART MASTER easy to use' in Davis (1989) became 'I would find this plan easy to use'). To supplement these existing (adapted) items, new items were generated with reference to the language used by focus group participants in the previous phase of study. A mixture of positive and negative framings was included for each of the constructs. This resulted in a total pool of 67 items (see appendix 10.6). At this point, as well as the extended TAM constructs shown above, items were also included to measure two theorized antecedents of perceived control – information and trust. However, these were later removed from the scale for reasons of parsimony (see below, this section).

#### *Item refinement*

The next stage of development was intended to reduce the number of items and to promote construct validity. This is partly done by demonstrating convergent and discriminant validity – or that items intended to measure the same construct give similar results, while differing from those intended to measure different constructs (Lund Research, 2012). Following the process described by Bhattacherjee (2002) in developing trust scales, a convenience sample of seven people who were main/joint electricity bill-payers was selected. They were provided with cards with operational definitions of the ten constructs (see appendix 10.7) and a card for each scale item. They were asked to allocate each item to a construct, and rank them in order of

perceived semantic proximity to that construct. They were also asked to discuss and comment on any ambiguities in the items and in the definitions. An item was only retained if all, or all but one, of the participants agreed on the construct to which it referred (that is, there was over 80% agreement on its meaning). In all, 47 items met the criteria for retention within the item pool, with at least three for each construct.

### *Pilot test and further refinement*

To create a manageably sized item pool and to further enhance validity, a pilot test of the scale was conducted. Using Google Forms, a questionnaire was created asking participants' views on a static time of use electricity tariff. Because heating is expected to constitute a large part of future electricity demand, participants were asked to imagine that their heating system works exactly as it currently does, but is powered by electricity. Responses were requested to the scale items using five Likert-type choices labelled: strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree. Such scales are widely used in social surveys, and allow participants to position themselves on an attitude continuum (Oppenheim, 1992). The choice of a five-point scale (rather than seven or more) was taken because they have been shown to produce sufficient discrimination in responses while taking less time to complete (Evans & Rooney, 2010). All scale items appeared on one (long) page of the survey; subsequent pages included other questions relevant to the wider study. A link to the survey was circulated via email and social media, and effort made to direct it to people outside of academia and energy research. In total, 63 responses were collected over a period of approximately a month in summer of 2014. A comparison of the number of click-throughs to the survey link and completed surveys suggest that there was a fairly high dropout rate, with comments in the survey indicating that this was due to the large number of items in the scale.

Exploratory and confirmatory factor analyses (EFA and CFA) were used to explore the pilot results. While recommendations vary about the sample size necessary to conduct a useful factor analysis, 50 has been suggested as an absolute minimum (de Winter et al., 2009). Since further validation of the final scale would take place with a much larger sample in the main study (if shown to be valid), 63 was deemed an acceptable size (and there was limited prospect of generating significantly more responses in the time available for this stage of the research). An initial EFA was conducted in SPSS 22. Oblique (promax) rotation was used since it was expected that there would be some correlation between the constructs. The attitude and

behavioural intention variables were excluded from this stage of the analysis since the primary interest was in the predictor variables, and high correlation between any of the predictor variables and these dependent variables would cause them to load highly together making the results less useful. The EFA showed the perceived usefulness items loading well together, as did those for perceived ease of use. The control variables loaded into several factors, but did not differentiate particularly well between the intended control constructs (control over spending, service level, timing and autonomy). This was thought possibly to be due to the 'fatigue' which qualitative feedback suggested was associated with responding to a very long list of reasonably similar items. In the interests of parsimony, and because it had been decided that they would not be manipulated in the subsequent experimental phase of research, it was decided to remove the information and choice constructs from the scale at this point.

Confirmatory factor analysis (CFA) allows relationships to be proposed between items and latent variables on the basis of theory (Matsunaga, 2010). A CFA was conducted in Amos Graphics. The constructs were modelled as first order variables. Items with a standardized factor loading of less than 0.7 with their theorized latent variable were removed, with the aim of reducing the number of items for each variable to three. While there is no 'correct' number of items for an attitude scale or subscale, a single item is known to be subject to very high measurement error (e.g. Gliem & Gliem, 2003). Increasing the number of items reduces the error but can also lead to fatigue in the respondent (as, indeed, was found in this pilot study). Three items per construct was therefore considered to be a reasonable compromise between the possibility of error and potential longer completion time. Where more than three items for each variable loaded at 0.7 or above, the highest three loading variables were retained. Several measures of construct reliability and validity were checked (Table 5-1). One item in each of the perceived ease of use, time control and autonomy constructs was substituted with one with lower loadings as this increased the overall convergent and discriminant validity. The final scale showed mostly acceptable values (defined as follows: composite reliability > 0.7; average variance extracted (AVE) > 0.5 to show convergent validity; maximum shared variance (MSV) < AVE and average shared variance < AVE to show discriminant validity (Hair (Jr) et al., 2013)), except for autonomy which showed marginally lower reliability and somewhat poor convergent and discriminant validity, and timing which showed somewhat poor discriminant validity.

**Table 5-1: Measures of construct reliability and validity. * indicates values which do not meet required thresholds.**

| | Composite reliability | Average variance extracted | Maximum shared variance | Average shared variance |
|---|---|---|---|---|
| **Perceived usefulness** | 0.951 | 0.866 | 0.370 | 0.236 |
| **Autonomy** | 0.682* | 0.446* | 0.738* | 0.485 |
| **Comfort control** | 0.899 | 0.748 | 0.738 | 0.432 |
| **Cost control** | 0.869 | 0.688 | 0.526 | 0.324 |
| **Perceived ease of use** | 0.814 | 0.596 | 0.370 | 0.244 |
| **Timing control** | 0.831 | 0.625 | 0.736* | 0.403 |

This process yielded three items for each of the six proposed predictor variables. Rather than dropping the constructs which did not adhere to the thresholds, it was decided to retain them so as to test them on the larger sample size of the main study, accepting that (especially) discriminant validity may be problematic. The pilot results had indicated that there was little variation in responses to the attitude and behavioural intention to use items, so two and one items (respectively) were selected to measure these variables. The final scale therefore consisted of 21 items, as listed in Table 5-2. The refinement process resulted in a large majority of positively framed items. Since an even balance is recommended (Oppenheim, 1992), one of the items was rephrased to alter its framing[14] -- but the scale still fell somewhat short of achieving a good balance. Limitations associated with this are discussed in section 7.1.

[14] The substitution was of “Being on this plan would not require a lot of mental effort” with “Being on this plan would require a lot of mental effort”.

**Table 5-2: The items used to measure the extended TAM constructs. The following introduction was included: 'How much do you agree or disagree with the following statements?' All used a five-point response scale as follows: strongly disagree; somewhat disagree; neither agree nor disagree; somewhat agree; strongly agree. *These items did not load well with their target constructs and were removed for the final analysis. **These items were used as a measure for the 'general control' construct (see section 5.3.1).**

| Construct | Item |
|---|---|
| Comfort control | With this plan I could make sure my home is warm enough.** |
| | With this plan I would have enough control over the comfort of my home. |
| | With this plan I could be sure of a pleasant environment in my home. |
| Spending control | With this plan I would have enough control over my spending on electricity. |
| | With this plan I would be in direct control of how much I spend on energy. |
| | With this plan I would be in charge of my spending on electricity. |
| Timing control | With this plan I would be able to do things when I want to do them.** |
| | With this plan I would be able to heat my home at the times I want to heat it. |
| | This plan would make it hard for me to do things when I want to do them.* |
| Autonomy | With this plan I would have enough control over my life.** |
| | With this plan I would be too dependent on automation.* |
| | With this plan I would be free to live as I choose. |
| Perceived ease of use | Learning to live with this plan would be easy for me. |
| | Being on this plan would require a lot of mental effort.* |
| | I would find this plan easy to use. |
| Perceived usefulness | This plan would be beneficial for me. |
| | I could see myself saving money with this plan. |
| | Being on this plan would save me money. |
| Attitude | Generally, I have a positive attitude towards this plan. |
| | I think that this plan is a good idea. |
| Behavioural intention to use | If it was offered to me now, I would sign up to this plan. |

### 5.2.2 Sample and online survey deployment

The research agency Populus[15] was commissioned[16] to administer the survey. They retain a panel of members of the British public whom they invite to respond to online surveys in return for an incentive. They also promote surveys through online advertisement on a range of websites. Invitation recipients and advert viewers together constituted the sampling frame. Representative quotas are set for the research population on the basis of gender, age, social grade and region. Once quotas have filled up, further potential participants are screened out. The survey was positioned at the beginning of an omnibus survey which also contained questions on other topics, so respondents did not know the subject of this study in advance of deciding to participate. A total of 2302 people completed the omnibus. Because quota sampling was used rather than probability sampling, it is not possible to associate a response rate with this figure. Of these, 2178 described themselves as main/joint energy bill-payers. Only these 2178 progressed to the study survey, with the remainder skipping straight to the next section of the omnibus.

The targeted sample size was 2000 participants – this sample size was calculated using G*Power 3.1.7 software as being sufficient to detect relatively small effects (mean difference of >0.2 Likert response scale points) significant at $p<.05$ in one-way analysis of variance (ANOVA) (one of the planned analyses – see section 5.2.5) at a power of 0.8. It also meant that the individual experimental groups would be large enough to undertake reliable regression analysis with a relatively large number of independent variables (e.g. demographic, attitudinal). It is in line with sample sizes employed by Parkhill et al. (2013) and Oseni et al. (2013) when exploring similar questions.

The data were checked for unengaged participants by calculating the standard deviation of their responses to a 21-item extended TAM scale (see section 5.2.1), an approach recommended by Gaskin (2015). In total, 176 people showed no variation in their responses. As certain items intended to measure the same

[15] See http://www.populus.co.uk/

[16] As stated in the front matter to this thesis, some of the funding for this research was contributed by Smart Energy GB, the industry-funded statutory body set up to coordinate public engagement with the smart meter roll-out in Great Britain. Specifically, they covered approximately 80% of the cost of administering the survey. Beyond financial support and assistance in the dissemination of the final report (Fell et al., 2015) they did not influence the conduct of the research in any way. No restrictions were imposed or requests or suggestions made on the questions which were included or the sharing of any results.

constructs were negatively worded, this means they either provided self-contradictory responses or selected the 'neither agree nor disagree' option for all items. Such responses were not considered to contribute useful information to the study and these participants were therefore excluded from the analysis, yielding a final valid participation of N=2002.

In spite of the use of quota sampling, gender and age variation in the sample was different to that found in census data for the population of Great Britain (ONS 2012). As such, a weighting factor was calculated based on these variables and applied in the analysis (Table 5-3). The weighting factors bring the age and gender distribution of the sample in line with that of the population, with values above 1.00 boosting the weight given to data collected from participants in relevant age/gender groups, and vice versa. For example, in this survey, men aged 18-24 were underrepresented relative to the population, so their data received a higher weighting. A table summarizing the demographic variables for each experimental group is available in appendix 10.8. Data collected on other quota factors (region and social grade, using default categories supplied by Populus) were not directly comparable with census data so it was not considered justifiable to further weight the data to adjust for them.

**Table 5-3: Weighting factors used in the data analysis.**

| Age | Males | Females |
|---|---|---|
| 18-24 | 1.72 | 0.82 |
| 25-34 | 1.30 | 1.23 |
| 35-44 | 1.04 | 1.30 |
| 45-54 | 0.91 | 1.13 |
| 55-64 | 0.82 | 1.04 |
| 65+ | 0.62 | 1.02 |

### 5.2.3 Questionnaire design

Participants proceeding to the survey were first asked to identify their electricity supplier, principally to ensure that people had their supplier's identity in mind when they completed the remainder of the survey. Participants were then assigned into one of five groups via simple randomization. Each group was presented with a short outline of the rationale for DSR, as follows:

> *Some electricity tariffs try to encourage people to use electricity at times of day when it is cheaper and cleaner to produce.*

*The next three pages ask for your thoughts on one such tariff. Please read the description and imagine that **it is being offered to you by your present electricity supplier**. A couple of points to note:*

- *People on standard flat-rate tariffs pay on average **14p per unit of electricity** (one unit is enough to run a fridge-freezer for a day, a PC for three hours or half a cycle of a washing machine).*
- *More people are expected to use electric heating in future. If you have a non-electric heating system, please imagine that **your heating system works exactly as it does now except that it runs on electricity**.*

The first line offers a brief statement of the benefits of DSR tariffs. This was included because this information is commonly seen in commercial tariff offerings. For example, from following suppliers:

- ActewAGL (Austrialia): '*On a long–term basis, shifting a household's electricity load to off peak/economy times has the potential to reduce the impact on the electricity network and maintenance requirements, which helps to keep electricity costs down.*'[17]
- Delmarva Power (US): '*Energy Wise Rewards is a tool for Delaware customers to take more control over your energy use, save money on your energy costs, and take a big step towards a more sustainable lifestyle.*'[18]

It was then emphasized that the tariff to be shown was being offered by the participant's current supplier. This was important because one of the key interests in the study was the role of trust in the DSR operator, and the supplier was a plausible operator, familiar to the participant about whom it would be possible to gauge the level of trust (see later in this section). The supplier's identity had been elicited by the previous question, and was therefore easy for the participant to call to mind. Brief information was also included about the current cost of electricity and the consumption of a range of appliances. This was done so that it was clear how prices in the tariffs differed from usual (rather than having participants focus on whether they thought the absolute level of price per unit was fair). Finally, participants were requested to imagine their heating was powered by electricity (the reasons for this are discussed in detail in section 5.2.4 below).

[17] http://www.actewagl.com.au/Help-and-advice/How-to-read-your-meters/Time-of-use-rates.aspx, accessed 13 August 2015
[18] https://energywiserewards.delmarva.com/de/index.php, accessed 13 August 2015

Each group was then shown a description of one DSR product offering, which was different for each group (see section 5.2.4). Directly below the tariff description, participants were asked to respond to the items forming the extended TAM scale as described in section 5.2.1. The items appeared over three separate screens, each accompanied by the tariff description, and the order of the items on each screen was varied at random for each participant (the order of the screens was the same each time).

For ease of completion, the survey software provided by Populus makes one question available per page. There followed a series of questions that can be classified into the following themes:

- Information on the participant's current electricity tariff, payment method, switching behaviour and home occupancy
- Attitudinal measures
- Information on the participant's home, heating system and insulation
- Demographic information that was collected using default Populus questions later in the survey

The full questionnaire is provided in appendix 10.9, while Figure 5-2 provides a schematic overview of the participant route through the questionnaire.

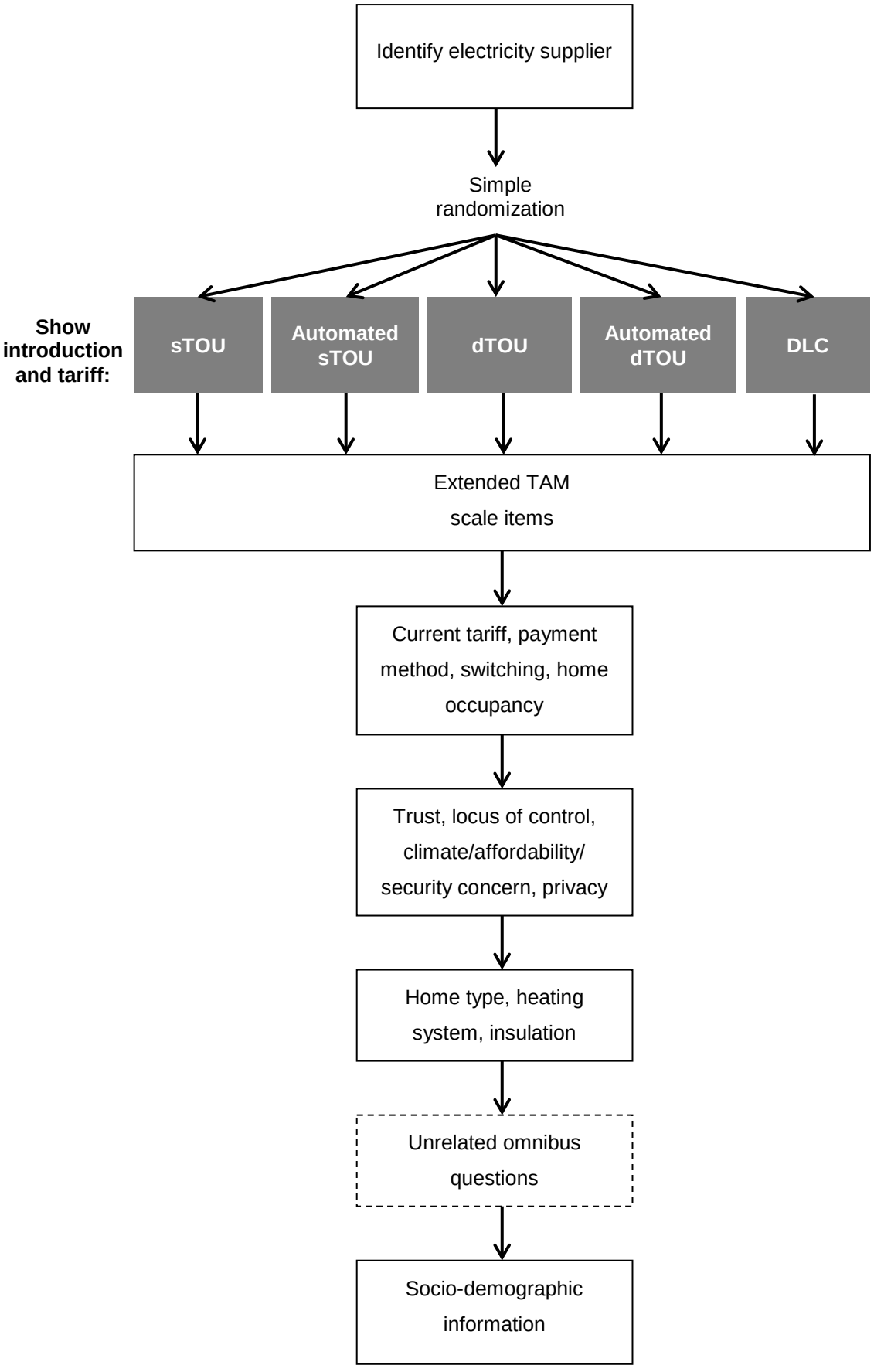



**Figure 5-2: Summary diagram of participant route through survey.**

The following paragraphs provide explanation of those questions whose topics receive more substantive consideration in the analysis.

The items for trust (Table 5-4) were adapted from a set used by the consumer organization Which? (2013b) in their tracking of UK public attitudes towards energy suppliers. They were selected because data was available to allow the results of this study to be compared with other work, which can enhance validity. They also broadly reflect three principal dimensions of trust as highlighted by Bhattacherjee (2002): ability (i.e. to perform their main function, which is providing electricity), integrity (e.g. in charging a fair price) and benevolence (e.g. in acting in the customer's best interest).

The privacy concern items (Table 5-4) were adapted from items originally developed by Culnan & Armstrong (1999). These items were selected because they tap ideas of both 'information privacy' and 'non-intrusion', which were identified in chapter 2 as being relevant to DSR. The scales were adapted to shorten the original items, and also to introduce the UK-specific telephone preference service (TPS).

Locus of control (introduced in chapter 2) was considered in this study both in the conventional psychological sense and as it relates to people's actual ability to take action in relation to energy use or their energy tariff. For this reason a combination of measures were used. A question was included to determine whether or not people thought they would be able to switch their energy supplier if they wanted to (with the option to indicate why). A number of items were also included with the intention of measuring perceived locus of control (Table 5-4). The last two items are based on items used by Spence et al. (2010) to measure personal agency and perceived responsibility in relation to climate change, as these came conceptually closest to the construct of interest.

Based on the evidence provided in chapter 2, three hypotheses were tested in relation to these constructs:

- H8: Trust in electricity supplier positively influences DSR tariff acceptance.
- H9: Privacy concern negatively influences DSR tariff acceptance.
- H10: Perceived locus of control is associated with DSR tariff acceptance.

Finally, three items were included to measure participants' level of concern about future climate change, affordability of energy and energy security. These 'trilemma'

concerns drive much of energy policy and assessments of their relative importance can have different implications for courses of actions that policy incentivizes. The items used are adapted from Spence et al. (2010). It should be noted that that the item dealing with energy security focuses on power cuts since this was viewed as more immediately relevant to DSR than issues associated with energy imports (for example).

**Table 5-4: Items and response scales used to measure trust, privacy concern, locus of control and climate/security/affordability concern.**

| Construct | Introduction | Item | Response |
|---|---|---|---|
| Trust | To what extent do you think your electricity supplier is trustworthy or untrustworthy with regard to the following… | • Ensuring you always have a reliable electricity supply<br>• Providing information that you can easily understand<br>• Charging a fair price for your electricity<br>• Acting in your best interest | Very trustworthy, Fairly trustworthy, Neither trustworthy nor untrustworthy, Fairly untrustworthy, Very untrustworthy |
| Privacy concern | Please indicate if each of the following statements apply to you: | • I have refused to give information to a company because I thought that information was too personal<br>• I have signed up to TPS [Telephone Preference Service, which allows people to opt out of receiving sales or marketing calls]<br>• I have asked an organization to take my name off of a mailing or email list | Yes, No |
| Locus of control | How much do you agree or disagree with the following statements? | • The amount of money my household spends on energy is largely out of my control<br>• There are external factors that make it difficult for me to take actions to reduce my energy bills<br>• It is hard to reduce your energy bills even if you want to | Strongly agree, Somewhat agree, Neither agree nor disagree, Somewhat disagree, Strongly agree |
| Climate/ affordability/ security concern | How concerned or not concerned are you about each of the following | • About climate change, sometimes referred to as 'global warming'<br>• That in the future, electricity will become unaffordable<br>• That in the future there will be power cuts | Very concerned, Fairly concerned, Neither concerned nor unconcerned, Not very concerned, Not at all concerned |

The questionnaire was pre-tested during the process of extended TAM scale development described in section 5.2.1. The pilot survey questionnaire included an additional question on each page asking for comments on whether any of the questions were unclear, and a final comment box for general comments on the questionnaire. A final check of the questionnaire was performed by experts at Populus who recommended some small changes in question wording.

### 5.2.4 DSR tariffs

As set out in chapter 2, three main kinds of DSR signal are available: price, volume and direct control. This research focused only on price and direct control. There were a number of reasons for this. New price-based offerings are assumed in the Government's cost benefits analysis of the smart meter roll-out as likely to be first to market in Great Britain (DECC, 2014d) and are therefore of most immediate interest. The concept of off-peak pricing is already familiar to many through products such as the Economy 7 tariff, so it was anticipated that such offerings would be easier than unfamiliar ones (e.g. volume based) for participants to take in in the short time available during the survey. While direct control options are generally viewed as being somewhat further off, there are services currently available which involve this (e.g. the radio teleswitch), while there are currently no volume based DSR offerings available. They are also especially interesting in the context of this research, which is concerned with perceptions of personal control in the context of outside influence. Both price-based and direct control-based offerings have been tested in recent trials in Great Britain (in the Low Carbon London (Carmichael et al., 2014) and Customer-Led Network Revolution (Bulkeley et al., 2014) trials). This means that we have some understanding of how people are likely to respond to them, but as yet little robust evidence as to how attractive they might be. Finally, this research is also interested in the role of automating response to DSR signals, and how this affects perceptions of control and acceptability. Both price- and volume-based approaches permit automation, but price was selected for the reasons described above. The overall number of DSR offerings that could be tested was constrained by the number of participants (see section 5.2.2).

Having established the basis of the tariffs to be tested, their individual characteristics had to be determined. One aspect of this stems from where control could objectively be considered to reside – or where the response to a signal is actuated. This may be manually done by an occupant of a home, automatically done on their behalf (e.g. by a washing machine that can be programmed to run at

the lower price period), or triggered externally by a third party. These options were covered by including a time of use tariff with and without automated response to price changes, and a direct load control option. The second aspect to be varied was the predictability of the signal. This is important for two reasons. Firstly, as discussed in section 2.1.1, having the ability to affect demand dynamically to reflect events that are not predictable in the long term (e.g. wind generation and system faults) is a valuable characteristic for DSR operators. Secondly, previous research and the focus group research presented in chapter 4 indicate that predictability is an antecedent of perceived control and may therefore have a bearing on control expectations and acceptability of different DSR options. The acceptability of unpredictability is therefore both important and uncertain, so worthy of research. This was captured in the study by the inclusion of both a static and a dynamic time of use tariff. Direct load control offerings available on the market at the moment (for example in the US) are mainly used to respond to unpredictable (in the long term) events, so a predictable version of this was not included in the tariff options. A combination of the above yielded the following types of DSR offering:

- Static time of use tariff
- Static time of use tariff with automated response to price changes
- Dynamic time of use tariff
- Dynamic time of use tariff with automated response to price changes
- Direct load control tariff

Several other factors could also have been investigated, for example the ability to override direct load control, whether people were asked to opt in or out of responding to signals, and price differentials in time of use pricing. Again, however, constraints on the number of participants (and therefore experimental groups) made this impractical (and a good subject for future work – see chapter 7).

The experiment was designed in such a way as to strike a balance between the ability to test specific hypotheses through controlled manipulations, the imperative to include a range of realistic DSR tariffs that are likely to be commercially feasible in the short to medium term, and constraints on sample size. As such, the following hypotheses were tested while other differences between tariffs in the constructs of interest were also explored:

- H11: Direct load control negatively influences perceived autonomy compared to DSR offerings that do not involve direct load control.

    - *Justification:* Direct load control gives an external entity direct control of the action of technology in the home, objectively reducing autonomy.
- H12: Greater predictability in a time of use tariff positively influences timing control.
    - *Justification:* Predictability was identified by the focus groups and analysis presented in chapters 2 and 4 as an antecedent of control, most specifically with respect to timing of activity.
- H13: Having the option of automated response to a time of use tariff positively influences perceived ease of use.
    - *Justification:* One of the reasons for introducing automation is to make tasks easier for humans (see chapter 2).
- H14: Time of use tariffs positively influence spending control compared to a flat rate tariff.
    - *Justification:* Focus groups suggested that where people associated time of use tariffs with having more control in comparison to flat rate tariffs, this was in relation to spending.

The actual tariff details presented to participants were designed to be as realistic as possible to enhance what is sometimes referred to as ecological validity (but which may better be described as their representativeness (Coolican, 2014: 111)). The design of the static tariff was based on a tariff developed by Frontier Economics (2012) for use by British Gas in the Customer-Led Network Revolution (CLNR) DSR trial mentioned above. Designed to be commercially viable in 2020, the basic structure of the tariff is shown in Table 5-5.

**Table 5-5: The three-tier static time of use tariff structure used in the Customer-Led Network Revolution trial (reproduced from Bulkeley et al. (2015: 3)).**

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

Currently, and at the time of the study in 2014, the average price per unit (kWh) for electricity in Great Britain on a standard rate tariff is 14.05p (Energy Saving Trust, 2015). Applying the conversion rates in Table 5-5 to this yields the following prices: day rate 13.5p, evening rate 28.0p, night rate 9.7p. For ease of comprehension these were rounded as follows for the current study: low rate 10p, medium rate 14p, high rate 30p. The tariff used in the CLNR trial also includes a standing charge, but it was decided not to explicitly include this in the tariff information provided to participants in this study. While doing so would have been more reflective of the real tariffs, there is evidence that consumers lack information and understanding about electricity tariffs (e.g. Ofgem, 2008). It was considered likely that while most people are aware of paying a price per unit of electricity, awareness of standing charges is low. Including mention of a standing charge on this basis might have risked attracting attention away from the variable rate pricing, which was principal focus of the study. The time bands and weekend pricing were preserved as for the CLNR trial.

The structure of the dynamic tariff employed was loosely based on that designed for E.On for use in the Low Carbon London trial (see Carmichael et al. (2014: 29) for summary details). That tariff was designed to be revenue neutral, so customers fitting a modelled standard profile for electricity consumption would pay the same for electricity over the course of a year. This tariff also used low, medium and high price tiers, but they varied unpredictably throughout the week with customers receiving an alert to changes at 8.30am the day ahead via SMS message and an in-home display. Some changes were made to the basic tariff structure for

implementation in the current research. Firstly, the Low Carbon London trial restricted high price events to three days per week. Because of the extra explanation already required to describe the workings of the dynamic tariff, this was considered likely to overcomplicate the offering and therefore not mentioned. It was also decided to retain the unit pricing as used for the static tariff (i.e. 10p, 14p and 30p) – the price differentials in the Low Carbon London trial were significantly higher. This was done as a control measure to ensure that the experiment tested the effect of unpredictability rather than price differential.

Both the direct load control tariff and the automated options were framed in terms of space heating, by asking participants to imagine that their heating system works as it does currently but is powered by electricity. Before describing how these tariffs were presented, it is necessary to justify this decision. Electrification of heating is a key part of the UK's plans for decarbonisation, and as such heating is expected to be an increasingly important constituent of electrical load (DECC 2013). It currently accounts for the majority of household energy use in the UK (Palmer & Cooper, 2013). It often already has elements of automation – for example, more than 90% of UK homes with central heating have a timer to control it (BRE, 2013). Finally, electric heating systems provide promising opportunities for DSR because electricity consumption can be lowered for a short time with only a small impact on room temperature, especially when heat pump technology is employed (Arteconi et al., 2013). For these reasons heating is likely to be a major target for DSR activity.

The principal drawback associated with framing the tariffs in relation to heating is that currently more than 80% of homes in the UK use gas as the primary heating fuel (Palmer & Cooper, 2013). The characteristics of gas heating are quite different from those of electric. For example, the optimal heat output temperature of a heat pump is lower than it would be for a gas boiler (Fawcett, 2011). It is therefore not likely that future electric heating systems will be experienced by users in the same way as their current gas equivalents. However, the main aim of this study is primarily to investigate the how perceptions of where control resides in the context of DSR affects acceptability. It was judged that the benefits of focusing on heat (as outline above) outweighed this disadvantage. Heating system characteristics such as this are discussed further in chapters 6 and 7.

To permit the option of an automated response to price changes and direct load control, all tariffs options were presented as being offered with a free 'smart'

thermostat. As demonstrated by Figure 5-3, such offers have been available recently on the market in Great Britain.

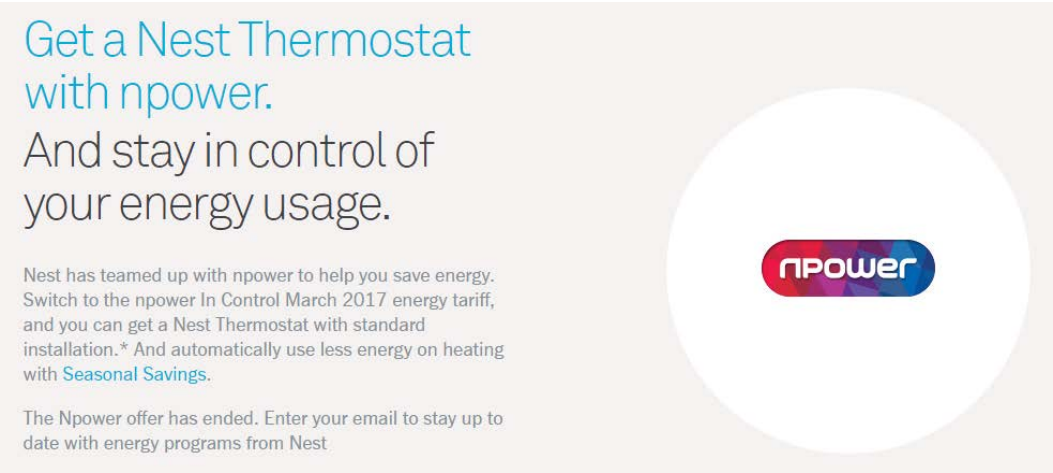



**Figure 5-3: Offer of a free Nest thermostat with nPower tariff (screenshot from https://nest.com/uk/energy-partners/npower/, accessed 12 August 2015).**

The thermostat was offered in all cases to maximise consistency between the experimental groups. In all cases, the ability of the thermostat to allow control online or via smartphone was highlighted, since this is a commonly cited selling point of these devices. For both the static and dynamic time of use tariffs, a duplicate tariff was created which was identical in all respects except that the thermostat was described as being programmable by the participant to respond to price changes and therefore minimize cost, for example by preheating during low price periods.

The direct load control tariff was based mainly on tariffs available in the US, which are usually applied to air-conditioning. An example of this is the Summer Advantage Program offered by Entergy (http://bit.ly/1Ht4JPY, accessed 12 August 2015). Customers agree to have a device installed on their air-conditioning system which allows it to be remotely cycled off and on by the utility at times of high demand for electricity, in return for a cash reward of $40 for the initial installation and $40 per year for participation. For an extensive listing of such products in the US – and therefore principally applied to air-conditioning – please visit http://bit.ly/1IPuJGC (accessed 12 August 2015).

Two major changes were made to this basic design for implementation in this trial. Firstly, to make it more appropriate for the British context (and for reasons described above), it was applied to electric heating rather than cooling. Secondly, instead of offering a cash reward, the tariff was framed in terms of a reduction on the usual price per unit of electricity (in this case from 14p to 12p). This was done to

retain consistency with the framing of the other tariffs which also gave prices per unit. In reality, this level of discount on unit price may be something of an overestimate – it has been estimated that load shedding using heat pumps may only be valued at £10-15 per year (Frontier Economics, 2012). Compared to the UK average gas bill (primarily for heating) of £752 per year (DECC, 2015c), this value is rather lower than the 14% reduction on unit price used in this study. The reduction was selected so as to be noticeable to the participant and less significant than the change to the low rate in the time of use tariffs. Additionally, in reality, a standing charge would likely apply, bringing the unit rate change closer in line with what might be expected in a commercial offering. However, it is relevant to note that Tempus Energy, a new energy supplier which offers DLC-based tariffs in the UK, has recently introduced a tariff for 'flexible domestic customers' which charges a flat 10.9p per unit rate with no standing charge (Vallely, 2015), which is in line with the details presented in this study.

The direct load control was framed as being achieved via the smart thermostat. It involved the participant's energy supplier being able to cycle their heating off and on during periods of high demand for electricity, with a constraint on the amount of deviation permitted from the set-point temperature of 1 $^{o}$C. The thermostat would indicate when this was happening, and unlimited overrides were possible. These conditions were intentionally quite low-impact, as previous research (including the focus groups presented in chapter 4) had suggested that people have strong reservations about direct load control offerings, and it was anticipated that as such more 'benign' offerings were more likely to be offered in reality (at least initially). Furthermore, the use of temperature constraints on the response, as well as the options of overrides (including unlimited overrides) are seen in a variety of US offerings (e.g. Degrees of Difference[19], which uses a 4 $^{o}$F (~2 $^{o}$C) limit on temperature increase, and a conEdison offering[20] which allows unlimited overrides).

In summary, the five tariff options presented to participants had the following characteristics:

- static time of use tariff (hereafter *sTOU*) with price bands: weekend (anytime)/weeknight (8pm-7am) 10p/unit; weekday (7am-4pm) 14p/unit; weekday peak (4pm-8pm) 30p/unit.

[19] https://www.reliant.com/en/residential/save-energy/smart-energy/earn-bill-credits.jsp, accessed 12 August 2015

[20] http://www.coned.com/energyefficiency/residential_directloadcontrol_program.asp, accessed 12 August 2015

- static TOU with automated response to price changes, e.g. by pre-heating the home when prices are lower (*automated sTOU*)
- dynamic TOU (with price band alerts 24 hours in advance, prices as for sTOU) (*dTOU*)
- dynamic TOU with automated response to price changes (with price band alerts 24 hours in advance) (*automated dTOU*)
- a lower than average (12p/unit) flat rate tariff with direct load control of heating (cycling of heating off and on at times of high demand, unlimited override, effect on temperature capped to 1 $^{o}$C) (*DLC*)

Because the time and space available in the survey was limited, the way in which the tariffs were actually presented to participants was important. Key aims were to convey the main characteristics of the tariff succinctly in a way that was easily understandable to participants, and resembled how such tariffs might be presented to in reality. Use of colour was avoided in case they prompted any unwanted brand associations. The final tariff descriptions are presented below:

*Static time of use:*

On this plan you have **three different rates** for your electricity – low, medium and high. They apply for **fixed times** of the day and week. Here are the rates:

| | |
|---|---|
| **Weekend (all day)** | **Low rate (10p/unit)** |
| **Weeknight (8pm-7am)** | **Low rate (10p/unit)** |
| **Week day (7am-4pm)** | **Medium rate (14p/unit)** |
| **Weekday peak (4pm-8pm)** | **High rate (30p/unit)** |

If you sign up your electricity supplier will give you a smart thermostat which allows you to monitor and change the temperature in your home remotely online or with a smartphone app.

*Static time of use with automation:*

On this plan you have **three different rates** for your electricity – low, medium and high. They apply for **fixed times** of the day and week. Here are the rates:

| | |
|---|---|
| **Weekend (all day)** | **Low rate (10p/unit)** |
| **Weeknight (8pm-7am)** | **Low rate (10p/unit)** |
| **Week day (7am-4pm)** | **Medium rate (14p/unit)** |
| **Weekday peak (4pm-8pm)** | **High rate (30p/unit)** |

If you sign up your electricity supplier will give you a smart thermostat which allows you to monitor and change the temperature in your home remotely online or with a smartphone app. You can also set it to **respond automatically** to price changes so that you have heat and hot water when you need them but at the lowest cost (e.g. by pre-heating your home when prices are lower).

*Dynamic time of use:*

On this plan you have **three different rates** for your electricity – low, medium and high. The times when these rates apply **change** depending on predicted amounts of wind power and national electricity demand. Your electricity supplier will send you an alert (by text message, email or an in-home energy monitor) the day before, letting you know when each rate applies. Here are the rates:

| | |
|---|---|
| **Low rate** | **10p/unit** |
| **Medium rate** | **14p/unit** |
| **High rate** | **30p/unit** |

If you sign up your electricity supplier will give you a smart thermostat which allows you to monitor and change the temperature in your home remotely online or with a smartphone app.

*Dynamic time of use with automation:*

On this plan you have **three different rates** for your electricity – low, medium and high. The times when these rates apply **change** depending on predicted amounts of wind power and national electricity demand. Your electricity supplier will send you an alert (by text message, email or an in-home energy monitor) the day before, letting you know when each rate applies. Here are the rates:

| | |
|---|---|
| **Low rate** | **10p/unit** |
| **Medium rate** | **14p/unit** |
| **High rate** | **30p/unit** |

If you sign up your electricity supplier will give you a smart thermostat which allows you to monitor and change the temperature in your home remotely online or with a smartphone app. You can also set it to **respond automatically** to price alerts so that you have heat and hot water when you

need them but at the lowest cost (e.g. by pre-heating your home when prices are lower).

*Direct load control:*

On this plan you pay a **lower than average flat rate** for your electricity – **12p/unit**.

If you sign up your electricity supplier will give you a smart thermostat which allows you to monitor and change the temperature in your home remotely online or with a smartphone app.

While you are on this plan, the thermostat also allows your electricity supplier to **cycle your heating off and on** for short periods at times when there is high demand for electricity, but this will only have a small (less than 1 degree C) effect on the temperature of your home. Your thermostat will show when this is happening, and you have the option to override it.

### 5.2.5 Data analysis

This section briefly summarizes the analyses conducted; more specific detail is given in the relevant results sections. Following the cleaning of data for unengaged participants (as described in section 5.2.2), categorical data were dummy coded for use in later regression analysis, and the responses to negatively phrased items were reverse coded. A list of the main dummy variables is provided in section 5.3.4. Data analysis was conducted in IBM SPSS Statistics 22 and IBM SPSS Amos 22. Exploratory factor analysis was conducted to determine the internal validity of the scales proposed to measure the trust, privacy concern and locus of control constructs. Harmann's single factor test (Podsakoff et al., 2003) and confirmatory factor analysis were employed to check for multicollinearity between the extended TAM constructs, while the latter also permitted assessment of how well individual items loaded onto their intended constructs.

One-way ANOVA was used to test for significant differences between the groups in behavioural intention to use the tariffs and attitude, perceived usefulness and ease of use. Because the control constructs are theoretically closely aligned, multivariate analysis of variance (MANOVA) was also employed here to protect against inflated error rates that can be associated with multiple univariate analyses (Haase & Ellis, 1987). Two-way ANOVA was used to test for interaction effects between predictability (i.e. whether prices changed at fixed, known times as for sTOU or unpredictably as for dTOU) and automation (the DLC group was excluded from this

analysis). There is debate as to whether it is appropriate to use parametric tests such as ANOVA on data obtained through the use of Likert-type response scales (Jamieson, 2004). This is because they yield ordinal data rather than continuous which, strictly speaking, should be used in parametric statistics. However, it has been argued that, especially when summative scales based on multiple items are used, the data approaches being continuous in nature and it is therefore appropriate to use (more powerful) parametric procedures (Carifio & Perla, 2008). This was the approach taken in this research. Finally, multiple regression was employed to identify associations between the extended TAM constructs and acceptance of the different DSR offerings, as well as other attitudinal (i.e. trust, privacy concern, locus of control, climate/affordability/security concern) and demographic variables.

## 5.3 Results

### 5.3.1 Pre-analysis

Chi square tests and one-way ANOVA were conducted for socio-demographic and attitudinal variables (excluding the extended TAM scale) to check that the experimental groups did not differ significantly from each other in these respects. For the variables included in the analysis presented here (see list in section 5.3.4 below), none of the groups differed significantly from each other at the level $p<.05$. The results of these tests are shown in appendix 10.10.

Harman's single factor test was conducted in SPSS to determine whether the items of the extended TAM scale were best explained by the constructs they were intended to measure or by a single underlying construct (Podsakoff et al., 2003). This was done by running an exploratory factor analysis without rotation and extracting a single factor only. Because this single factor explained more than 50% of the variance between the items, the test was failed, meaning that any subsequent analysis based on the individual constructs would likely be susceptible to problems associated with high multicollinearity (see below in this sub-section). The possible reasons for this are discussed in chapter 7. Confirmatory factor analysis was performed using IBM SPSS Amos 22 to assess how well individual items loaded onto their theorized latent constructs (e.g. perceived usefulness, spending control, etc.). Items with factor loadings lower than 0.7 were excluded (see Table 5-2), and the means of the remaining items calculated to yield a mean value for each construct. Confirmatory factor analysis (without the excluded items)

also showed high multicollinearity between all the constructs measured, with interfactor correlations ranging from .81 to 1.00 (Figure 5-4).

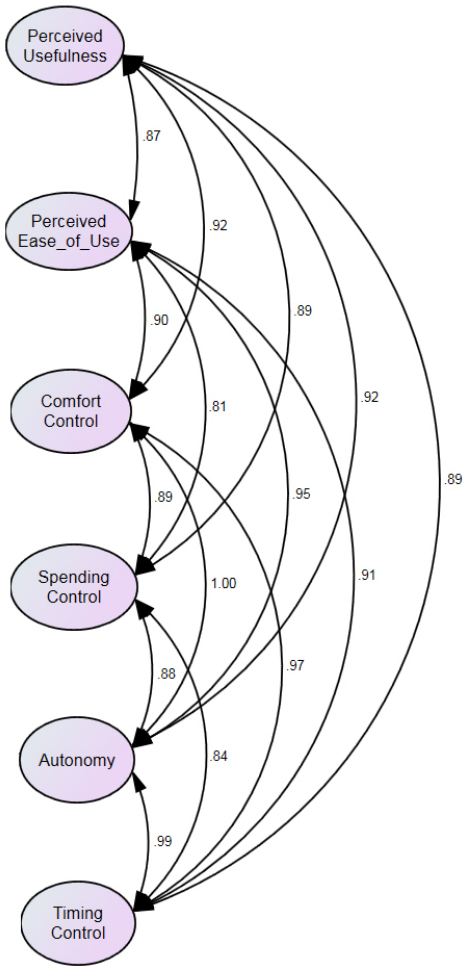



**Figure 5-4: Interfactor correlations between the extended TAM constructs.**

The highest correlations (all >.95) were between the control over comfort, timing and autonomy variables. The correlations between perceived usefulness and perceived ease of use, and between these constructs and control over spending, were all <.90. The extreme multicollinearity in the comfort, timing and autonomy variables suggested that the items measuring these constructs may have been perceived by participants as conceptually very close to each other.

Because high multicollinearity can be problematic for analysis (making it difficult to determine the relative influence of each construct), the decision was taken to treat the three highly collinear constructs (comfort control, timing control and autonomy) as a single construct for the purposes of all further analysis presented here. This new construct is referred to as 'general control'. The number of items for this construct was also reduced to three (to bring it in line with the other constructs) by

selecting the one item for each of the comfort, timing and autonomy that loaded most strongly on the new general control factor. A new confirmatory factor analysis revealed that interfactor correlations now ranged from .82 to .91, with the highest correlation (.91) between the general control construct and perceived ease of use (and .82 between general control and spending control). Acknowledging the potential problems associated with such high multicollinearity (discussed further in section 5.4), analysis proceeded on this basis.

The next sub-section presents the overall acceptance of the tariffs and the results of one-way ANOVA and MANOVA to compare the extended TAM constructs between experimental groups. The results of two-way ANOVA for tariff predictability/automation are then given, followed by the results of multiple regression to show the relative contribution of the extended TAM constructs to overall acceptance.

### 5.3.2 Tariff acceptability

Figure 5-5 shows the breakdown of responses to the item asking whether people would sign up to the tariff presented (reflecting their behavioural intention to use it). DLC provoked the most positive response, and was the only tariff for which more people gave a positive (37% strongly or slightly agreed they would sign up) than a negative (30% strongly or slighted disagreed) response. Strongly or slightly positive responses for the TOU tariffs ranged from 25% for dTOU to 30% for sTOU, while strongly or slightly negative responses showed a greater range across the tariffs, from 33-43%. For the TOU tariffs, at least twice as many people were strongly negative as were strongly positive in each case.

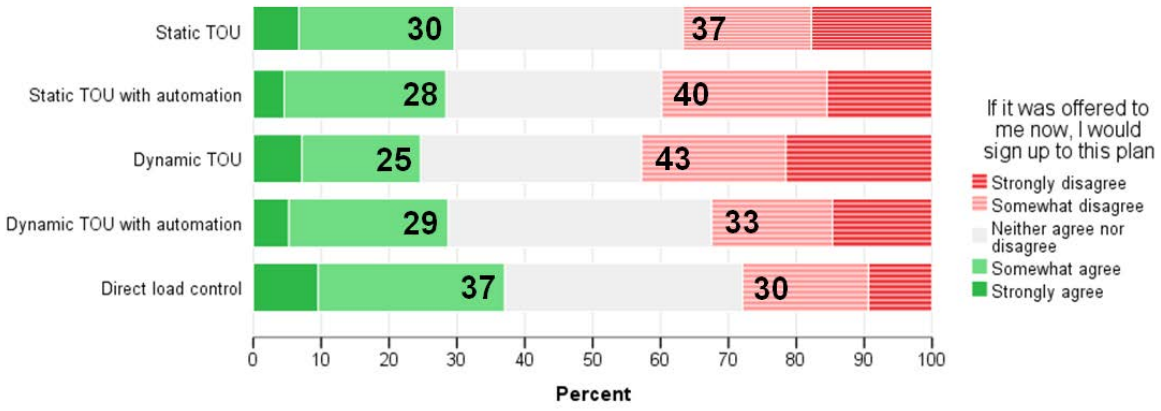



**Figure 5-5: Responses to the item measuring behavioural intention to use each tariff. The numbers on the chart represent the percentage of participants either strongly or somewhat in favour of, or strongly or somewhat against, switching to the tariff in question.**

One-way ANOVA was used to test for differences in each of the extended TAM constructs between the experimental groups, and post hoc tests with Bonferroni correction were employed to test for pairwise differences. It showed that reported behavioural intention to use the tariffs differed significantly ($F$[4,1976]=7.534, $p$<.0005). Post hoc tests revealed that behavioural intention to use DLC was significantly higher than the other tariffs (sTOU $p$=.006, automated sTOU $p$=.001, dTOU $p$<.0005) except for automated dTOU, where it neared significance ($p$=.060). There was no significant difference between the intention to use any of the TOU tariffs (interaction effects were observed however – see next sub-section). Attitudes towards the tariffs (measured by asking participants whether they thought the tariff was a good idea, and whether they had a positive attitude towards it) also differed significantly ($F$[4,1976]=16.810, $p$<.0005). DLC was viewed significantly more positively than all the other tariffs (for sTOU, automated sTOU and dTOU all $p$<.0005, automated dTOU $p$=.003). Indeed, only 13% of people strongly/somewhat disagreed with the item stating that the DLC tariff was a good idea. Automated dTOU was viewed significantly more positively than dTOU ($p$<.0005), as was automated sTOU ($p$=.020). No other significant differences were identified between people's attitudes towards the tariffs.

Figure 5-6 shows the mean value for each tariff for the original TAM constructs perceived usefulness and perceived ease of use.

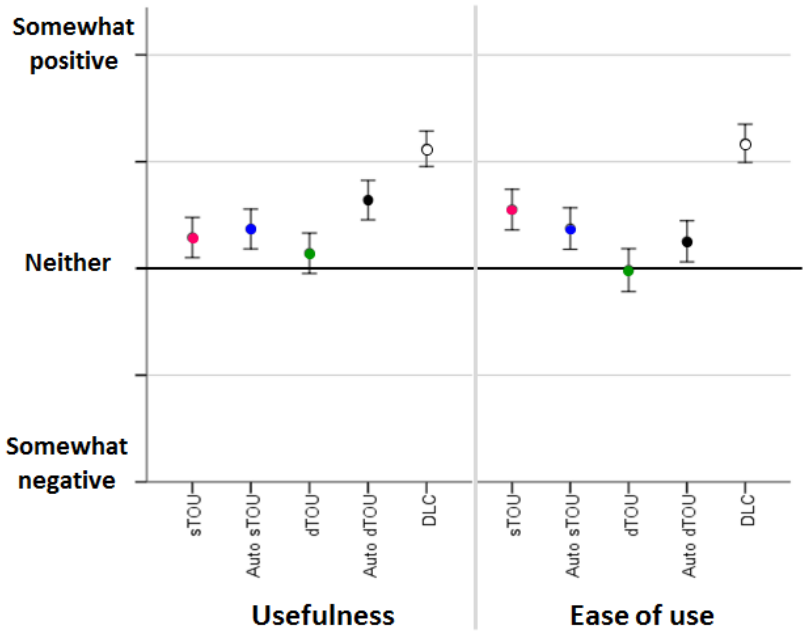



**Figure 5-6: Mean values for perceived usefulness and perceived ease of use for each tariff. Error bars represent 95% confidence intervals.**

One way ANOVA again revealed significant differences between the groups:

- *Perceived usefulness*, $F(4,1976)=18.385$, $p<.0005$. Post hoc tests showed DLC was viewed as more useful than all of the other tariffs (all $p<.0005$ for sTOU, automated sTOU and dTOU, and $p=.007$ for automated dTOU). Automated dTOU was viewed as significantly more useful than dTOU ($p=.001$), with no other significant differences between the tariffs.
- *Perceived ease of use*, $F(4,1976)=21.112$, $p<.0005$. DLC is viewed as easier to use than all the other tariffs ($p<.0005$ in all cases). The sTOU tariff is seen as significantly easier to use than dTOU ($p<.0005$). No other significant differences were detected between the groups, although automated sTOU was close to being viewed as significantly easier to use than dTOU ($p=.051$).

Figure 5-7 shows the results for the new control constructs: general control and spending control.

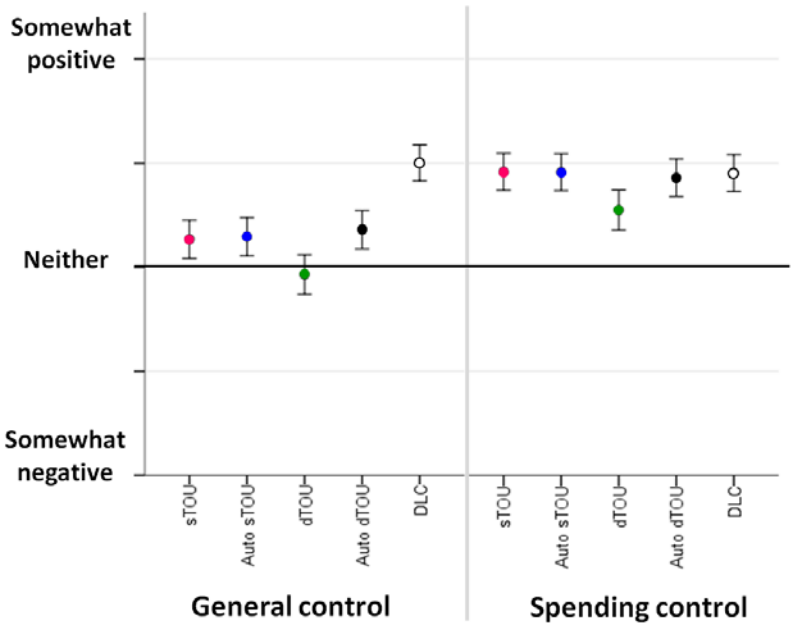



**Figure 5-7: Mean values for general control and spending control for each tariff. Error bars represent 95% confidence intervals.**

Because the general and spending control constructs are theoretically closely related, one-way MANOVA was employed to control for the possibility of inflated error rates. It included both control constructs as dependent variables. As multicollinearity can be problematic for MANOVA the Pearson correlation was calculated for the mean responses to general control and spending control items.

Pearson correlation was .688, which is lower than a range of proposed thresholds[21] and was therefore considered acceptable. MANOVA showed significant differences between groups on the combined control variables, $F(8,4084)=14.783$, $p<.0005$, Wilks' $\Lambda=.945$, partial $\eta 2=.028$. Univariate analyses with Tukey post hoc tests showed the following significant differences for the individual control constructs:

- *Spending control,* $F(4,2043)=2.444$, $p=.045$, partial $\eta 2=.005$. Tukey post hoc tests did not show any significant pairwise differences between the experimental groups.
- *General control,* $F(4,2043)=18.158$, $p<.0005$, partial $\eta 2=.034$. Tukey post hoc tests revealed that DLC was viewed as giving significantly more general control than all the other tariffs ($p<.0005$). sTOU ($p=.046$), automated sTOU ($p=.041$) and automated dTOU ($p=.006$) were all viewed as giving significantly more general control than dTOU. No other significant differences between tariffs were found.

The hypotheses tested in this section (dealing with the role of external control, and variable vs flat-rate pricing), and their findings, were as follows:

- H10: Direct load control negatively influences perceived autonomy compared to DSR offerings that do not involve direct load control.
    - Autonomy was combined into general control construct, revised hypothesis disproved for all tariffs.
- H14: Time of use tariffs positively influence spending control compared to a flat rate tariff.
    - Disproved.

### 5.3.3 Interaction between predictability and automation

Two-way ANOVA was employed to test whether there was interaction between the predictability of the tariff (i.e. whether prices changed at fixed, known times as for sTOU or unpredictably as for dTOU) and having the option of automation. Data are mean ± standard error, unless otherwise stated. There was found to be a statistically significant interaction between predictability and automation for behavioural intention to use, $F(1,1627)=4.593$, $p=.032$, partial $\eta 2=.003$. People were statistically significantly more likely to say they would switch to the

[21] Proposed thresholds include .90 (https://statistics.laerd.com/spss-tutorials/one-way-manova-using-spss-statistics.php, accessed 17 June 2015) and .80 (http://www.statisticssolutions.com/checking-the-additional-assumptions-of-a-manova/, accessed 17 June 2015).

unpredictable dTOU tariff where there was the option of automation (0.21±0.08) than where there was not, $F(1,1627)=6.731$, $p=.010$, partial η2 =.004. Neither a main effect of predictability nor of automation was significant. Significant interactions were also revealed for the following constructs:

- *Attitude towards use*, $F(1,1627)=6.653$, $p=.010$, partial η2=.004. The option of automation significantly improved people's attitude towards the unpredictable dTOU, $F(1,1627)=18.720$, $p<.0005$, partial η2=.011. Where automation was not offered, its predictability improved people's attitude towards sTOU, $F(1,1627)=6.219$, $p=.013$, partial η2=.004.
- *Perceived usefulness*, $F(1,1627)=5.062$, $p=.025$, partial η2=.003. The option of automation significantly increased people's perceived usefulness of the unpredictable dTOU, $F(1,1627)=14.216$, $p<.0005$, partial η2=.009.
- *Perceived ease of use*, $F(1,1627)=5.615$, $p=.018$, partial η2=.003. The option of automation made the unpredictable dTOU appear significantly easier to use, $F(1,1627)=4.508$, $p=.034$, partial η2=.003. Where automation was not offered, the predictable sTOU was perceived as significantly easier to use, $F(1,1627)=17.280$, $p<.0005$, partial η2=.011.
- *General control*, $F(1,1627)=5.292$, $p=.022$, partial η2=.003. The option of automation led to people expecting to have significantly more general control for the unpredictable dTOU, $F(1,1627)=11.287$, $p=.001$, partial η2=.007. Where automation was not offered, the predictable sTOU was perceived as giving significantly more general control, $F(1,1627)=7.434$, $p=.006$, partial η2=.005.

No significant interaction between automation and predictability was shown for spending control, but where there was no automation, the predictable sTOU tariff was viewed as giving significantly more spending control than unpredictable dTOU, $F(1,1627)=4.030$, $p=.045$, partial η2=.002. In summary, having the option of automation made people more willing to switch to the dTOU tariff, improved people's attitudes towards it (this was the largest effect), and increased people's perceived usefulness, ease of use and general control on the tariff. Where the option of automation was not offered, the predictable sTOU tariff was viewed more positively (i.e. attitude) than dTOU, and as being easier to use (the largest effect) and giving more control over spending. Overall, it should be noted that the effect sizes of these interactions as shown by the partial η2 were small.

The hypotheses tested in this section (dealing with the effects of tariff predictability and availability of automation), and the findings, were as follows:

- H12: Greater predictability in a time of use tariff positively influences timing control.
    - Timing control was combined into general control construct, revised hypothesis confirmed where there was no offer of automation, but not confirmed where automation was offered.
- H13: Having the option of automated response to a time of use tariff positively influences perceived ease of use.
    - Confirmed for dynamic tariff, but a negative association was found for the static tariff.

### 5.3.4 Relative contribution of the extended TAM constructs

To test hypotheses H1-2 and 4-7, a multiple linear regression was run to identify associations between behavioural intention to use each tariff (outcome variable) and the predictor variables: perceived usefulness; perceived ease of use; spending control; and general control for the different tariffs. The following factors were controlled for by including them in the regression model (dummy variables are listed for each, with reference category in italics, see Table 5-4 for attitudinal items):

- Age (18-24, 25-44, *45-64*, 75-74, 75+)
- Gender (female, *male*)
- Housing tenure (*home owner*, social tenant, private tenant, other tenure)
- Employment status (*employed full-time*, employed part-time, not in paid employment, retired)
- Annual household income (less than £14k, £14k to less than 28k, *£28k to less than 48k*, £48k+, income not disclosed)
- Presence in the household of children aged 15 or under (*not present*, present)
- Whether the participant lived alone (*does not live alone*, lives alone)
- Whether the participant was already on a TOU tariff (*not on TOU tariff*, on TOU tariff)
- Whether they had ever, or in the last year, switched energy supplier (*never switched*, switched but not in last year, switched in last year)
- Their assessment of how easy their home was to heat (two items, five-point response scale)

- Their stated level of trust in their current electricity supplier (four items, five-point response scale)
- Their perceived locus of control in relation to energy use (three items, five point response scale)
- Their stated level of concern about future climate change, and reliability and affordability of energy (five-point response scale)
- Their level of privacy concern (three items, binary response)

Three models were run using hierarchical regression, as follows: model 1 (basic socio-demographic and attitudinal variables only), model 2 (model 1 plus original TAM variables) and model 3 (model 2 plus perceived control variables). The results are reported in Table 5-6 (detailed results are only included for the four main constructs of interest – for discussion of the results regarding trust, privacy concern and locus of control please see section 5.3.5 below). The issue of multicollinearity has been discussed in the pre-analysis section above. A standard collinearity metric is the variance inflation factor (VIF). A range of tolerances have been proposed for an acceptable VIF threshold, usually ranging from 5 (e.g. Rogerson, 2001) to 10 (e.g. Kennedy, 2003) – although some lower thresholds have also been suggested (see section 5.4). In this case the VIFs for the four constructs of interest ranged from 2.56 to 4.68.

**Table 5-6: Multiple regression results showing association of the four constructs of interest with behavioural intention to use each of the DSR tariffs. Adjusted $R^2$ values are given for model 1 (basic socio-demographic and attitudinal variables only), model 2 (model 1 plus original TAM variables) and model 3 (model 2 plus perceived control variables). B = unstandardized regression coefficient; Beta = standardized coefficient. * = *p*<.05, ** = *p*<.01, *** = *p*<.001. The reported *F*, $R^2$ and *p* values include the other socio-demographic and attitudinal variables that were included in the regression for model 3, but for clarity the detailed significance and effect size information is only provided for the four main constructs of interest.**

| | Model 1 | Model 2 | Model 3 | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tariff | Adj. $R^2$ | Adj. $R^2$ | Adj. $R^2$ | F (df) | Variable | B | Std. Error | Beta |
| sTOU | .172 | .711 | .736 | F(32,390) =37.721*** | Perceived usefulness | .583 | .063 | 0.486*** |
| | | | | | Perceived ease of use | .298 | .051 | 0.253*** |
| | | | | | Spending control | -.231 | .058 | -0.177*** |
| | | | | | General control | .330 | .061 | 0.269*** |
| Automated sTOU | .100 | .620 | .656 | F(32,340) =23.186*** | Perceived usefulness | .358 | .063 | 0.297*** |
| | | | | | Perceived ease of use | .282 | .057 | 0.243*** |
| | | | | | Spending control | .014 | .071 | 0.010 |
| | | | | | General control | .399 | .070 | 0.321*** |
| dTOU | .174 | .742 | .771 | F(32,380) =14.555*** | Perceived usefulness | .536 | .062 | 0.437*** |
| | | | | | Perceived ease of use | .274 | .049 | 0.237*** |
| | | | | | Spending control | -.071 | .054 | -0.057 |
| | | | | | General control | .374 | .052 | 0.306*** |
| Automated dTOU | .141 | .623 | .641 | F(32,337) =21.611*** | Perceived usefulness | .614 | .075 | 0.508*** |
| | | | | | Perceived ease of use | .205 | .059 | 0.177*** |
| | | | | | Spending control | -.116 | .073 | -0.092 |
| | | | | | General control | .295 | .068 | 0.244*** |
| DLC | .102 | .590 | .607 | F(32,369) =20.382*** | Perceived usefulness | .469 | .079 | 0.359*** |
| | | | | | Perceived ease of use | .268 | .069 | 0.223*** |
| | | | | | Spending control | -.057 | .081 | -0.043 |
| | | | | | General control | .342 | .081 | 0.272*** |

For all tariffs the explained variation in intention to use was statistically significantly (*p*<.0005) higher (as shown by change in adjusted $r^2$ value) for model 3 (where the perceived control variables were included) than for model 2 (where only the original TAM variables were included), which in turn was significantly (*p*<.0005) higher than for model 1 (including only basic socio-demographic and attitudinal variables). The measured variables in model 3 (including all socio-demographic, attitudinal and extended TAM variables) explained most variation in willingness to switch (as evidenced by the adjusted $R^2$) for dTOU (adjusted $R^2$ = .771) and sTOU, followed by automated sTOU and automated dTOU, which least variation explained for DLC (adjusted $R^2$ = .607).

Perceived usefulness was significantly positively associated with willingness to switch to all of the tariffs. It was the most important variable in terms of effect size for all the tariffs except automated sTOU, where general control was slightly more important. Perceived ease of use was also significantly positively associated with willingness to switch to all of the tariffs, as was general control. The latter was second to perceived usefulness in effect size for all the tariffs, except automated sTOU. Control over spending was significantly associated with willingness to switch only in the case of sTOU, where the relationship was negative. To test hypothesis H3, a further regression was run as for model 3 above except this time with perceived usefulness as the dependent variable. Perceived ease of use positively influenced perceived usefulness for every tariff, so confirming the hypothesis. The regression results, with effect sizes and significance for perceived ease of use (PEOU) are as follows:

- sTOU: Adj $R^2$ .722, $F(31,391)=36.285$***, PEOU Beta=.209***
- automated dTOU: Adj $R^2$ .589, $F(31,341)=18.191$***, PEOU Beta=.197***
- dTOU: Adj $R^2$ .699, $F(31,381)=31.820$***, PEOU Beta=.237***
- automated dTOU: Adj $R^2$ .684, $F(31,338)=26.775$***, PEOU Beta=.167***
- DLC: Adj $R^2$ .614, $F(31,370)=21.589$***, PEOU Beta=.208***

In summary, the hypotheses tested in this section, and the findings, were as follows:

- H1: Perceived usefulness positively influences behavioural intention to use (original TAM)
    - Confirmed for all tariffs.
- H2: Perceived ease of use positively influences behavioural intention to use (original TAM)
    - Confirmed for all tariffs.
- H3: Perceived ease of use positively influences perceived usefulness (original TAM)
    - Confirmed for all tariffs.
- H4: Comfort control positively influences behavioural intention to use (extended TAM)
    - Comfort control was combined into general control construct, revised hypothesis confirmed for all tariffs.
- H5: Spending control positively influences behavioural intention to use (extended TAM)

    - Disproved for all tariffs, with either no significant association of negative association in the case of sTOU.
- H6: Timing control positively influences behavioural intention to use (extended TAM)
    - As for H4.
- H7: Autonomy positively influences behavioural intention to use (extended TAM)
    - As for H4.

### 5.3.5 Trust, privacy, locus of control and other factors

People who judged their electricity supplier to be fairly or very untrustworthy ranged from 6% of the sample for 'ensuring a reliable supply', to 29% of the sample for 'acting in your best interest'. Regarding privacy concern, 69% and 70% of people had respectively opted not to provide personal information and asked for personal information to be removed from a database, while 55% said they had signed up to the Telephone Preference Service.

Table 5-7 shows the results of an exploratory factor analysis of the trust, privacy concern and locus of control items.

**Table 5-7: Exploratory factor analysis with promax rotation.**

| | Factor | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| **Trust (price)** | ***.853*** | -.017 | .039 |
| **Trust (best interest)** | ***.833*** | .024 | .072 |
| **Trust (info)** | ***.807*** | -.017 | -.041 |
| **Trust (supply)** | ***.559*** | .011 | -.117 |
| **Locus A** | .051 | ***.765*** | -.001 |
| **Locus B** | -.005 | ***.745*** | .039 |
| **Locus C** | -.050 | ***.690*** | -.045 |
| **Privacy (remove)** | -.024 | .005 | ***.736*** |
| **Privacy (refuse)** | .026 | -.001 | ***.464*** |
| **Privacy (TPS)** | -.059 | -.011 | ***.425*** |

As Table 5-7 indicates, there is no cross-loading between factors and the constructs exhibit reasonably good convergent and discriminant validity (the loadings are quite low, but acceptable, for the privacy concern construct). Mean scores were therefore

calculated for the trust and locus of control constructs, while a sum was calculated for the privacy construct. While loadings for all items intended to measure the trust construct were high, they were higher for the items measuring the integrity and benevolence aspects of trust (i.e. charging a fair price, providing clear information, acting in consumer's best interest) that for the ability item (i.e. provide a reliable electricity supply). It was therefore decided to use a mean score for the integrity and benevolence items (hereafter simply 'trust', and to treat the ability item separately in case this yielded any additional insights (hereafter 'trust (supply)').

Since trust, privacy concern and locus of control should be relatively stable in individuals, they should be unaffected by the experimental group which an individual was assigned to (i.e. which DSR offering each participant saw). To check this, a one-way ANOVA was performed. None of the constructs were significantly different between groups:

- Trust, $F(4,1976)=1.134$, $p=.339$
- Trust (supply), $F(4,1976)=.588$, $p=.671$
- Privacy concern, $F(4,1976)=1.427$, $p=.223$
- Locus of control, $F(4,1976)=1.780$, $p=.130$

A multiple regression was run to identify associations of the constructs trust, trust (supply), privacy concern and locus of control, with acceptance of the different DSR offerings. Table 5-8 gives the overall regression results. Specific details are included for trust, trust (supply), privacy concern and locus of control for all tariffs, along with other variables where they show significance of at least $p<.05$.

**Table 5-8: Multiple regression results for trust, privacy and locus of control. B = unstandardized regression coefficient; Beta = standardized coefficient. * = $p$<.05, ** = $p$<.01, *** = $p$<.001.**

| Tariff | *F (df)* | *Adj. $R^2$* | *p* | Construct | B | Std. Error | Beta |
|---|---|---|---|---|---|---|---|
| sTOU | *F*(28,394) =4.125 | 0.172 | <0.0005 | Trust | 0.273 | 0.073 | 0.217*** |
| | | | | Trust (supply) | 0.054 | 0.072 | 0.042 |
| | | | | Privacy | -0.160 | 0.053 | -0.141** |
| | | | | Control | 0.044 | 0.066 | 0.033 |
| | | | | Age 18-24 | 0.582 | 0.23 | 0.133** |
| | | | | Age 25-44 | 0.361 | 0.149 | 0.143** |
| | | | | Age 65-74 | -0.389 | 0.197 | -0.138* |
| | | | | Existing TOU | 0.399 | 0.143 | 0.134** |
| Automated sTOU | *F*(28,344) =2.484 | 0.100 | <0.0005 | Trust | 0.163 | 0.078 | 0.130* |
| | | | | Trust (supply) | 0.049 | 0.079 | 0.038 |
| | | | | Privacy | -0.120 | 0.057 | -0.113* |
| | | | | Control | 0.083 | 0.071 | 0.066 |
| | | | | Live alone | 0.476 | 0.157 | 0.175** |
| | | | | Concern about future power cuts | 0.15 | 0.068 | 0.137** |
| dTOU | *F*(28,384) =4.099 | 0.174 | <0.0005 | Trust | 0.375 | 0.075 | 0.286*** |
| | | | | Trust (supply) | -0.231 | 0.076 | -0.169** |
| | | | | Privacy | -0.144 | 0.059 | -0.120* |
| | | | | Control | -0.097 | 0.066 | -0.071 |
| | | | | Age 65-74 | -0.472 | 0.222 | -0.153* |
| | | | | Private tenant | 0.438 | 0.165 | 0.136** |
| | | | | Income £14-28k | -0.33 | 0.142 | -0.134* |
| | | | | Income not disclosed | -0.519 | 0.254 | -0.100* |
| | | | | Concern about future climate change | 0.135 | 0.054 | 0.128* |
| Automated dTOU | *F*(28,341) =3.168 | 0.141 | <0.0005 | Trust | 0.171 | 0.074 | 0.137* |
| | | | | Trust (supply) | 0.068 | 0.071 | 0.055 |
| | | | | Privacy | -0.256 | 0.054 | -0.245*** |
| | | | | Control | -0.005 | 0.062 | -0.004 |
| | | | | Social tenant | -0.434 | 0.162 | -0.149** |
| | | | | Existing TOU | 0.46 | 0.143 | 0.164** |
| | | | | Concern about future climate change | 0.122 | 0.056 | 0.123* |
| DLC | *F*(28,373) =2.618 | 0.102 | <0.0005 | Trust | 0.285 | 0.070 | 0.239*** |
| | | | | Trust (supply) | -0.130 | 0.074 | -0.104 |
| | | | | Privacy | -0.160 | 0.056 | -0.145** |
| | | | | Control | 0.228 | 0.069 | 0.180** |

Trust is significantly positively associated with acceptance of all the tariffs, although to a lesser degree for the automated TOU tariffs than for the non-automated tariffs

and the direct load control (DLC) option. The largest effect size was for the dynamic TOU tariff (Beta=0.286), followed by DLC and the static TOU tariff, and finally the automated TOU tariffs. The specific item dealing with trust in the reliability of supply was only significant in the case of the dynamic TOU tariff with automation, in which case there was a negative association with acceptance.

The measured level of privacy concern was negatively associated with acceptance of all tariffs – that is, the more someone reported actions taken to protect privacy, the less likely they were to accept the tariffs. The effect size was largest for the automated dynamic TOU tariff (Beta=-0.245), and in all other cases fell in the range Beta=-0.113 to -0.145. Locus of control was only significantly associated with one tariff – DLC – and in this case the more external the locus of control, the higher the acceptance of the DLC tariff. The hypotheses tested in this section, and the findings, were as follows:

- H8: Trust in electricity supplier positively influences DSR tariff acceptance.
    - Confirmed for all tariffs.
- H9: Privacy concern negatively influences DSR tariff acceptance.
    - Confirmed for all tariffs.
- H10: Perceived locus of control is associated with DSR tariff acceptance.
    - Confirmed for DLC, where external locus of control is associated with higher acceptance, but disproved for all other tariffs.

On the basis of the result that external locus of control was associated with the acceptance of the DLC tariff, two possible explanations for this were explored further. It was considered possible that (a) people who already thought that energy use was out of their control might be less resistant to the idea of external control, or (b) that people who see no other way to save money on energy might accept external control, but be no more happy about it than the average person. The above regression was re-run containing the demographic variables (with same reference categories) and locus of control only, but replacing intention to use as the dependent variable with (a) attitude towards use (measuring whether people felt positive towards the tariff) and (b) perceived usefulness (measuring their expectations of saving money on the tariff). The regression model with attitude as dependent variable was found not to be significant ($F$[28,373]=1.34, $p$=.117, adj $R^2$=.02), suggesting that people with external locus of control feel no more positive about the DLC tariff than average. However, the model with perceived usefulness as the dependent variable was significant (F[28,373]=2.09, p=.001, adj R2=.07),

and showed that external locus of control had a significant effect (Beta = .136, p=.009). This suggests that people with external locus of control were significantly more likely to think they would save money on the tariff.

Regarding the demographic and other variables:

- There are significant associations between age and acceptance only for the unautomated static and dynamic TOU tariffs. In both cases the tariffs are less popular with people aged 65-74, while for the static TOU tariff is also more popular amongst people under 45.
- Being on a TOU tariff currently is associated with higher acceptance of the sTOU and dTOU with automation tariffs.
- Tenure is significant for both dTOU tariffs, where being a private tenant is positively associated with acceptance of dTOU without automation, while being a social tenant is negatively associated with the automated dTOU tariff.
- Living alone is positively associated with acceptance of the sTOU tariff.
- Income is only significant for the dTOU tariff without automation, where income of £14-28k and non-disclosure of income with negatively associated with acceptance.
- Concern about future climate change was positively associated with both of the dTOU tariffs, while concern about future power cuts was positively associated with the sTOU tariff with automation.
- Acceptance of DLC was not significantly associated with any of the other demographic/attitudinal control factors.

Further regressions were run to determine whether reported home occupancy at different times of the day during the week and at the weekend were associated with tariff acceptability. When correcting for the demographic variables listed above, no significant association was found for any of the tariffs.

### 5.3.6 Summary of hypotheses

For ease of reference, the hypotheses and their associated findings are recapped below:

- H1: Perceived usefulness positively influences behavioural intention to use (original TAM)
    - Confirmed for all tariffs.

- H2: Perceived ease of use positively influences behavioural intention to use (original TAM)
    - Confirmed for all tariffs.
- H3: Perceived ease of use positively influences perceived usefulness (original TAM)
    - Confirmed for all tariffs.
- H4: Comfort control positively influences behavioural intention to use (extended TAM)
    - Comfort control was combined into general control construct, revised hypothesis confirmed for all tariffs.
- H5: Spending control positively influences behavioural intention to use (extended TAM)
    - Disproved for all tariffs, with either no significant association of negative association in the case of sTOU.
- H6: Timing control positively influences behavioural intention to use (extended TAM)
    - Timing control was combined into general control construct, revised hypothesis confirmed for all tariffs.
- H7: Autonomy positively influences behavioural intention to use (extended TAM)
    - Autonomy was combined into general control construct, revised hypothesis confirmed for all tariffs.
- H8: Trust in electricity supplier positively influences DSR tariff acceptance.
    - Confirmed for all tariffs.
- H9: Privacy concern negatively influences DSR tariff acceptance.
    - Confirmed for all tariffs.
- H10: Perceived locus of control is associated with DSR tariff acceptance.
    - Confirmed for DLC, where external locus of control is associated with higher acceptance, but disproved for all other tariffs.
- H11: Direct load control negatively influences perceived autonomy compared to DSR offerings that do not involve direct load control.
    - Autonomy was combined into general control construct, revised hypothesis disproved for all tariffs.
- H12: Greater predictability in a time of use tariff positively influences timing control.

    - Timing control was combined into general control construct, revised hypothesis confirmed where there was no offer of automation, but disproved where automation was offered.
- H13: Having the option of automated response to a time of use tariff positively influences perceived ease of use.
    - Confirmed for dynamic tariff, but a negative association was found for the static tariff.
- H14: Time of use tariffs positively influence spending control compared to a flat rate tariff.
    - Disproved.

## 5.4 Discussion

As in chapter 4, the findings of this phase of the research are discussed briefly here, and in greater detail as part of an integrated discussion of all the phases in chapter 7.

This chapter focused on what the possible acceptance might be of a range of demand-side response tariffs in Great Britain, and the extent to which this was associated with various dimensions of perceived control in relation to energy. Results of a representative survey experiment indicated that a direct load control tariff (allowing electricity suppliers to cycle people's heating off and on for short periods in return for a lower flat rate cost per unit) was more acceptable than the time of use tariffs presented (static and dynamic, with and without automated response). People rated it higher than the time of use tariffs in terms of giving a general sense of control (over comfort, timing of when they do things, and autonomy), control over spending, usefulness and ease of use. While it was not possible to test hypothesis H11 directly as autonomy was not analysed as an individual construct, it is likely that not only was the hypothesis (that the existence of DLC reduces perceived autonomy compared to offerings where DLC is not used) disproved, but the reverse was found to the true. This was surprising because of concerns about loss of control highlighted by previous research. It suggests that the idea of direct load control is acceptable in principle to many (possibly the majority of) people, at least when operated within tightly defined bounds and with the option to override it. The possible explanations for, and implications of, this are discussed in detail in chapter 7.

Having the option of an automated response to price changes led to people expressing significantly greater intention to use the dynamic time of use tariff (with

no significant difference from the static tariff). This finding, combined with the acceptability in principle of direct load control, should be encouraging for DSR operators because automatic responses to DSR signals have been shown to be more reliable and durable. It suggests that firms could offer the option of automated response to price changes to encourage the uptake of dynamic time of use tariffs. Overall, 25-30% of people expressed a strongly or somewhat favourable intention to use time of use tariffs. While it is difficult to infer from this what actual uptake may be, this is not inconsistent with UK Government's business case for the introduction of smart meters which is predicated on 20% uptake of static time of use tariffs by 2030 (DECC, 2013b). It is also very similar to the finding by Nicolson et al. (under review – see Fell et al. (2015) 'framing study' for a published overview) that 31% of participants were positive towards switching to a static TOU tariff, which adds to the external validity.

Hypothesis H13 held that having the option of automated response to a time of use tariff positively influences perceived ease of use. This was found to be confirmed in the case of the dynamic TOU tariff, but not the static (where there was a negative association, suggesting automation was viewed as complicating it). It was not possible to test hypothesis H12 directly as timing control was not analysed as an individual construct. General control significantly increased in the more predictable static tariff compared with the dynamic tariff (in two-way ANOVA) when there was no option of automation, confirming the hypothesis in this case (but not where automation was offered). This suggests that predictability does have a role to play as an antecedent of control, but its effects can be reduced by the addition of automation. H14 posited that time of use tariffs positively influence spending control compared to a flat rate tariff. This was not confirmed. However, it is notable that unlike for the other constructs, the DLC option (with flat rate) was not rated significantly higher – and indeed the time of use tariffs (with the exception of the unautomated dynamic tariff) were generally rated relatively highly for spending control (see also next paragraph). Possible reasons for these findings are discussed further in chapter 7, in the context of findings from other phases of the research.

Integrating perceived control constructs into the Technology Acceptance Model for application to DSR tariff acceptance yielded a small but significant increase in explanatory power. The TAM constructs on their own explained on average 52% of variability across the tariffs (on top of that associated with socio-demographic and other attitudinal variables), while the control constructs added on average 3% to

that. Perceived usefulness, perceived ease of use and general control (including items measuring the hypothesized constructs of timing control, comfort control and autonomy) were all positively associated with acceptance, confirming hypotheses H1-5 and H7. However, spending control was found not to be significantly associated with intention when controlling for the other extended TAM variables (except for the sTOU tariff, where it was negatively associated with acceptance). As such hypothesis H6 is not confirmed.

The findings of the regression should be treated with some caution due to multicollinearity between the constructs. This multicollinearity may have been caused by method-related issues such as common method variance, or to the constructs being naturally very highly correlated (discussed further in chapter 7). However, measuring the control constructs still provided useful insights. While most of the TOU tariffs were rated highly for control over spending, this was not associated with higher intention to use. This suggests that the emphasis in product design and communications should be on assuring a general sense of control (taking in considerations such as comfort and timing), rather than control over spending. It also helped highlight the areas where adding automation was most valued (again, in general control rather than spending control), which may inform communication of the benefits of automation.

Trust in electricity supplier was found to be positively associated with acceptance for all tariffs (confirming hypothesis H8), and most strongly for the static and dynamic TOU tariffs without automation and for direct load control. This has several implications for the design of DSR product offerings, who offers them, and to whom they are offered. The findings on trust should be of concern to energy industry incumbents in the UK, since levels of trust in energy companies are low relative to comparable industries. They suggest that they will need to work to improve trust amongst their customers if they are to successfully offer DSR products – or alternatively that the door is open to new entrants to the industry, perhaps known and trusted by consumers from their work in other sectors. However, they also suggest that when consumers have the option of automating their response to TOU pricing the role of trust is less important.

Privacy concern was negatively associated with acceptance (confirming hypothesis H9), most strongly for the dynamic TOU tariff with automation. This result re-emphasizes the importance of this subject in acceptance of smart energy systems in general, especially where the presence of automation means that large quantities

of data are likely to be changing hands. Somewhat surprisingly, direct load control did not have the strongest association with privacy concern, suggesting that the mere fact that an external agent is acting directly in the home is not considered to be a greater threat to privacy than having an automated (or even manual) response to price signals. Those people with an external locus of control in relation to energy use are most likely to say they would sign up to a direct load control tariff, but there was no association with the other tariffs (thus providing partial confirmation for hypothesis H10). Further analysis revealed that people with external locus of control were more likely to think they would save money on the DLC tariff, but no more likely to feel positively towards it. While targeting such people certainly should not be ruled out (indeed, it may be a way for previously disempowered people to play a larger role in the energy system), appropriate protections should be considered to ensure people are not exploited.

No consistent demographic differences were observed across the tariffs. Where age was a factor, as in the unautomated sTOU and dTOU, younger people were more likely to be accepting of the tariffs. It is not clear why this should be. One possibility is that features such as the ability to control temperature remotely via a smartphone app was less attractive to older people since they are known to be less likely to possess a smartphone (Ofcom, 2014). However, were this the case it should be expected to apply to all the tariffs since they all offered this feature. Further work would be necessary to verify whether these differences are durable and, if so, what the contributing factors may be. Existing time of use tariff customers are more willing to switch to a static time of use tariff than the general population. This is a potentially important finding because they represent people who have actually had experience of living with time of use tariffs. One possible explanation for this result is that British time of use tariff customers are generally happy with their time-based tariffs, as was found by recent qualitative research by (Consumer Focus, 2012). The implications of this result are discussed in the context of the other phases of research in chapter 7.

Main limitations of this study are discussed in detail in chapter 7. However, a few are worth pointing out at this stage. As considered in chapter 3, using online panel research may introduce systematic bias to the sample – for example over-representing people who have access to the Internet (although as Internet penetration has increased this problem is thought to have decreased (Populus, 2015)). Because the study dealt with a subject related to information and communications technology, any under-sampling of people without Internet access

may have affected the results. A random probability sample which included more people without Internet access would be required to test this – although such sampling can require more resources and introduces the possibility of different kinds of bias (e.g. non-response bias).

It is known that stated behavioural intention to act (which this study measured) does not closely relate to actual behaviour. A review by Sheeran (2002) found that, on average, 28% of variance in behaviour was explained by intention. The results presented here should therefore be viewed as indicative rather than predictive of likely tariff acceptance. However, at a time when DSR tariffs are not widely offered, they can provide a useful insight into the factors that might ultimately affect adoption. The tariffs were designed to be realistic. However, requesting that people imagine they have electric heating (while justified by the reasons provided in the methods section) may have been confusing for some. The tariffs were presented in an intentionally neutral tone, while it is likely that people will ultimately encounter such offerings through adverts which would make a more positive case for signing up.

## 5.5 Summary

This phase of research used a survey experiment to investigate the dimensions of perceived control identified by the focus groups in the preceding phase, and their associations with the acceptability of a range of DSR tariffs. The most popular tariff involved direct load control in return for a lower flat rate unit price, which was surprising given previously expressed concerns around loss of control. It suggests that DLC of heating is acceptable in principle to many people. The dynamic time of use tariff was the least popular, but a two-way ANOVA showed that offering the option of automation made it significantly more popular. This is important because dynamic tariffs allow response to less predictable inputs such as variable renewable generation and faults. High multicollinearity between the comfort control, timing control and autonomy constructs was addressed by amalgamating them into a single ‘general control’ construct. The addition of this and the spending control construct added a little explanatory power to Technology Acceptance Model, but while general control was always a significant predictor of acceptance, spending control was not. This has implications for how DSR tariffs may be designed and framed to consumers. Of the non-control factors, trust in electricity supplier (here positioned as the DSR operator) was positively associated with acceptance of all tariffs, but has less of an effect for the automated than for the unautomated TOU

tariffs. Privacy concern was associated with lower acceptance, while people who reported feeling less personal control over their energy use currently were more likely to accept DLC. These findings are discussed further in chapter 7, while the next chapter presents the final phase of research.

# 6 Experiencing control

The final research question addressed by this work focused on people's experiences of control in the context of DSR, and how these compared with their expectations. A combination of surveys and interviews were undertaken during a trial of a new 'intelligent' heating controller in south-west England in the winter of 2014/15. Sampling and data collection are discussed in detail, followed by the results with a discussion of the key findings.

## 6.1 Method

### 6.1.1 Case study selection and background

Research question 4 of this research asks, '*How do experiences of control in DSR compare to expectations?*' As discussed in chapter 3, the current study was based around a trial of an 'intelligent' heat pump control system able to respond to time of use pricing and direct load control signals, focused mainly on older social tenants in the south-west of England. The following paragraphs provide an overview of this project, hereafter known as the 'HeatSmart'[22] project. The research plan for the project is summarized, as is the actual progress of the project (which ended up diverging in some important ways from the original plan). HeatSmart was run by HomeTech[23], a private company specializing in home energy management systems, in collaboration with University College London. HomeTech has developed a new control system for heat pumps, with the following key aims/features:

- Optimized heat pump performance
- Permit central control and monitoring by HomeTech
- Automated cost-optimizing response to DSR signals
- Easy-to-use consumer interface with associated smartphone app

The main aim of the trial was to demonstrate effective performance of the control system in a field setting. HomeTech planned to conduct a randomized control trial, recruiting a sample of heat pump users and randomly assigning individual households to either a treatment group (which would receive the new control system in full functioning mode) or a monitoring group (which would receive only the

[22] Project name changed to respect anonymity of collaborating partners.
[23] Name changed.

part of the control system which monitors internal temperature, heat pump electricity use, heat pump output temperature, etc.). The trial had a longitudinal design, allowing for a period of data collection, followed by the intervention, and subsequently with all households receiving the functioning control system. HomeTech estimated that they would need to recruit approximately 120 households to show a statistically significant treatment effect.

Recruitment (coordinated by HomeTech) initially took place through advertising on a low-carbon energy information website. This approach was then modified to include contacting registered social landlords (RSLs) since these were determined as likely to have high densities of heat pump installations in relatively small geographic areas. They would also be able to facilitate contact with potential participants. Following approaches to a number of RSLs, two from the south-west of England were enlisted to take part in the trial – hereafter referred to as Valley Housing and Oak Housing[24] (a third RSL later provided a small number of homes). Participant recruitment approaches differed between the two main RSL partners. Valley Housing had, in recent years, installed heat pumps in a proportion of its retirement housing properties, which were reserved for older residents. They held coffee mornings with residents and representatives of HomeTech to present the trial, and interested individuals could volunteer to take part. Oak Housing provided access to residents of family homes, both through inviting them to attend 'event bus' events and by door-knocking.

In total, monitoring equipment was installed in 79 homes of residents who agreed to participate, with 25 ultimately receiving the functioning control system (with six participants later dropping out of the study from the monitoring group, and two leaving the group that received the controller). It was not possible to use random assignment into the different groups, since broadband connectivity issues meant that only a small sub-sample of homes were suitable to use with the control system. The control systems were therefore installed in these homes only, acknowledging the possible bias that this may introduce (discussed further in section 6.3.3). Monitoring equipment was installed in November and December 2014, with control systems being fitted in late January and early February 2015. Monitoring continued until April 2015. The project timeline is summarized in Figure 6-1.

[24] Names changed.

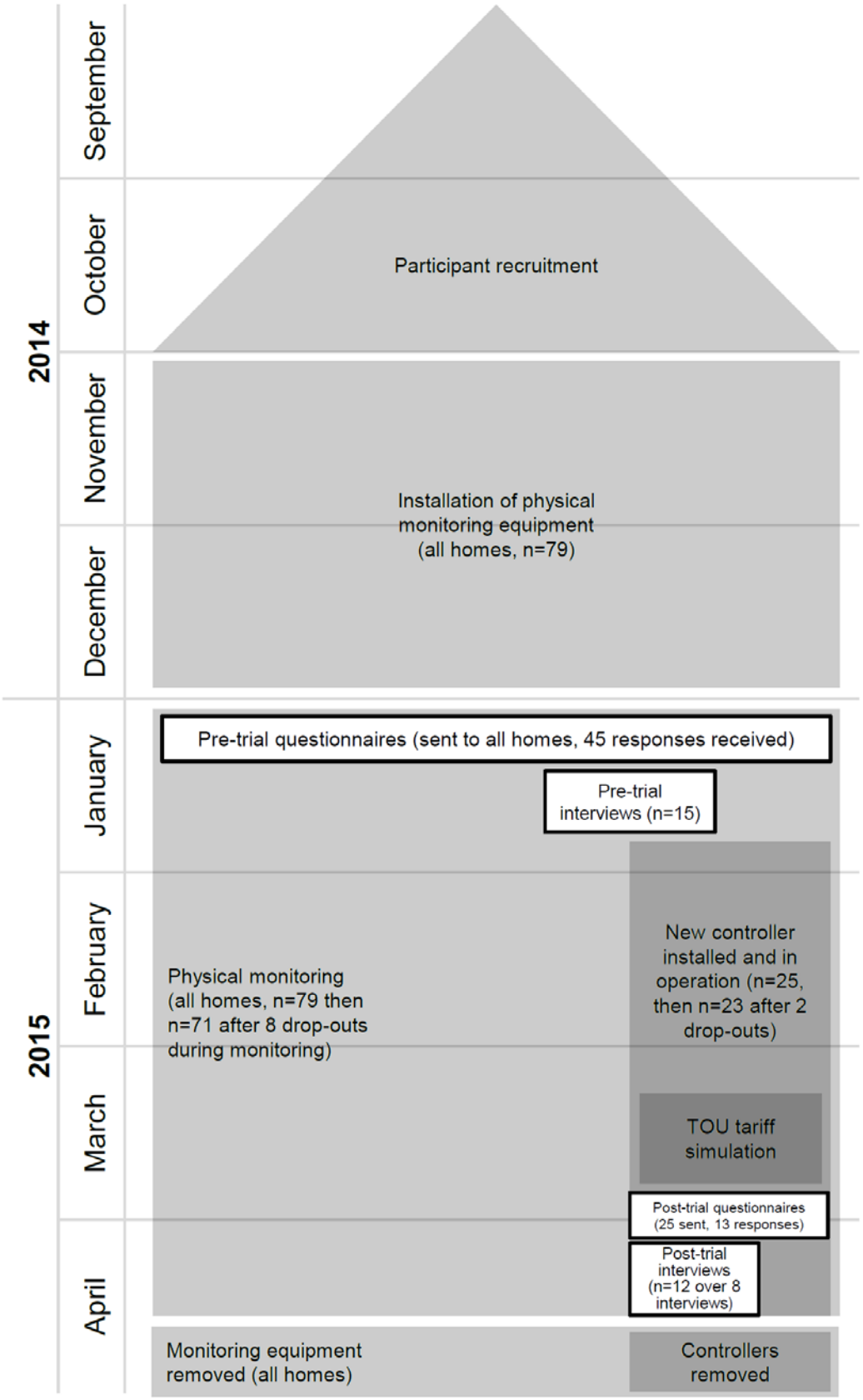



**Figure 6-1: Summary diagram of structure of the HeatSmart project. White boxes indicate gathering of data which is referred to in this thesis, while shaded boxes show trial stages and interventions.**

### 6.1.2 The control system

To understand more specifically how the trial is relevant to the current research it is necessary to explore in some more detail the precise function of the control system and how it operated during the trial. The system consisted of two main components – the heating controls and the control algorithm. The heating controls were the physical equipment fitted in the participants' homes, replacing their existing heating controls. These consisted of a tablet computer contained in (but removable from) a wall-mounted holder. The control is programmed with a weekday/weekend heating schedule which is set up by the installer on installation. This schedule can only be changed by calling HomeTech and asking them to do so remotely. HomeTech's rationale for this was to keep the actual controller interface as simple as possible. Figure 6-2 shows a screenshot of the tablet's home page. In overview, the functionality is as follows:

- The + and – symbols can be used to adjust the temperature up and down – changes remain in place until the next pre-programed temperature transition point when they reset to default.
- The 'out' button can be used to turn the heating off for a short period (e.g. two hours) if the occupant plans to go out.
- The 'away' button allows occupants to programme in absences of over a day so they can turn the heating off (to a frost protection setting) when they are away on holiday.
- The 'in' and 'asleep' buttons are for information on the status of the controller and can be used to override previous settings.


**Figure 6-2: Screenshot of the HomeTech controller.**

As well as accessing this interface via the installed tablet, participants also had the option of downloading a smartphone app providing the same functionality (which could be used anywhere). Homes fitted with monitoring equipment could be monitored in real time by HomeTech, and those with the control system could (in theory) be actively controlled in real time (for example, the thermostat set-point could be changed).

The second aspect of the control system was the control algorithm. By feeding in data including, for example, historic home temperature patterns and weather predictions, this sets out to cost-optimize the operation of the participant's heat pump. This means that it should reach the specified target temperatures and times but at lower cost than if the algorithm were not being applied. The main way in which this works is by maintaining a more constant heat output, since heat pumps work most efficiently when providing a constant input of relatively low temperature rather than attempting to heat up quickly from a cold start (Energy Saving Trust, 2014). The algorithm was also able to adapt the action of the heat pump to optimize

cost in variable electricity price scenarios. With some foreknowledge of price changes, it can undertake pre-warming when prices are lower so that acceptable temperature levels are achieved throughout higher pricing periods, while reducing the need to actively heat during these periods.

Initial plans for the trial had involved moving participants receiving the control system onto a time of use tariff for the trial period so as to test the control system's ability to optimize cost in this situation. This was ultimately not possible as new metering arrangements would have been required which were not feasible in the timescale of the trial. Instead, simulated time of use tariff information was fed into the control algorithm for periods of several days during the trial and the response of the heat pump recorded. This created a challenge for the current research because if participants were unaware that they were being subject to any DSR activity, it would be difficult to gauge their attitudes towards it. This was addressed through the design of the questionnaires and interviews – see next sections.

### 6.1.3 Survey method

A survey questionnaire was posted to all participants at the beginning of the trial prior to installation of monitoring equipment, and a follow-up survey was sent to those participants who had received a control system in late March 2015, towards the end of the trial period. Pre-trial and post-trial surveys had already been developed by HomeTech for use in the trial, but it was agreed (with HomeTech) that limited additions could be made to these for the purposes of the current research. The full questionnaires are available in appendices 10.11 and 10.12. Both collected information on age and number of occupants and occupancy patterns. The pre-trial questionnaire asked about current methods of heating control and satisfaction with current controls, while the post-trial questionnaire asked about usage of and satisfaction with the new control system. With the limited space available for additions, it was decided (for the purposes of the current study) to include a reduced version of the extended TAM scale developed for the survey presented in chapter 5. It was shortened to included one item for each of the extended TAM constructs (excluding intention to use), giving a total of seven items (see Table 6-1).

**Table 6-1: Items added to the HomeTech questionnaire. Responses were: strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree.**

| Survey | Construct | Item |
|---|---|---|
| Pre-trial | Spending control | I will be in charge of my spending on electricity for heating |
| | Timing control | I will be able to do things when I want to do them |
| | Autonomy | I will be too dependent on automation |
| | Comfort control | I will be able make sure my home is warm enough |
| | Perceived usefulness | I can see myself saving money |
| | Perceived ease of use | I would find it easy to control my heating |
| | Attitude towards use | Overall, the controller is a good idea. |
| Post-trial | Spending control | I felt in charge of my spending on electricity for heating |
| | Timing control | I felt able to do things when I wanted to do them |
| | Autonomy | I felt too dependent on automation |
| | Comfort control | I felt able make sure my home was warm enough |
| | Perceived usefulness | I saved money |
| | Perceived ease of use | I found it easy to control my heating |
| | Attitude towards use | Overall, the controller is a good idea. |

All except one of the items chosen were those used in the final analysis of the survey research (chapter 5). The exception was autonomy, where the item dealing with automation was considered preferable to ones dealing with a sense of control in life in general. This was because it applied more specifically to the scenario being experienced in the trial. Further small alterations were also made to the items:

- Items were rephrased in the future tense for the pre-trial survey and the past tense for the post-trial survey to reflect future expectations and past experience.
- Reference was made to ‘the controller’ rather than ‘this plan’ where relevant.
- The ‘spending control’ item was changed to refer specifically to spending on electricity for heating, since this is the only area in which the controller would

be expected to act (rather than in a time of use tariff, which would affect all electricity spending).

Unlike in the previous survey, the outcome measure could not be whether the participant would sign up to the tariff presented. It was also not possible to ask whether the participant would like to retain the controller, even in principle, since this was not an option in the trial and it was important to be clear about this when communicating about the benefits of participation with participants. Instead, it was decided to present participants with three hypothetical options. An introductory text was included before the edited TAM items as follows (in the post-trial survey it was worded in the past tense):

> *The HomeTech heating controller that we are trialling is designed to run your heating more cheaply and efficiently. For example, it can turn down the heating when no-one is at home and use weather forecasts to work out just how much heat will be needed. It can also help reduce "peaks" in electricity use on the national grid (these peaks make electricity more expensive and polluting for everyone). It can do this by heating more when demand for electricity is low, and less when demand is high – while always sticking to the temperatures you have set.*

Following the TAM items, participants were asked if they would choose to have the following features of the controller turned on or off: turn heating down when no-one is at home; respond to weather forecasts; reduce peaks in electricity use. In this way participants could indicate whether or not they were happy in principle with those capabilities of the controller. In the post-trial questionnaire, an existing question asked participants whether or not they would recommend the HomeTech system to a friend. While responses to this would not necessarily reflect the participants' own preferences (for example, they may think it is more well suited to a friend than to them personally), it could give a further indication of whether or not they were generally accepting of the system.

The surveys were sent out in hard copy by post, printed double-sided on A4 paper. Hard copy questionnaires were used (rather than online) as it was known that not all participants had access to the Internet. Included in the envelope were a cover slip explaining the purpose of the questionnaire and thanking participants in advance for their response, along with a stamped addressed return envelope. Please see appendix 10.13 for these additional materials. Pre-trial questionnaires were posted to all participants, while post-trial questionnaires were only posted to

those who had received the control system (since its purpose was to gauge use of and satisfaction with that system). As well as returning questionnaires in the post, some completed questionnaires were also collected by operatives installing the monitoring equipment or during the conduct of the post-trial interviews. Questionnaires were returned to HomeTech, the data coded and anonymized by participant number, and passed to the author for analysis of the relevant sections.

### 6.1.4 Interview method

#### *Sampling*

Two rounds of interviews were held (see chapter 3 for rationale). Telephone interviews were scheduled to take place prior to or shortly after installation of monitoring equipment (but before controller installation), and longer face-to-face interviews towards the end of the trial once the controller had been in place for at least a month.

A series of selection criteria were used to decide who would be approached about taking part in an interview, based on pre-trial survey responses. A question was included in the pre-trial questionnaire asking if the respondent was happy to be contacted about taking part in interviews for the trial. In total, 35 participants indicated their assent to be contacted. Next, a check was performed as to which trial group the participant had been assigned to. While in the original plan all participants were ultimately scheduled to receive the control system, those in the first treatment group would have had the longest exposure to the system by the time the follow-up interviews took place and were therefore targeted. Of the 35 participants who assented to be interviewed, 15 had at that time been assigned to that group.

Responses to the item asking whether participants would select to have the controller's ability to reduce peaks in electricity use turned on were then examined. The intention was to select an even balance of people with each preference, allowing exploration of a range of people's reasons for this choice, and tracking of whether the decision following experience of the control system was consistent with their expectation. However, only two participants who fulfilled the criteria of assenting to interview and being in the group first receiving the controller selected the 'off' option. So as to be able to explore reasons for this choice with a larger range of people, the selection criteria were loosened to include people in the monitoring only group who had selected the 'off' option for the system's ability to reduce peaks. This yielded a total of five participants selecting this option. The

remaining assenting participants in the group scheduled to receive the controller had selected the 'on' option – all were contacted for interview. As a number of participants proved uncontactable in the time allotted, this yielded a total pre-trial interview sample of *n*=15 participants who successfully provided an interview.

All pre-trial interviewees were asked at the end of the interview if they would be happy to be contacted again for a post-trial follow-up interview, and all gave their assent. The original intention was to contact a sub-sample of around ten of these for the post-trial interview, based on an even balance by original preference on whether or not to have peak reduction ability turned on or off. A lower number of participants was considered preferable for these interviews since the longer duration would provide much more data for analysis, which combined with the logistics of conducting the interviews in person would make a higher number impractical from the point of view of resources. As described above, however, the original planned trial group allocations were not observed and the control system was installed only in those properties where it was technically feasible. This meant that many of the pre-trial interviewees did not in fact receive the control system, while certain participants who were not considered for pre-trial interview did receive it. So as to provide a suitable sample size for post-trial interview, it was decided to conduct post-trial interviews with participants who had not undergone a pre-trial interview.

Because of the high proportion of older participants in the trial (see Figure 6-3), and given other constraints (e.g. reduced size of group receiving the controller), it was decided to focus the post-trial interviews on this demographic so as provide potentially more robust evidence for findings for this group, rather than collecting more diffuse data for a wider demographic range of participants. There was also some evidence from the previous stage of the current research (described in chapter 5) that older people were less accepting of certain approaches to DSR. Sampling was therefore focused on participants living in retirement housing provided by Valley Housing, allowing the study to explore this interesting and important demographic group in greater detail. Four of the pre-trial interviewees were in this group and had had the control system installed. An additional six participants with the control system at Valley Housing were therefore targeted to reach the intended sample size of ten. Of these only five could be reached, and one agreed to be interviewed but subsequently had to drop out for health reasons. This left four additional participants who had not taken part in a pre-trial interview to add to the four who had, yielding a final post-trial interview sample size of eight

participants. Because other household members were encouraged to take part in the interviews where appropriate, the final interview sample was *n*=12 (over a total of eight interviews).

### *Data collection*

As described in chapter 3, pre-trial interviews were conducted over the telephone while post-trial interviews were held face-to-face in participants' homes. Pre-trial interviews were arranged by telephoning targeted participants and sorting out a suitable time to call them for the interview. They took place over a period of roughly a week in mid-January 2015, after monitoring equipment had been installed in participants' home but before installation of any control systems. The duration of the interview was kept intentionally quite short, to around 15 minutes. This was to encourage participation and because previous work has shown that telephone interviews tend to last for less time that equivalent interviews using other modes (Gillham, 2005; Irvine et al., 2013). Interviews were conducted by the author, and began with an explanation of the research and a request for permission to record the interview. The guide/note sheet for the pre-trial interviews can be found in appendix 10.14, but the main themes were as follows:

- How did they hear about the trial?
- Why did they decide to take part?
- What do they hope the control system will do for them (with examples)? How does their current system/controls work for them?
- Are they on Economy 7? (This gave a reason to introduce the aim of DSR.)
- What are their views on the DSR functionality of the system (following brief explanation), and do they have any concerns?

The opening questions were primarily of interest to HomeTech, but also followed good interview practice by first posing tangible questions which are easy to answer to make the participant feel more comfortable talking (Raworth et al., 2012). The question dealing with their hopes and expectations for the controller was intended partly to capture that information, but also to allow the participant the opportunity to describe problems they may be experiencing with their existing system. This was expected to be helpful in attributing any subsequent issues following control system installation to either the existing system or the new controller. The final questions focused on DSR and attempted to capture information on people's current views towards it. This was important in establishing a benchmark to which their subsequent experiences could be compared. At the end of the interview participants

were asked if they had any questions of their own, and whether they would be happy to take part in a post-trial interview. The interviews were all audio recorded, and detailed notes subsequently made based on the recordings.

The post-trial interviews were also arranged by telephoning participants and asking if they would be prepared to take part, followed up by a confirmation letter with an information and consent form (appendix 10.15). They were conducted in participants' homes over the course of two days in mid-April 2015. By this point participants had been living with the new control system for approximately two months. Participants were advised that interviews were expected to last no longer than an hour. Where possible, the participant was encouraged to have other household members present for the interview (see chapter 3). In accordance with standard practice, it was emphasized to participants at the beginning of the interview that there were no right or wrong answers and that it was important to the research to hear their honest opinion (Krueger & Casey, 2000).

The interview guide used for the post-trial interviews can be found in appendix 10.16, but the main themes were as follows:

- How easy was the controller to use – initially and now?
- How have they been using it?
- Did it allow them to maintain the desired temperature?
- Did it fit with their schedule?
- How did it affect their spending on electricity?
- What were their views of the DSR capability of the control system, and DSR in general?
- What was their overall view of the system?

These themes were largely reflective of the extended TAM constructs and were used to explore more thoroughly how people conceived of and understood them in the context of having experience of automated DSR. All interviews were audio recorded and later transcribed verbatim. Content analysis of both the pre-trial and post-trial interview data was conducted by the author in NVivo 10 using codes generated from multiple passes of the data, and collecting these into themes in the same way as the process described in chapter 5. However, in this case the content analysis was somewhat more 'directed' (Hsieh & Shannon, 2005) in that views on previously identified control motivations, antecedents, etc. were specifically elicited in the questioning and sought and coded for in the data.

### 6.1.5 Ethical considerations

The HeatSmart trial was approved by the UCL Research Ethics Committee (project ID 3760/003). The key concerns around the research described here were the same as for focus group research described in chapter 4, namely inconvenience to participants and concerns around confidentiality. These were addressed in the same way as for the focus group research – by endeavouring to arrange interviews at convenient times for participants and providing information on the study and on anonymity in sharing of results (see appendix 10.15). However, the trial also involved extra issues which were not present in the focus group work.

Firstly, many of the participants were older residents living in retirement housing. Retirement housing provides extra services beyond that of usual accommodation – for example, a warden is on call and health alarm systems are installed. However, living in retirement housing does not mean that an individual should necessarily be considered to be especially vulnerable, although they may be. Indeed, the notion that older people are inherently more vulnerable has been blamed for an excess of caution having led to under-researching of this population (Russell, 1999). Nevertheless, it was important to carefully assess vulnerability on a case by case basis and to look for signs that interviews were becoming onerous. This only happened on one occasion, where a participant began to talk about recent health problems they had experienced. In this case the planned interview structure was discarded and the researchers spent some time discussing the participant's issues and making sure that the participant had support (they did, from a sister), before terminating the interview. Another issue was that, in the case of this trial, technology was being installed in people's homes which had the potential to affect how well they might be able to heat it. While this was not within the control of the author, any reports of discomfort or problems that were picked up in interviews were immediately fed back to HomeTech for investigation. Since HomeTech were able to remotely monitor functioning of the control system and temperature in people's homes, this provided arguably more security against the threat of breakdown that the existing system (indeed, this was one of the intended benefits of the HomeTech system for application in retirement homes).

## 6.2 Results

In total, the pre-trial survey was posted to 78 participants and responses were received from 45, giving a response rate of 58%. The post-trial questionnaire was sent to the 25 participants who had received the control system, and responses

were received from 13, yielding a response rate of 52%. Of the participants who responded to the post-trial survey, three did not respond to the pre-trial survey, meaning that only ten participants completed both surveys. The survey data is therefore considered to be of most use in respect of participants' expectations of the system (and of DSR), but of very limited use in respect of experiences and comparing experiences to expectations due to the small sample size available. Statistical before-after comparisons were not considered feasible because the already small sample size was diminished even further by missing values in the completed questionnaires. The results of this study therefore draw mostly on the qualitative data collected through interviews, introducing the quantitative data where possible and relevant. Where quotes are provided the participant is identified by a pseudonym.

### 6.2.1 Background and expectations

The surveys and interviews provide useful background information on participants' satisfaction with and use of their existing heating controls and heating system in general. Figure 6-3 shows the age distribution of the occupants of participating households who returned the pre-trial survey. Of a total of 78 occupants, 44 (56%) were aged 65 or over, compared to a proportion in Great Britain of 11% (ONS, 2012). Of the 45 participating households who completed the survey, 30 (65%) contained only people aged 65 or over, while five (11%) contained at least one child under 18. Specific demographic data for the person who completed the questionnaire are not available as they were only required to provide this information at the household level.

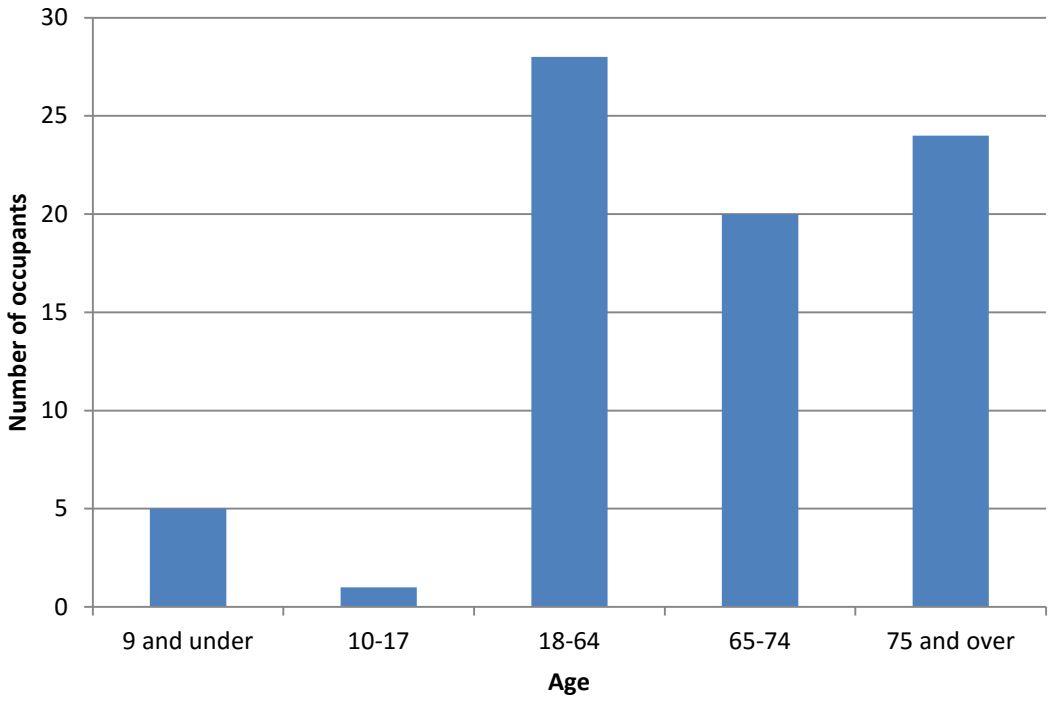



**Figure 6-3: Age of occupants based on pre-trial survey responses. Based on questionnaire responses from 45 participants.**

A wide range of levels of satisfaction with the current heating system and controls were reported. Figure 6-4 shows that almost half of the participants who returned the pre-trial questionnaire reported some level of discomfort during the winter, while this fell to less than a fifth in summer.

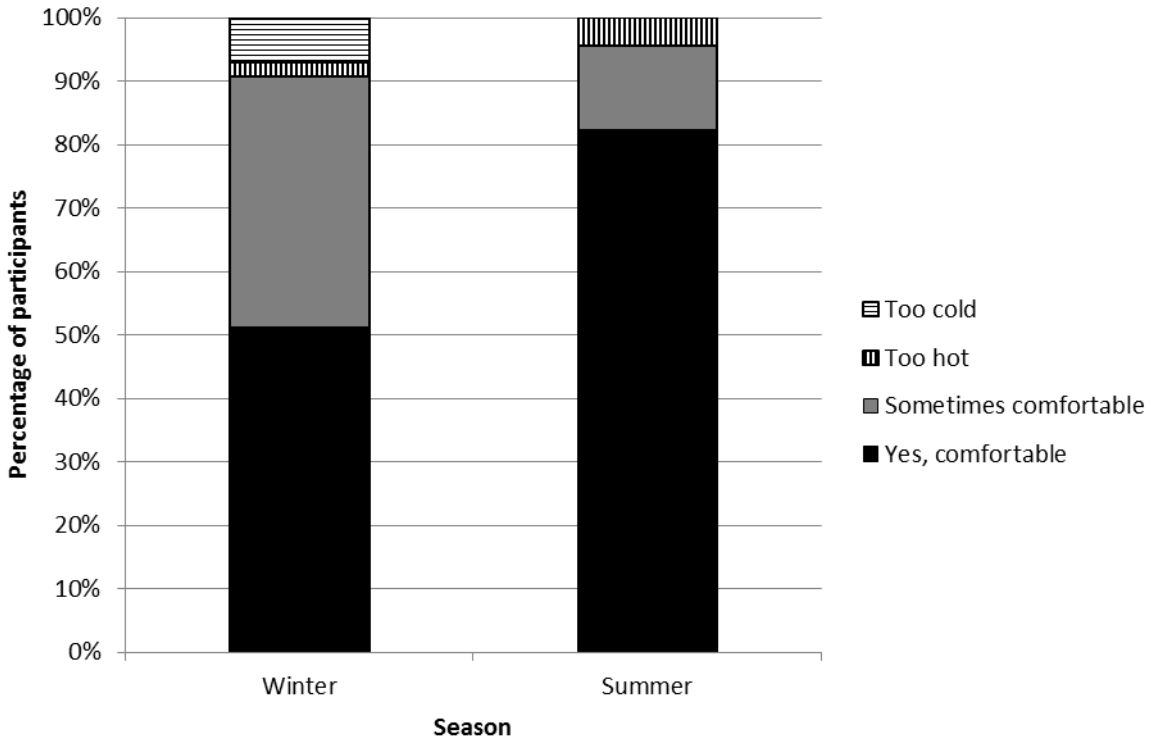



**Figure 6-4: Participant reported comfort in winter/summer. Based on questionnaire responses from 45 participants.**

Approximately a third of interviewees reported problems with their existing heating system setup. Some problems were centred around getting the heating to come on and off at times the participants wanted. This may be because people said they didn't understand how to use their current controls ('*No-one can understand, not even engineers who come here, they can't set it up – it's so complicated*', Christopher), because they said they had been instructed not to touch them ('*They told me not to touch the controls, leave it on, but it's too hot*', Eric) or were worried about making adjustments ('*I didn't touch anything, I didn't press anything, it was on all summer*', Isabelle). Instead, people often reported relying on room thermostats to control whether or not the heating was on. This was borne out in the questionnaire results (Figure 6-7), in which only 10 people (out of 45 who returned the pre-trial questionnaire) reported using a timer, but 18 said they use their thermostat to turn the heating off and on and 25 said they set their thermostat and let it control when the heating goes off and on. Figure 6-7 shows that of the heating control functions asked about in the questionnaire, setting the timer was the only function which more people rated as more difficult than easy.

Inability to control when the heating comes off and on led to people experiencing problems such as some radiators staying on all the time (Isabelle, Eric), and

generally a perception that heating was costing more than it should (Joanna, Barbara). Some people were also concerned about equipment (such as pumps or fans) seemingly running more than it should, such as overnight when the heating should be off (David, Katherine). This led to noise disturbance and, again, concerns about spending. More than half of participants who returned the pre-trial questionnaire said that the billpayer had worried a lot or a fair amount about energy bills in the last three months (Figure 6-5) (again, the HomeTech questionnaire did not request respondents to specify whether this was them personally or another householder). Two people specifically said that the system was easy to use, while the remainder had no strong view either way.

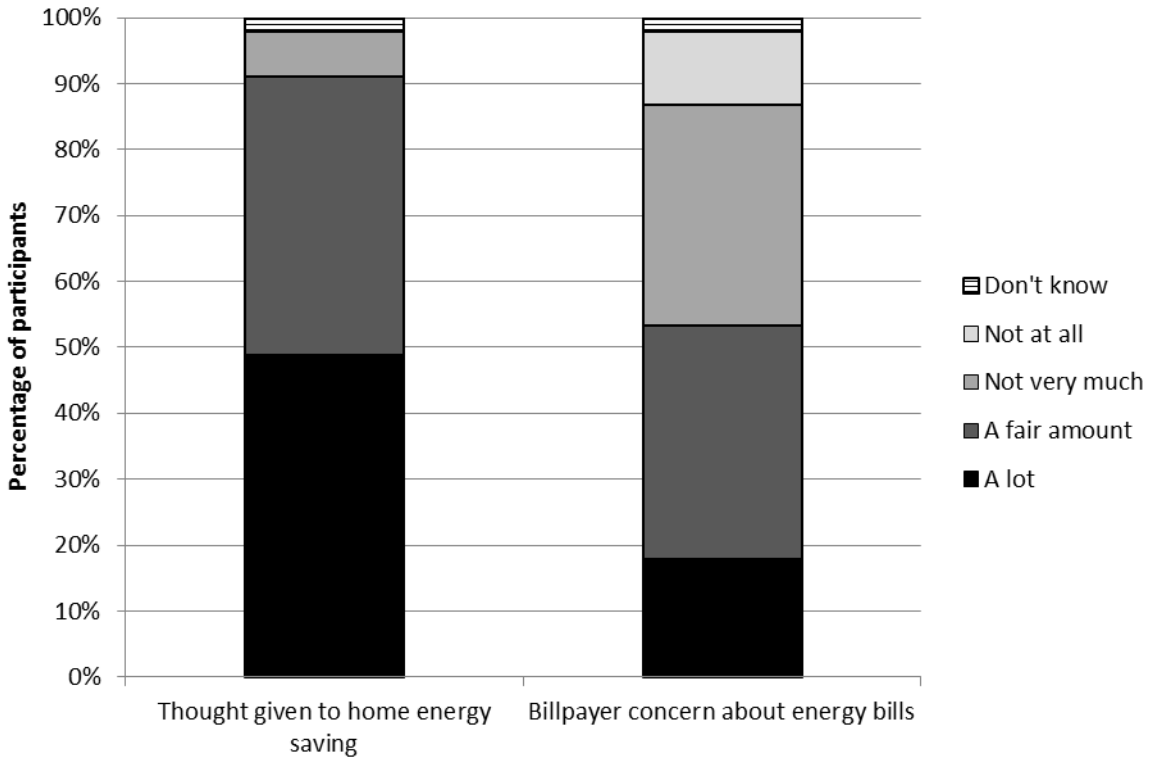



**Figure 6-5: Participants reporting their level of thought about energy saving and concern about energy bills. Based on questionnaire responses from 45 participants.**

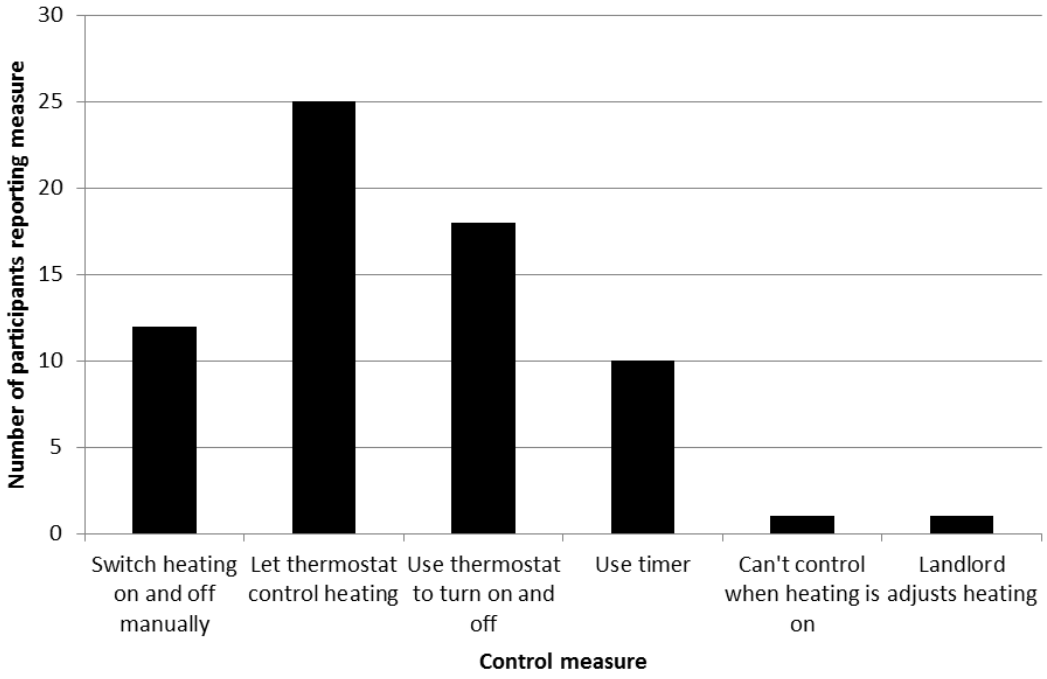



**Figure 6-6: The number of participants reporting taking each heating system control measure. Based on questionnaire responses from 45 participants.**

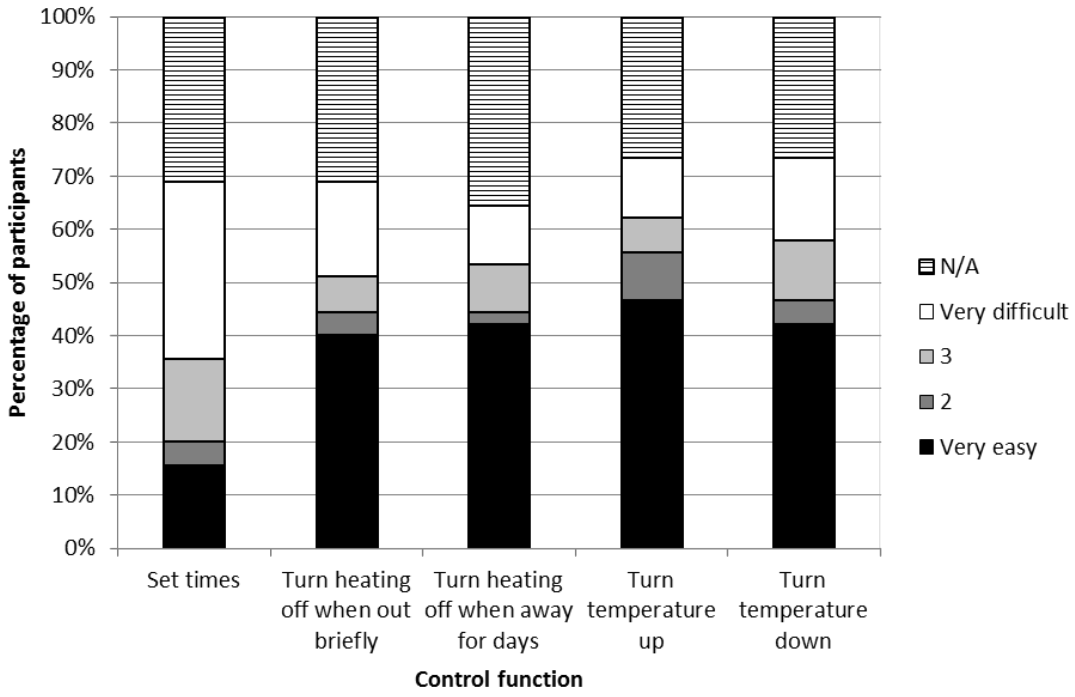



**Figure 6-7: Reported ease of completing a range of heating control functions. Based on questionnaire responses from 45 participants.**

Interviewees gave a range of reasons for deciding to participate in the trial. The three reasons that were mentioned most frequently were:

- that they wanted to try something new (*'…It's try new things isn't it … it sounded good at the time'* [Neil]) (mentioned by seven participants).
- the possibility of saving money with the new controller (*'I'm interested to see what the savings are on the electric'* [Lee]) (mentioned by six participants)
- the possibility that their system would be easier to control (*'that's easier for use, I think, if we want to put it on and off'* [Maureen]) (mentioned by five participants)

Other reasons that were mentioned less often (by no more than two interviewees) were:

- gaining better overall control of the heating system (as distinct from just being easier to use)
- reducing electricity use (as distinct from reducing cost)
- the hope that faults can be detected and diagnosed
- the desire to contribute to research that should benefit others
- the ability to control heating using a smartphone app

The final point, concerning use of a smartphone app, was only mentioned by two households, both of which included only people between the ages of 18-64. Taking these results together with the above on people's experiences of their current system, there could be said to be broadly three types of participant amongst the interviewees – those who see the possibility that the new controller might help solve issues with a problematic system, those who see the possibility that it might enhance a currently good or functional system, and those who are simply interested in being part of a trial (and potentially contributing to future benefits). Three interviewees specifically mentioned that they found the coffee-morning briefings held by HomeTech interesting and useful.

Figure 6-8 summarizes the responses to the extended TAM items in the pre-trial survey. All of the mean values (except that for autonomy) are between four and five, suggesting an expectation that the new control will bring high levels of comfort, spending and timing control as well as perceived usefulness and ease of use. The item for autonomy asked if participants thought they would be too reliant on automation – as this is negatively framed it was reverse coded in the analysis. Taken at face value, the results indicate that on average participants did not think

they would be too reliant on automation as the (reverse coded) mean value was above three. This result is not as positive about the controller as for the other constructs. However, there was more deviation around this result than for the other values. It is possible that, as the only negatively phrased item, participants were reluctant to go all the way to the other end of the response scale if they disagreed.

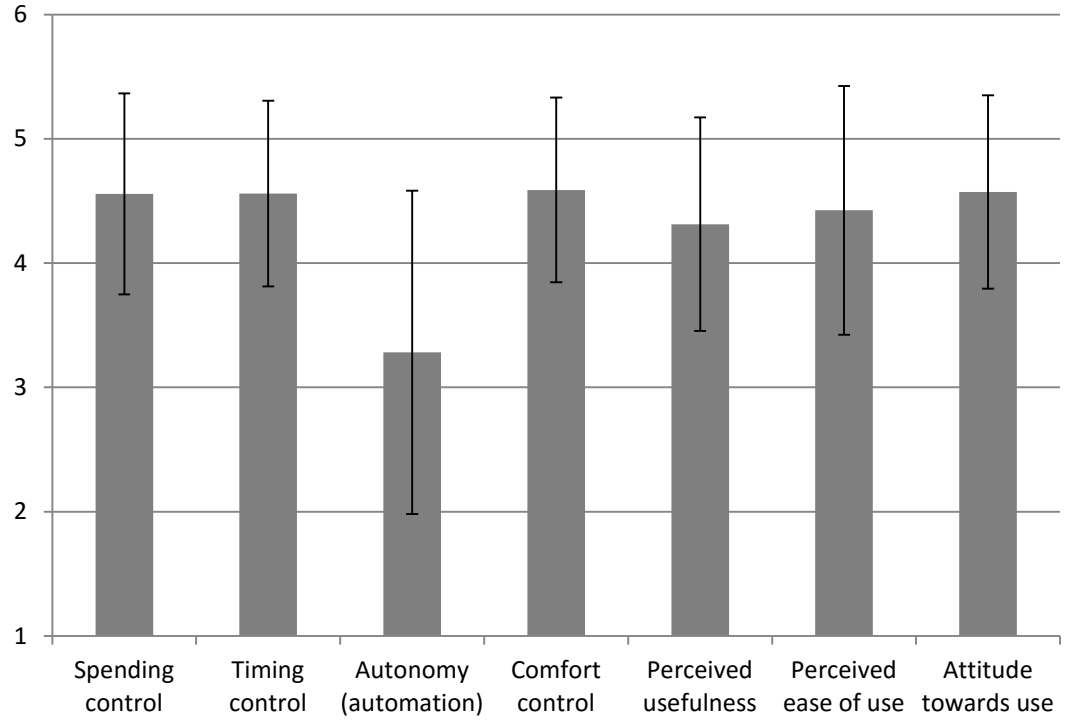



**Figure 6-8: Mean (pre-trial) survey results for extended TAM items. On the vertical axis, 5 = most strong/positive, 1 = least strong/positive. Error bars are +/- 1 standard deviation.**

Figure 6-9 shows the number of participants selecting whether to have specific control functionality turned on or off. Of the 46 respondents to the pre-trial questionnaire, 26 (or 57%) indicated that they would choose to have the control system's ability to reduce peaks in electricity demand turned on. The same proportion said they would have its ability to turn down when they are out turned on, while 33 respondents (72%) said they would turn on its ability to respond to weather forecasts. A higher proportion (28%) gave no response to the question on reducing peaks than for turning down when out (22%) or responding to weather forecasts (20%). Thirty-one participants (68%) indicated that they had at some point been on an Economy 7 or 10 tariff.

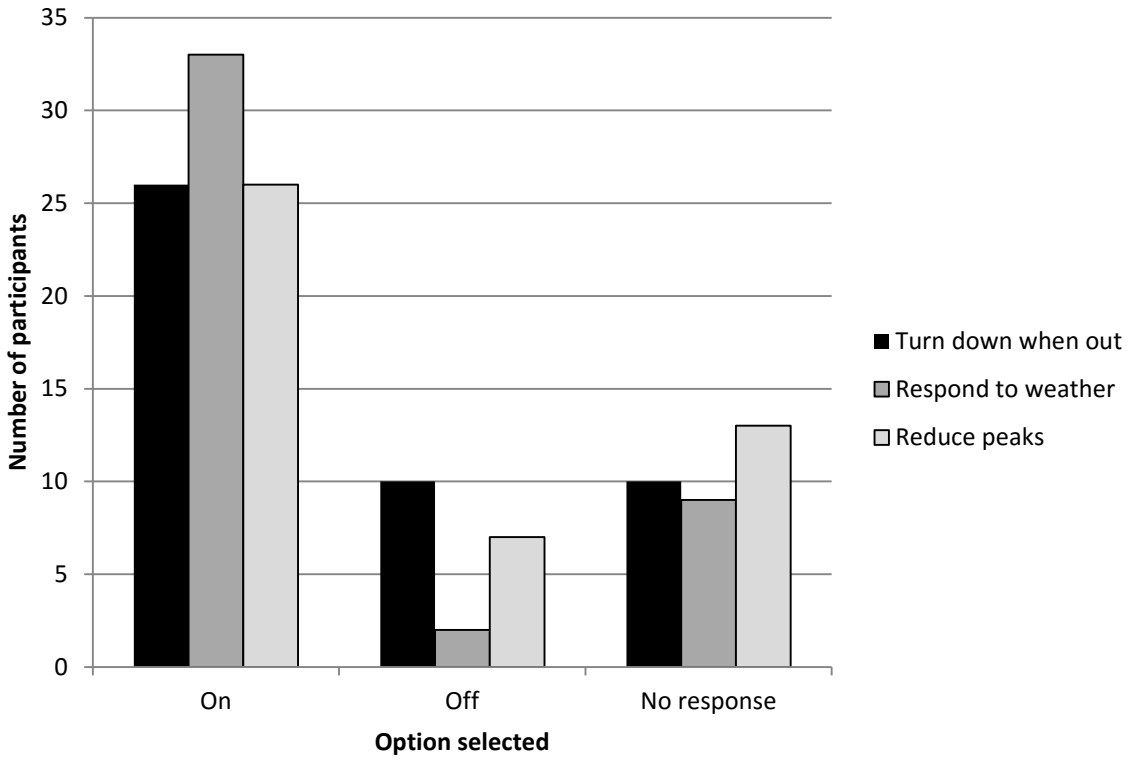



**Figure 6-9: Number of pre-trial survey participants selecting whether to have specific control functionality turned on or off.**

The final questions of the pre-trial interview probed further into participants' views on DSR. In general, these could best be described as most participants giving qualified endorsement. Of the 15 interviewees, nine said they were positive towards the idea of the controller affecting their heating to reduce peaks in electricity demand. Almost all of them qualified this with a caveat. Most referred to the warmth they could expect in their home:

> *As long as the house is kept warm at a certain temperature I'm fine with that, but you don't want, especially in the wintertime if it's really cold you don't want the, if there was a demand for electric, for it to turn off and you're like, you're going to be sat in the cold …* (Lee)

> *I think in some ways that might be a good idea, because that way we wouldn't be left cold, you know like every so often there would be some heating coming through [compared to Economy 7 with night storage heaters]* (Olivia)

> *… only now and again, especially when it really does get cold.* (Joanna)

> *… all for that … as long as it keeps the bungalow the temperature we want it …* (Christopher)

There was generally little mention of the thermal characteristics of the homes themselves, with only two participants mentioning it explicitly. In both of these cases the participants related good insulation to DSR being more acceptable as they expected that their homes would cool down more slowly:

> *… here you can turn the heating off at least half an hour before you go to bed and you're still quite warm* (Olivia)

Some people referred to cost or other concerns such as the noise of the heat pump running overnight:

> *I think it would be a good function really, if it does what it says … as long as it didn't, it's a bit dear that's all I worry about, if it's dear I wouldn't be interested at all.* (Maureen)

> *That wouldn't be bad if it cycled it off and on for short periods but not all night long because it drives me up the wall that drone …* (Katherine)

Where participants were not explicitly supportive of DSR, it often appeared to be because they did not follow the explanation that was given and their answer did not relate to the question that was asked.

Notably, some participants who said they would select to have the DSR option turned off in the questionnaire indicate their support for DSR in the interview. This suggests either that they did not fully understand the options either in the questionnaire or the interview, or possibly that in the context of the interview they were more inclined to give what they perceived to be a socially acceptable response. Alternatively, some did not believe that their heating system contributed to peaks in electricity demand, and therefore did not see the point in participating:

> *As far as we're concerned the way this heating system works I can't see how it's putting any extra pressure on the grid.* (David)

Discussion of the Economy 7 tariff was used in the interview to introduce the idea of DSR. However, it was also useful to get people's impressions of that tariff and to see whether they related that experience to the new control system. People's experience of that tariff, where reported, was not usually positive – although complaints tended to focus on technology (i.e. night storage heaters) rather than the tariff itself. In common with the focus groups described in chapter 4 people often complained about its inability to facilitate effective heating throughout the day:

*By late afternoon when you need the heating, it starts getting cold.* (Olivia)

### 6.2.2 Experiences

Of the 13 people who responded to the post-trial questionnaire, only eight gave a response to the question on whether they would have the controller's ability to reduce peaks in electricity demand switched on (Figure 6-10). Of them, six people (46% of the total) indicated they would have it on. This was exceeded by both the option of ability to turn down heat when out and ability to respond to weather forecasts, both of which were selected to be on by eight people (62%).

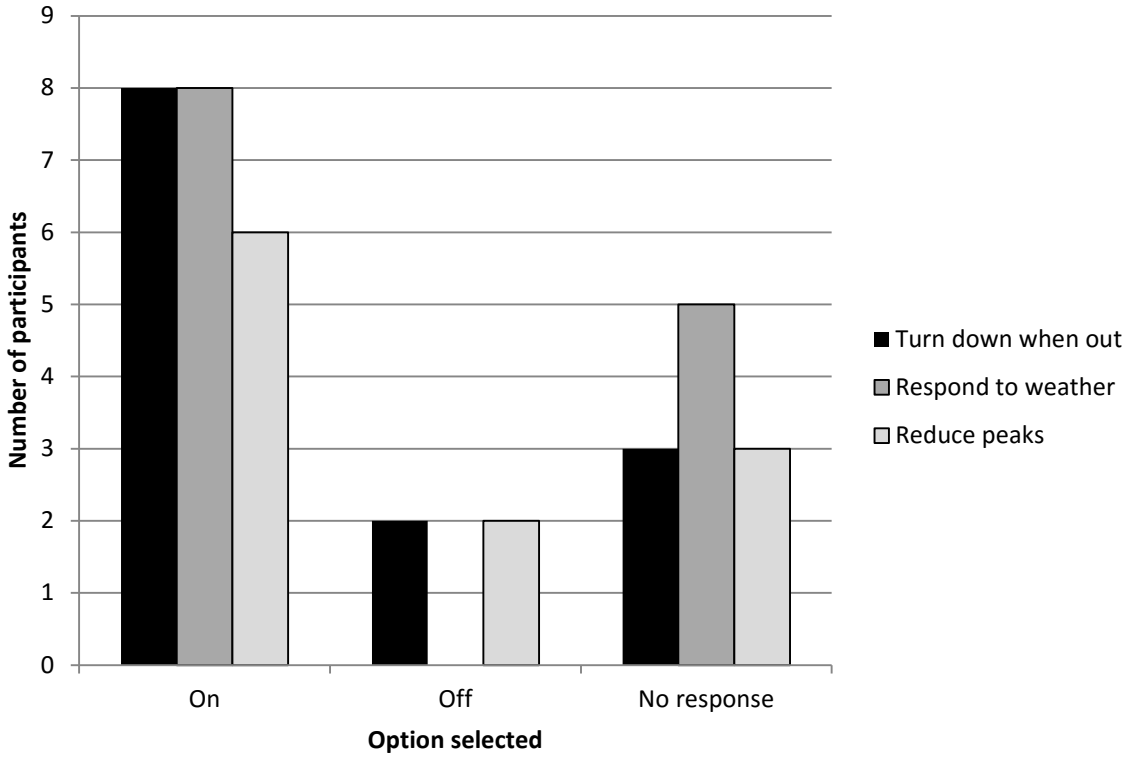



**Figure 6-10: Number of post-trial survey participants selecting whether to have specific control functionality turned on or off. Based on questionnaire responses from 13 participants.**

Only six participants gave a response to this question in both surveys. All stayed with their original choice, except one who said they would have the functionality turned off before the trial, but on afterwards. This is too small a sample to draw any statistically meaningful conclusions.

Figure 6-11 shows mean responses to the extended TAM items in the post-trial survey. Visual inspection suggests that reported experiences were, on average, less positive than their expectations (with most values falling between three and four, rather than four and five). There was also higher deviation in responses. Again, however, due to both the small sample size and the difference in standard

deviation between the results of this and the pre-trial survey it is not possible to make useful statistical comparison between the two.

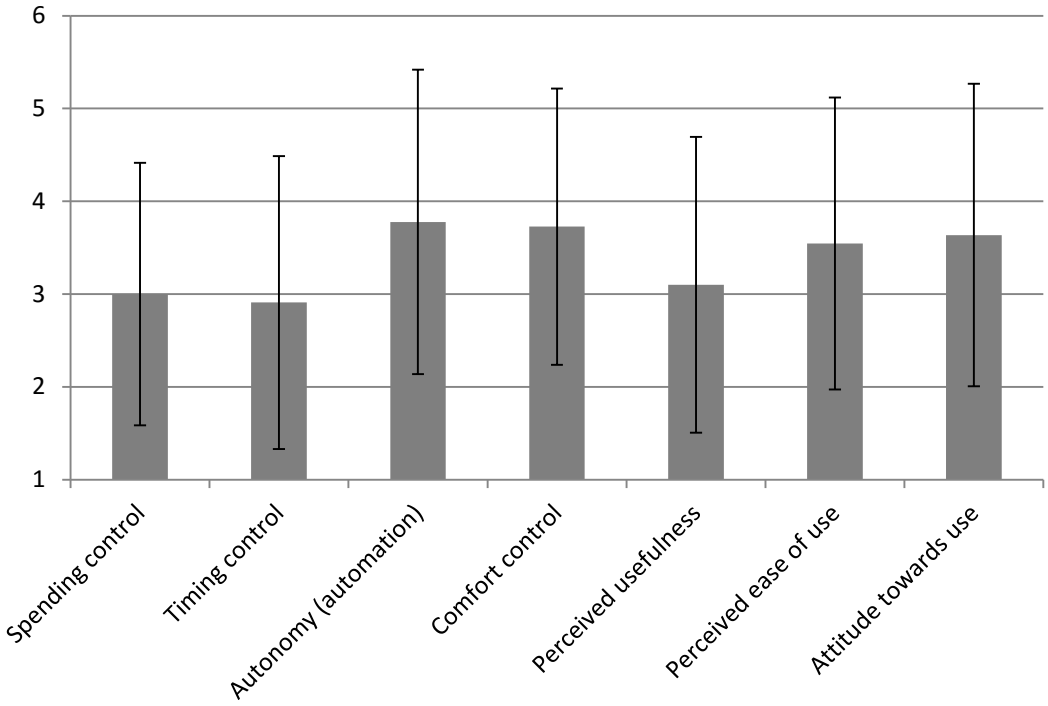



**Figure 6-11: Mean (post-trial) survey results for extended TAM items. On the vertical axis, 5 = most strong/positive, 1 = least strong/positive. Error bars are +/- 1 standard deviation. Based on questionnaire responses from 13 participants.**

Because the post-trial interviews collected more detailed data on participants' experiences of the new control system and of DSR, more detail on the background and context is merited. As mentioned in section 6.1.4, all post-trial interview participants were resident in Valley Housing retirement properties. Eight interviews took place with a total of 12 participants, with the mean interview duration being 40 minutes. While precise age information was not collected, all were aged 65 or over. The homes occupied by the participants were all of a similar type, being detached or semidetached brick bungalows built in the 1960s. All had had either an air or ground source heat pump installed in recent years, replacing night storage heaters. Some participants were existing residents before the replacement, others had moved in subsequently.

With respect to DSR, the picture presented by the interview data was more negative than that suggested by the survey results. Of the eight households interviewed, none were completely positive towards it, while most of the remainder were against it on the basis of their experience during the trial and would accept it only with caveats (and in one case the interview was terminated before DSR was discussed).

For example, one couple (Charlotte and Christopher) said they would engage in DSR, *'On the basis that it worked, yeah'* – this followed a discussion about the problems they had experienced. The reasons for this are varied and reflect different aspects of participants' experiences of the trial. When considering the results, it is important to bear in mind that while participants knew that DSR was taking place via the initial information coffee mornings, the pre-trial survey and pre-trial interview (where appropriate), it was not emphasized as one of the key customer offerings (e.g. compared to having an easy-to-use display) and participants were not actually switched onto a time of use tariff.

Almost all participants reported experiencing some kind of technical problem with the controller during the trial. In some cases it was found not to be working on inspection during the interview – there were three examples of communication problems between the controller and communications hub or the hub and HomeTech meaning that the controller was out of action. HomeTech confirmed that communications had been a big challenge for the project, and indeed it had led to the smaller-than-anticipated number of households in the trial receiving the controller. All of the tablet computers used in the trial were replaced a few weeks into the trial – in some cases this appeared to resolve technical problems, while in other cases it seemed to cause them. In other cases participants reported technical problems but no evidence was found of them on inspection during the interview. For example, two households reported that the tablet had to restart every time they wanted to use it making it very slow to interact with:

> *… but the problem with it was, it was never on when he was leaving, so he had to turn the thing on … but it would take 10 minutes! … the open thing was sort of whirling round and then nothing would happen and there would be a flashing light here and I'd ring 'em up and say, "look, something's not happening."* (Hector)

> *We've tried, day in and day out, pressing the top button, as you told me, and it will come on, sometimes it will start the system from zero, with Google coming up and then your lines and all the rest of the information it should bring up and sometimes it will go off before you get to the control buttons, and another time, you press it ... we'll try it in a minute, you press it and the control buttons will come up and nothing else! And maybe it'll come on for half a minute, switches off again, and that's it.* (David)

It is possible that technical issues had been existent but did not occur during the interview. However, on observing the participants using the controller, it seemed

more likely that they were not using it as intended by HomeTech. For example, in the second quote above, it appears that they were fully shutting the tablet down and restarting it each time they wanted to use it, rather than just letting it stay in 'sleep' mode. This related to issues around ease of use which are discussed later in this section. Whether technical issues are real or a result of mis-use, the upshot is that this negatively affected these participants' experience of the new control system and, apparently, of its DSR function.

As highlighted above, one of HomeTech's key objectives was that that the new controller be easy to use. Participants' views on whether this objective was accomplished were mixed. The main factor tended to be whether participants considered themselves to be 'tech savvy' or not. For example, Alan, a former engineer, had little problem learning how to use it: *'Yeah [it was easy to use] because if you look in there, you'll find that I've got loads of computers and stuff there.'* Likewise, Georgina was currently doing a distance learning course on her laptop and uses Skype to speak with her family: *'The controller's dead easy to use.'* At the other end of the scale, various participants reported either lack of experience with, or antipathy towards, ICT such as computers and smartphones:

> *I'm a bit of a technophobe really.* (Barbara)
>
> *… it's too complicated for us. We've got a laptop, we're not the generation for iPads.* (Fionn)
>
> *'Cos we're not into internet, or computers, or nothing.* (Charlotte)

In such cases participants reported difficulty using the controller, or just a general feeling that it wasn't suitable for them:

> *[the instructions were] alright if you knew what they were talking about … I just wanna know that I can switch it on and off.* (Christopher – husband of Charlotte)
>
> *It just wasn't straightforward, it wasn't easy for him … perhaps a tablet was the wrong thing* (Hector, speaking about his father Harold)

Where participants expressed this view, it could cloud their overall impression of the system:

> *For people like you, who can understand it, all this gadget stuff, fair enough, it's easy, but not for ... I'm 74 and I don't want anything where I've got to press this and press that.* (Christopher)

*I certainly don't think it's something that my father wants.* (Hector, speaking about his father Harold)

There were specific cases where either the user interface design of the controller or behaviour of the heating system in response to controller use did not act as expected by the participants, leading them to conclude either that the system was too complicated or that it was not functioning correctly. One commonly reported source of confusion was that when participants pressed the 'minus' button to reduce the thermostat set point, they expected to see the central number showing the current internal temperature reduce. However, because the system did not provide cooling, pressing the minus button only meant that the system stopped heating, and the internal temperature would only fall slowly (or not at all if other gains were causing the house to heat up). This is illustrated by this exchange with Barbara:

Interviewer*: What would you expect to see happen when you press the down one?*

Barbara*: For it to go down.*

Interviewer*: The number? The temperature?*

Barbara*: Yeah, that's what I would expect to see, but if you do it again, it's still not changing is it.*

This issue was also mentioned by three other households: Alan, Charlotte and Christopher, and Diane and David. As highlighted in chapter 2, when the outcome of actions is unclear, there appears to be a lack of connection between actions and outcomes (or contingency), diminishing a sense of control.

The importance of this becomes clear when considering a more fundamental capability of the controller – whether it can help maintain a comfortable temperature. Three households – Alan, Georgina, and Fionn and Francis – reported being broadly happy with the temperatures maintained by the new control system. The latter two households said they interacted very little with it and were happy to let the controller operate with little interference from them. The remaining households, however, reported problems with the temperatures they had experienced. The most significant of these appeared to be night-time overheating:

*… it was like being in the tropics for two nights. We had the butter dish ... you're gonna laugh at this, we got no heating in our kitchen, but we opened all the doors and windows to let the air through and the butter melted in the butter dish on my kitchen table and there's no heat out there!* (Christopher)

*It's only coming on at night and then the place gets so hot, you're under the duvet and the place is just like a sweat box and then you get up and the heating goes off.* (Barbara)

*Well, I've been getting up about four o'clock to go to the toilet, and this thing's been running on and off all night. The temperature in that bathroom this morning was something silly …* (David)

Both Christopher/Charlotte and Barbara had asked for the controller to be removed – mainly due to such temperature regulation problems. Overnight heating occurred for two reasons – to optimize the cost-efficiency of the heat pump, and to facilitate DSR by pre-heating when (simulated) prices were lower overnight. Other participants reported experiencing it, even if it was not a problem for them personally:

*… it doesn't worry me too much because if it comes on, I think "oh, it's wasting electricity again," because I'm in bed.* (Alan)

*I didn't expect it to be on between ten in the evening and seven in the morning, but two, three o'clock in the morning, sometimes, yes, it's on … I was puzzled, it was supposed to be on SLEEP, and it was, I checked and it was on SLEEP. Perhaps it was because it was cold.* (Georgina)

As most participants knew that their controller was only set to come on during the day, this night-time activity was confusing and, to many, seemingly erroneous. Furthermore, participants who had air source heat pumps reported an increase in fan activity overnight:

*… with these heat pumps running outside your windows, we had to keep the windows open overnight and you'd hear that thing cutting in and out. Those two nights, when it was hot, we thought it was gonna blow up out there 'cos it never stopped, it was just continually going.* (Christopher)

*… and this blower out here. Should that one blow as much as it does overnight?* (David)

*… it does get noisy at times.* (Fionn)

The overheating and noise, combined with the lack of feedback from the controller when they tried to turn down its operation, led to a sense that they were not in control of their own heating system.

All of the participants were asked for their view on the system being externally monitored by HomeTech. This was widely accepted, and indeed participants sometimes welcomed the fact that problems could be diagnosed remotely:

> *Don't worry us really, if they did or not, if they did know [how the system was operating].* (Charlotte)

> *I got no complaints about it … I rang up the office a couple of times, two or three times in fact, I rung up [HomeTech] and they've told me that yes, what we've done, they picked it up at control.* (David)

> *It's fine. If it's gonna improve the heating an hot water system for us, I don't mind that at all.* (Francis)

There was, however, some confusion as to whether HomeTech were only monitoring the system or were actually able to control it remotely:

> *They're like Big Brother, keeping an eye on you. They seem to have more control, maybe, than I have, I don't know.* (Alan)

Participants also reported that the HomeTech monitoring sometimes showed results that was at odds with their own experience:

> *… the viewing of it by [HomeTech] back in their place, they could see what was happening here … I thought it was pretty clever, I was quite impressed with it. The problem being was it was him [father] that was managing it, not [HomeTech], it was him managing it by turning the heater on in the lounge.* (Hector, speaking about his father Harold)

> *Well, it went wrong and I phoned up [HomeTech] and he told me my heating was working and I said to him, "Well, I may be coming up 77, but an idiot I'm not and I know when the radiators are cold and when they're hot," and I said, "and I haven't got any heating." He said, "Well, this is showing that your heating is working." That didn't give me a lot of faith, or encouragement.* (Barbara)

On first appearance, the participants' views on DSR are reasonably positive. However, nearly all of them caveat this by some reference either to their experience on the trial or to their personal situation with the result that few of them might be considered to choose to participate in such a DSR programme were it available commercially. Table 6-2 summarizes the views of participants who addressed this matter.

**Table 6-2: Summaries of participants' views on DSR. Bold text indicates caveats.**

| Participant(s) | Summary of views on DSR |
|---|---|
| Alan | He used to be on E7, and thought it was a good system, although he didn't like storage heaters. *'All I'm interested in is what you pay at the end of the day. I'm on a pension, a low one at that.* ***If it's going to save me money, well I'm all for it****'*. He does not want dynamic pricing that reacts to wind power: *'No, not really, I like reliable things like a thing like a nuclear power station, it's turning out on a constant basis, when proper switch grid, and proper loaded and what not throughout the country.'* He was also concerned about amount of software that would be needed to do smart grid balancing. |
| Barbara | She originally went off of Economy 7, but requested to go back on it when bills went up (and is therefore potentially significantly overspending on electricity – this information was fed back to HomeTech). She likes it being cheaper at night when she has heating and is working her oxygen machine. In general she is not keen on some aspects of automated DSR though, such as pre-heating: *'No, it's just a complete waste of electric as far as I'm concerned at that time of the morning 'cos I'm all snuggled under my duvet and I'm nice and warm anyway. So, no, I don't agree with that one.'* **She wouldn't mind idea of HomeTech turning down heating for short periods:** ***'No, that wouldn't worry me at all.'*** |
| Charlotte and Christopher | They were on Economy 7, and liked it: *'I was very happy with that for what we use, yeah, it suited us.'* They don't think DSR would really work for them: *'I don't know how it would work really 'cos we don't have much heat on in the morning. Perhaps it's for storage heaters, I know my sister's friend's got storage heaters, he's on Economy 7 and he has a load of heat in the morning and not at night when he wants it. With ours, I've found if we didn't turn that on, we didn't have no heat and only in the afternoon and the evening.'* Christopher was partly interested to take part in trial because of it, but it didn't work out: *'…he said it was gonna help the grid. That's the reason why I done it really, but it just didn't work out for us.'* They don't mind the overall principle, but only: *'****On the basis that it worked, yeah.****'* |
| Diane and David | They are happy in principle with DSR: ***'If it works, then I'm quite happy with it****. Who wants to use electricity in high peaks, when it's not necessary.'* They haven't noticed problems with it being trialed, although they now wonder if the night overheating (see above) may be linked to it. They would be interested in DLC: *'Yeah, I'd be interested in looking into it, see how it goes … That doesn't worry me. If I can save money with the electricity somehow, then I'm all for it. Why use electricity for the sake of it.'* |

| | |
|---|---|
| Fionn and Francis | Their views on DSR evolved over the course of the interview. Initially they didn't mind idea of DSR being done on ongoing basis, although were a bit concerned about noise issues (see above): *'the idea is good, yeah … but it does get noisy at times.'* They didn't worry about temperature: '*switching it off if it's going to be a peak period, or if they're expecting high demand, doesn't matter because the rooms are warm.'* They do think they should get some benefit from it: *'**Well, it should be, we should get a benefit from it, but don't think we are.**'* It would be attractive if resulted in fewer power cuts: *'so everyone's heating will go down two degrees, but you wouldn't have a power cut which went on for two or three hours, so you're winning.'* However, they later expressed some worry about temperature: *'Because we're home all the time, we don't want it keep going up and down and off.'* |
| Georgina | She used to have Economy 7, and didn't like it (especially the storage heaters). She would be interested to find out more about automated response to heating: *'I'm going to have to choose a new tariff. So, I'd be quite interested to know if that would benefit me.'* She would be OK with it so long as her preferred temperature was maintained: *'**So long as they kept the heating at a steady temperature for me**. As I say, I have lung disease, I've got COPD, so I need the warmth, I chill very, very quickly, so I wouldn't want anything that was going to put the heating down at a time when I really needed it.'* She wouldn't be keen on DLC for same reason: *'Not really because as I say, I do chill very quickly, so if the heating went down ... **even one or two degrees can make a difference and if I get chilled, it takes a long time for me to get warm again and I think anybody that has any kind of lung disease, you'll find the same kind of thing**.*' |
| Hector and Harold | Hector believes DSR tariffs are only good if the system set up to work properly with them: *'we're looking at the moment to something like Economy 10, or something, which I believe gives some cheaper electricity between two and five in the afternoon, but that's only any good if the system's set up to warm water up. The system's got to be set up, it's no good having cheap electricity between two and five if the water heater comes on at nine o'clock in the morning.'* He likes the idea in principle, but probably not in practice: *'It sounds a great idea and I suspect you probably wouldn't notice it, it's something you probably wouldn't notice on the system, you wouldn't notice it while you were here, unless it went on for a long time, of course, you would, but you could probably cut the temperature by a bit and it wouldn't actually make that much difference, so yeah, **I love the ideas that this thing has got, it's just it didn't work**. It was very, very frustrating in that it just didn't work for him.'* |

Finally, there was evidence from the trial for a reasonable amount of discussion with neighbours about the new control, and heating settings in general. In some cases this was simply sharing expressions of preferences and experiences:

> *Some people probably like it and get on well with it, I believe one or two of 'em gets on well round here with it, but I don't at all.* (Christopher)

> *And ours [heat pump fan] is not directly under the bedroom window, some of them, they fitted them right underneath, literally, underneath the bedroom window. They moan a bit about the noise.* (Francis)

> *Some of them have them full blast, which is like a sauna.* (Fiona)

In other cases neighbours had played a more direct part in either looking out for neighbours or directly assisting them:

> *I had another neighbour down there, Saturday, their heating went off completely, everything went off, the outside, the whole lot, so I said, 'We'll ring [Valley Housing], get the emergency people and they'll come and sort it out …* (David)

> *I came here and set up all the computers here for him, my father-in-law lived next door, I set his up, and where I live in [town], I ended up sorting out the neighbours as well. There was various neighbours having a problem with it as well …* (Hector, son of Harold)

The Valley Housing retirement homes were spread over several sites, but each site contained quite a few homes and there was evidence of residents visiting and looking out for each other. For example, a neighbour came to visit during the interview with Christopher and Charlotte.

## 6.3 Discussion

This study set out to compare people's expectations and experiences of an 'intelligent' heating controller with functionality including automated response to DSR signals. In reality, practical challenges for the trial meant that very few direct before/after comparisons were possible. However, the research has provided a useful qualitative insight into participants' experiences of living with automated DSR.

### 6.3.1 Challenges for acceptability

Participants were found to be broadly accepting of automated DSR before and after the trial, as suggested by survey responses and interview data. However, analysis of post-trial interviews revealed that for many this was acceptance 'in principle', but not necessarily on the basis of their experience during the trial. While by no means relevant in every case, problems such as technical failures, usability issues and difficulties controlling temperature resulted in some participants requesting that the new controller be removed or giving it quite negative feedback – with some saying they were in favour of DSR nevertheless. Essentially, this is summed up by the comment from David: '*If it works, then I'm quite happy with it*'. The question is: to what extent were the problems experienced those which would be expected to crop up in the first field trial of an innovative device – or are they part and parcel of having certain kinds of automated response to DSR? The next paragraphs deal with the main problems in turn.

The technical problems experienced by many participants (mainly concerning communications) may be largely attributed to this being principally a technical innovation trial. The results should inform future iterations of the product that improve the reliability. However, it is clear that where technical problems were experienced, participants were unhappy and apparently began to mistrust the ability of technology to function as intended in any way, including DSR. In essence, DSR as it was experienced by the participants was often 'tarred with the same brush' as the malfunctioning technology. By introducing elements of outside control to heat pump heating systems – already relatively complicated technologies compared to simple boilers – the risk of failure in some element of the system is increased, potentially negatively impacting on perceptions of automated DSR, or at least of the technology which is necessary to facilitate it. Reliability is naturally (and must continue to be) a key concern of product developers and manufacturers – recognizing, however, that combining innovative controls with heat pump technology that is not yet fully mature in the UK (e.g. concerning installation (Energy Saving Trust, 2010)) is likely to mean that technical issues of the kind experienced here remain a reality for some time.

Aspects of the ease of use of the control system were also shown to be important in determining participants' attitudes towards using it. A key point to emphasize in relation to automated DSR was that under certain circumstances the graphical feedback provided by the controller was not perceived by participants as adequate,

making it hard for them to connect their actions with a tangible outcome. For example, pressing the 'minus' button on the controller did not appear to have any effect, whereas in reality the thermostat set point was being reduced. This meant that participants did not consider themselves to have a viable override opportunity when, for example, high temperatures were experienced as a result of pre-warming. This serves to re-emphasize the importance of perceived contingency between actions and outcomes if override ability – which is likely to be an important factor in acceptance of automated DSR (e.g. Butler et al., 2013) – is to have a role in encouraging acceptance. One key area in which this issue can be addressed is in user interface design.

The majority of the post-trial interviewees reported experiencing problematic night-time heat pump operation, resulting either in overheating or excessive noise. As mentioned in the previous section, this activity out of scheduled times was an intentional and necessary part of achieving both more efficient operation of the heat pumps and effective demand response. This is potentially therefore the most significant challenge in making automated response to DSR involving heating acceptable. It is already well-established that existing DSR tariffs (such as Economy 7) with complementary technologies such as night storage heaters have been widely criticized from the point of view of comfort (see chapters 2, 4, and Consumer Focus (2012)). Indeed, many of the participants in the current trial had recent (mostly negative) experience of night storage heaters, which often appears to have been somewhat mitigated by replacement with heat pumps (a finding also noted by Bell et al. (2015) during the Customer-Led Network Revolution trial). While new tariffs and more modern approaches to automation (such as the HomeTech system) can avoid some of the problems associated with legacy systems (e.g. by allowing more top-up heat during the day), unless better storage solutions emerge they will always encounter problems associated with the pre-heating that is necessary if sufficient temperatures are to be maintained later on.

One approach to resolving overheating is to lessen the amount of pre-heating that occurs, but this will directly impact the amount of demand response that can be achieved. Potentially more effective approaches would involve a focus on the physical properties and setup of the home and heating system. Better use of zoning, for example, might allow pre-heating to be constrained to living areas rather than bedrooms (perhaps through the use of thermostatic radiator valves) – effectively using living areas as heat stores. This would reduce the problems of interrupted sleep due to overheating reported by participants here. Noise problems

could be tackled by ensuring where possible that heat pump fans are positioned away from bedrooms (of both the owner and any neighbours). What is key to emphasize is that even though automated DSR systems may be some way from the commercial mainstream in Great Britain, the conditions which they will require to work effectively are already being created – for example in the way that heating systems are installed and buildings constructed and retrofitted. Part of ensuring the acceptability of DSR will be in anticipating the sort of problems raised by this trial and acting now to avoid them.

### 6.3.2 Trial context

It is important to emphasize again the context in which this trial was conducted. All of the participants were social housing tenants living in the south-west of England. Many of them (and all of those who participated in the post-trial interviews) were older than 65 and lived in dedicated retirement properties. It is therefore useful to consider two questions. To the extent that the participants tested here are representative of people with similar characteristics, how important is this group in the context of DSR? And to what extent might the findings discussed here be relevant in the wider context of Great Britain?

According to the usual understanding of diffusion of innovations (see Rogers (2003) and chapter 2), initiatives such as automated DSR would be expected to be taken up first by innovators and early adopters. Being a largely technological innovation, considerations such as an interest in new technology might be expected to feature in whether someone falls into one of these brackets. The post-trial participants here often emphasized their lack of interest in technology, and compared to younger participants in the pre-trial interviews showed little interest in features such as the smartphone app. This is not inconsistent with national statistics on use of ICT – for example, just 25% of people aged over 55 owned a smartphone in 2014 compared to 88% of people aged 16-24 (Ofcom, 2014: 271). Another potentially unusual characteristic of the study participants is that, as residents of retirement properties, they may be more than usually accustomed to the idea of external parties having involvement in their home life. For example, wardens based nearby would have keys to homes allowing them access in case of emergency – a situation which would not be the case for people in most other forms of accommodation. Among other things, this might be expected to affect participants' willingness to accept external monitoring and control of their heating systems. This is an important point in the context of the current research and is discussed further in chapter 7.

Nevertheless, there are also reasons to believe that demographics such as that involved in the trial might well be at the vanguard of exposure to innovative automated DSR. As noted in section 6.1.1, HomeTech determined to work with social landlords because they were likely to find high heat pump penetration amongst their tenants. Housing associations are in a position to install large numbers of both heat pumps and, if they choose, smart thermostats with the potential for automated DSR of the kind tested by HomeTech. This is all the more likely in rural areas away from the gas grid such as that involved in this trial. Such areas might also be expected to be more prone to network constraints and faults, for example due to extreme weather events (although no central publicly accessible record is maintained of power cut location), making the local need for effective DSR more pressing. Finally, older people are more likely on average to be at home during the day (McKenna et al., 2007), requiring heating but therefore also using electricity which, in theory, should provide flexibility to the grid. It is therefore not unreasonable to expect that demographic groups such as that represented in this study would be of significant interest for DSR operators. More generally, there is no reason to believe that problems such as technical issues, night-time overheating and noise would be experienced as less problematic by other groups than the one focused on here.

### 6.3.3 Limitations

It is important to point out a number of limitations of this stage of the research. Firstly, recruitment bias is likely to mean that the residents who opted to take part in the trial differed in systematic ways from those who did not. For example, they may have been more than usually interested in new technology, or they may have been experiencing problems with their current heating systems which they (perhaps wrongly) thought the new system might be able to ameliorate. Further practical issues such as broadband connectivity reduced the number of homes that could ultimately be fitted with the new control system. As well as limiting the possibility of making statistical comparisons between the experimental groups, this may also have introduced other biases into the selection process. For example, better broadband connections might be correlated with proximity to more highly populated areas and therefore better transport links, increasing the possibility that residents would be out during the day. While no specific evidence was found for such a bias, it is reasonable to believe that problems such as this could have affected the results.

A wider issue, which has already been alluded to, is that participants were not actually moved onto a DSR tariff (as was originally intended for the trial). Instead, the controller responded to simulated time of use tariff prices. On one hand this may be considered problematic since in the 'real world' it might be expected that DSR would be a more obvious part of any consumer offering. On the other, it is not unreasonable to expect that DSR operators would prefer for it to operate in the background without being the focus of attention. For example, the 'Rush Hour Rewards' programme offered by the Nest thermostat in the US operates without user involvement on a range of different supplier tariffs (Nest, 2015). In Scotland, the Northern Isles New Energy Solutions (NINES) trial offered participants new electric storage heating systems which would continue to operate on their existing tariffs, but charging times could be altered remotely depending on availability of wind power (SSEPD, 2013). As such, the results may be viewed as giving an insight into this kind of 'invisible' DSR.

## 6.4 Summary

This study used a combination of interviews and surveys to compare people's expectations and experiences of control in a trial of an 'intelligent' heating controller with DSR capability. Pre-trial, participants were generally very accepting of the controller's DSR function, so long as there were assurances that temperatures would be maintained and that they would not be financially worse off. Following approximately two months of living with the controller, participants' general attitudes towards DSR were mainly still positive. However, many participants experienced problems with the new control system – including technical issues, usability challenges and functioning outside of scheduled hours leading to overheating and noise. As such, DSR acceptance was often accompanied with a caveat that is should work properly. It is reasonable to expect that technical and usability problems identified in the trial could be eliminated in future iterations of the product and, if addressed appropriately, do not pose an intrinsic challenge for DSR. However, some of the problems experienced (such as night-time overheating and noise) may be considered intrinsic to doing DSR successfully. These will most likely need to be addressed by focusing on whole systems – for example considering the interaction of layout and thermal characteristics of buildings with possible DSR measures when installing heating systems which might be expected to play a future role in DSR. Recommendations for research, policy and practice are developed in the next section (alongside those based on other stages of this research).

# 7 Global discussion

The chapter discusses the findings of all three phases of research and positions them in the context of previous research as reviewed in chapter 2. The first two sections focus on people's understandings of control, the factors which influence this and how it relates to acceptance (and in so doing address research questions 1 and 2 – see section 2.4). Specific focus is then given to the acceptability of external control. Research question 3 is then considered by turning to associations between non-control factors and acceptance. Research question 4 is not dealt with in a specific section – rather, reference to the HomeTech trial throughout serves to show how experience of DSR may influence people's perceptions of its acceptability.

## 7.1 Motivations for control in DSR

Part of the aim of this programme of research was to unpick people's understandings of control (or lack of it) in the context of home energy use and demand-side response. This was driven by a framework proposed by Skinner (1996) underlining the need to identify the motivations for, antecedents to, and agents/means/ends of control. The first phase of research (using exploratory focus groups) identified four key motivations for control in the context of home energy use: service level (e.g. comfort), timing of activity, spending, and a general sense of autonomy. When these constructs were operationalized in a representative survey of energy bill-payers in Great Britain, however, high multicollinearity was found between participants' responses for comfort control, timing control and autonomy. Because factor analysis did not provide evidence for four distinct control constructs, only two were used in regression analysis – general control and spending control. What does this, taken together with the results of the HomeTech trial, mean for the first research question posed in this thesis, or '*How do domestic energy bill-payers in Britain interpret "control" in the context of home energy use and demand-side response?*'? It is first useful to consider possible limitations to the study that may have influenced the results.

First, it is worth noting that fairly high levels of multicollinearity were detected between all the constructs in phase 2 of the research, not just those relating to control. While regression analysis proceeded on the basis that VIF scores were below quite widely used thresholds (i.e. 2.56 to 4.68 against thresholds of 5-10), some have argued for lower thresholds to be used (e.g. 3.3 [Diamantopoulos and

Siguaw, 2006] or 2.5 [Chan et al., 2012]). Common method variance (CMV) is a potential cause of such multicollinearity (e.g. Chang et al. [2010]). This can arise *'if the respondents have a propensity to provide consistent answers to survey questions that are otherwise not related'* (Chang et al., 2010: 178). For example, a survey respondent may favour one end of a response scale in a list of items, perhaps reflecting a general view rather than a considered response to each item. There is some evidence that this was the case in this study. The negatively framed items did not load well onto their target constructs (e.g. *'Being on this plan would require a lot of mental effort'* did not load well with positively framed items onto the target construct of perceived ease of use). This may be because people who were otherwise answering *'strongly agree'* or *'strongly disagree'* were more likely to tend towards that end of the scale than go to the other end to strongly or somewhat disagree. If this were the case overall, responses may have reflected a generally positive or negative view of the tariffs, rather than specifically addressing each item.

There is reason to believe that CMV has only blurred the results, rather than obscured them entirely. For example, the focus group study found that where people felt time of use tariffs increased their control in relation to energy, it was specifically with regard to spending. In the survey experiment, the time of use tariffs were rated highest for the spending control construct. If people were just clicking through the survey without considering the items, this construct in particular would not be expected to rate higher than any of the others. It is possible that people who form part of a retained panel of respondents, and therefore are called to answer many questionnaires, may be more inclined to click through surveys as quickly as possible. However, it should be noted that agencies such as Populus, who administered this survey, do have controls in place to prevent this (such as by comparing actual to expected completion times). Future work could minimize the risk of CMV by varying the scale end-points for the (hypothesized) predictor and dependent variables. Using a scale with fewer items (to maximize the attention participants pay to each item), and with a more even balance of negatively framed items, may also reduce its effects (although it is noted that the scale was developed according to a prescribed method and already had a low number of items for each construct).

Another possible reason for high multicollinearity is that the constructs were indeed highly related and interdependent, such that big differences would not be expected to distinguish them. For example, participants may have viewed the 'comfort'

construct as actually encompassing an element of timing. The items used to measure comfort were as follows:

1. *With this plan I could make sure my home is warm enough.*
2. *With this plan I would have enough control over the comfort of my home.*
3. *With this plan I could be sure of a pleasant environment in my home.*

As evidence from the interviews conducted in the HomeTech trial demonstrate, comfort is as much about heating at the right time as to the right temperature – both are necessary to feel a sense of control in relation to comfort. Indeed, it is clear that every experience of comfort (or discomfort) must have a temporal element. It may be, therefore, that while separate facets can be discerned when people talk about issues related to comfort and timing, in practice they are not (quantitatively) distinguishable. It is, however, important to note that the timing control construct aimed to focus more on people's schedules (or when they do things), rather than explicitly being about when electricity is used. The timing control items were as follows:

1. *With this plan I would be able to do things when I want to do them.*
2. *With this plan I would be able to heat my home at the times I want to heat it.*
3. *This plan would make it hard for me to do things when I want to do them.*

It is clear that while items 1 and 3 are about people's general schedules, item 2 focuses on a particular energy service (heating). This slight lack of conceptual clarity (although it resulted from the scale development exercise described in chapter 5) may have contributed to the observed blurring of these hypothesized constructs. In a similar way, it is likely that perceived usefulness and perceived ease of use are closely linked to people's perceptions of control. If someone feels they would not have much control over when they do activities, and this is unacceptable to them, they are also unlikely to think they are going to save money with a TOU tariff, or that it will be easy for them to use.

Another possible reason for the discrepancy with the focus group analysis is the context in which DSR was introduced in the survey – specifically in relation to heating. In the focus group discussions (and in evidence from other research), timing considerations especially were raised in relation to tasks such as laundry or cooking. These require certain activities (e.g. putting clothes in the washing machine, taking them out, hanging them up to dry) to be undertaken at points in time, requiring physical presence, attention, etc. Heating, on the other hand, often

requires less direct interaction with the control technology – especially in highly automated systems (such as the smart thermostat offered in phase 2 of this research, and tested in phase 3). It is possible that if DSR had been explicitly introduced in another way (e.g. based around laundry and cooking instead of, or as well as, heating) then constructs such as timing control may have emerged more distinctly in people's responses – further research (especially that which takes a practice-centred perspective) would be required to investigate this. However, it is important to remember the justifications given for the choice of heating in the study – especially its expected importance in future DSR scenarios.

It is possible that the control constructs do indeed exist separately, but were not optimally operationalized in the survey. As chapter 5 describes, a careful process of scale development was followed to yield an instrument capable of measuring the hypothesized constructs of interest. However, this work flowed from the operational definitions provided for each of the constructs at the outset. In particular, it is possible that the understanding of the 'autonomy' construct (operationalized in this work as *'How much someone thinks they are in overall control in their life'*) could more appropriately have been defined slightly differently. Specifically, including reference to freedom from outside influence may have been both more pertinent to the context of DSR but also more distinct from other constructs such as comfort and timing control. It may be that this operationalization led to items which the focus groups (and other) research suggested could have been suitable for inclusion being omitted (for example: *'This plan would be a case of Big Brother taking over'* and *'With this plan the energy company would be telling me what I can and can't do'*). The actual items used were as follows:

1. *With this plan I would be free to live as I choose.*
2. *With this plan I would be too dependent on automation.*
3. *With this plan I would have enough control over my life.*

None of them explicitly refers to external agency or influence. It is possible, therefore, that the items used to measure autonomy were in fact closer to an idea of 'general control' than of 'autonomy'. It is noted that the pilot survey used in the scale development process did not unequivocally distinguish between the hypothesized control constructs, a situation which at the time was attributed to fatigue on behalf of the respondents in completing the long list of items (based on participant feedback). Further research would be required to determine whether alternative items with

more overt reference to third-party involvement would yield a more distinct construct.

Research question 1 focused on people's understandings of 'control'. On the basis of the various stages of this research, therefore, and bearing in mind the above limitations, there is evidence for two distinct motivations for control in relation to energy: control over spending and a general sense of control that reflects people's assessments of service quality (with a temporal element), and possibly the degree of external influence. The addition of these constructs to the Technology Acceptance Model increased its explanatory power slightly in this research (mainly due to the general control construct), confirming the role that perceptions of control have to play in DSR acceptance and partly responding to research question 2 (concerning how perceived control is linked to acceptability). The original TAM construct of perceived usefulness – largely reflecting perceived savings potential – was the most important factor in intention to use all but one of the tariffs. However, general control always had a greater effect that the second original TAM construct, perceived ease of use.

The finding that that spending control was not related to acceptance when controlling for the other extended TAM variables (or was even negatively associated with it in the case of sTOU), if reliable (bearing in mind the possibility of problems due to multicollinearity), is potentially important. Firstly, the regression result does not appear to be obviously misleading when considering that, while all of the tariffs (except dTOU) were rated quite highly for spending control, and without significant differences between them, this did not translate into equivalently high acceptance for all the tariffs. General control, perceived usefulness and perceived ease of use more closely mirror ultimate acceptance.

While this result does not contradict the finding in the focus group phase of research that spending was the area where people feel most additional control on TOU tariffs, it does suggest that spending control may not be the most effective area for DSR operators to appeal to when promoting such tariffs since it does not show a clear association with acceptance. Instead, it is more important that operators design tariffs that people consider will give them a general sense of control (considering factors such as comfort, timing and a feeling of autonomy), that are easy to use and that they feel will save them money (or be useful in some other way). The findings of this study show, for example, that a more positive view of dynamic time of use pricing in these respects can be achieved by offering the option

of automated response. While emphasizing the spending control benefits of DSR may not in most cases be off-putting, the results indicate that communication that foregrounds those aspects of the design which promote feelings of control in other areas, savings potential and ease of use could be more effective.

These findings provide answers to RQ1, focusing on people's interpretations of control, and part of RQ2 which explores associations between perceived control and acceptance. The other part of RQ2 asks how these associations differ with different approaches to DSR – this subject is tackled in the next section.

## 7.2 Antecedents of control and acceptability of DSR

If, as has been demonstrated, people's expectations of general control are associated with DSR acceptance, how might these perceptions be affected? The focus group phase of this research, along with a review of the literature, suggested a number of key antecedents of control: information, familiarity, predictability, trust and choice. The experimental phase of the research could have been used to investigate how manipulating any of these factors affected acceptance. It was ultimately decided to manipulate one of them – predictability – through offering either static or dynamic time of use tariffs. The other main manipulation was the response to DSR signals was actuated (manually, via automation or remotely). This section first considers the effects of predictability and automation on perceived control and acceptance, before going on to discuss the other antecedents and their relevance to the design and communication of DSR offerings.

### 7.2.1 Predictability and automation

Phase 2 of this work showed that a range of 25-30% of participants were strongly or somewhat in favour of switching to TOU tariffs. The most consistent difference between these tariffs was the comparatively negative perception of the dynamic TOU tariff. It was rated significantly lower than automated dTOU for attitude, perceived usefulness and general control; significantly lower than sTOU for perceived ease of use and general control; and significantly lower than automated sTOU for attitude and general control. There were no significant differences in main effects between sTOU, automated sTOU and automated dTOU for any of the constructs measured. However, there was an interaction between predictability of the tariff and automation, and giving the option of automated response to the dynamic tariff made it significantly more acceptable. Automation gave people a

greater sense of general control on the dTOU tariff, made it seem easier to use and people felt they were more likely to save money on electricity.

Where the option of having an automated response to the dTOU tariff is made explicit, the dTOU tariff becomes as acceptable to people as sTOU and automated sTOU. Stenner et al. (2015) had a similar result in their survey experiment of different DSR tariffs, with automation making the unpredictable (and previously least popular) real-time pricing and critical peak rebate tariffs more acceptable. This is an important finding for two reasons. Firstly, as established in chapter 2, different approaches to DSR can achieve different benefits for the network. While static tariffs allow regular peaks to be managed, they cannot incentivize demand that follows variable supply (such as from wind generation) or a response to unexpected peaks or faults. Dynamic tariffs, on the other hand, do permit such flexibility and are therefore potentially more valuable to networks. If by highlighting the possibility of automation the dynamic option becomes as attractive as the static, this bodes well for acceptance of the more valuable dynamic tariff. Secondly, having an automated response to DSR signals has consistently been found to deliver the greatest and most persistent demand response (see review by Frontier Economics and Sustainability First (2012)). The finding that automation makes the dynamic tariff more attractive is therefore doubly encouraging in terms of their potential contribution to the energy system.

Two notes of caution need to be highlighted regarding these findings, both in relation to dynamic time of use tariffs and to automated response to DSR signals. In relation to the former, it is interesting to contrast the findings of this study with those of a recent large-scale trial where participants actually spent time living with a dynamic time of use tariff – the Low Carbon London project (Carmichael et al., 2014). In that trial, 77% of the 708 people who completed the final survey (out of a total participation of 1044) said that they would like to remain on the tariff if they had the chance, suggesting it was very popular. There are several possible explanations for the difference between this and the result of the current study. Firstly, participants had to opt in to take part in Low Carbon London (and the final survey), so may already have been more interested than average in the products being tested. Secondly, while the structure of the tariff used was similar, the prices were different (with greater differences between price bands in the Low Carbon London trial). The possibility of exceptionally high savings may have proved attractive. Thirdly, unlike in the survey experiment, participants in the Low Carbon London trial actually had experience of living with the tariff. Our survey participants responded

only on the basis of their expectations. This may suggest that people found dynamic time of use tariffs better to live with than they might expect. If this were the case, offering people the opportunity to experience a tariff before they commit to it (such as through a trial period) could help increase uptake.

In relation to automated response to DSR, it is useful to view this result in the context of phase 3 of the current research – the HomeTech trial. In this case participants tended to have positive expectations of automated DSR, but their experiences appeared to be generally less positive. A combination of technical issues, difficulties using and understanding the controls, and unexpected operation resulting in night-time overheating and noise were contributing factors. As Rogers (2003) describes, acceptance of an innovation is demonstrated by ongoing use. In this case, automated response to DSR signals could only be considered as accepted if people not only decide to use, but decide to continue using it. As stated above, the review by Frontier Economics and Sustainability First (2012) of domestic DSR trials found that automated responses were highest and most persistent. Of the eleven trials reviewed, nine of these focused on air conditioning (the remaining two focused on low-prioritized loads including pool pumps and water heating), and nine were based in the USA. The review also cites the example of night storage heaters on an Economy 7 in the UK. As phases 1 and 3 of this research (as well as other studies e.g. Consumer Focus (2012)) have found, levels of satisfaction with night storage heaters are generally low. The HomeTech trial provides evidence that, for heating at least, while automating response to DSR may theoretically provide a more consistent response, in practice the long term acceptability of it may be a challenge. For reasons set out in chapter 6, while technical issues should be expected to be fixed in future, what to do with excess heat produced if demand is to be shifted away from peak hours is a key sociotechnical challenge.

As stated in chapter 5, the hypothesis that having the option of automated response to a time of use tariff positively influences perceived ease of use was confirmed for dynamic TOU, but the opposite was found for static TOU. The justification for the hypothesis was that one of the roles of automation is to help humans undertake tasks that they otherwise wouldn't be able to do, or do well, or that they don't like doing (Wickens et al., 2015). It may be that participants saw the dynamic tariff as suitably complex that, without automation, they would not be able to use it effectively. There was evidence for this from the focus group study, for example: *'This [dynamic tariff] is the one where the price changes so often that no-one knows*

*what they're doing!'* [GCH7]. Participants in the focus groups saw the static tariff, on the other hand, as being simple:

> *… it's [static tariff] quite a simple system that probably would, you've got a bit more control.* [GCH5]

> *I think the principle is that if it's simple, and Economy 7 was simple, then you have more control, you might not like it but it's very very simple, I think the more complex that systems get the less people are likely to understand them and therefore use them …* [GCH1]

In this case, it is possible that participants in the survey just thought adding automation here was unnecessary, and indeed just complicated what was otherwise quite a simple offering. The experiences reported in the HomeTech trial suggested ease of understanding tariff such as Economy 7 but problems with the automated response (either with original storage heaters or the new control system). From a network benefits perspective, for the reasons described above, having an automated response will usually be desirable. It is therefore potentially problematic if offering automated response alongside a static tariff makes it no more desirable to consumers, or in some respects (such as ease of use) less desirable. While the evidence of this study suggests that offering automation with a dynamic tariff is likely to be a reliable incentive to sign up, the question of whether to offer it for static tariffs is more nuanced. It may be preferable for operators to focus on the simplicity of the static offering first, with automation being a less prominent option (and one which is simple to implement).

### 7.2.2 Other antecedents

The ability to choose whether or not to respond to DSR signals was identified as an important antecedent of perceived control. Unfortunately, resource restrictions meant that it was not possible to test the effect of varying the number and nature of override options in the survey experiment conducted in phase 2 of the research. This would be an interesting avenue for future study. However, on the basis of the relative acceptability of the DLC tariff which was offered with unlimited overrides, it is possible to conclude that this is consistent with idea that choice is an antecedent of control. The results of the HomeTech trial provide some more detailed insight into how choice might be perceived, and its role in perceptions of control. During that trial participants' ability to override the automated response was unclear to them. It was possible for them to press the 'minus' button on the interface to reduce the thermostat set point. However, because the DSR response was only required to

meet a minimum temperature and not a maximum, such reductions would have been ignored during periods of preheating (since the minimum would clearly be met – and exceeded). Furthermore, some participants understanding of the 'minus' button was that it should result in cooling, when the system was unable to provide such a function. As such, both the reality and perception on behalf of those participants who were negatively affected by overheating was that they had no choice but to endure it or have the system removed (which two chose to request).

The challenge for DSR operators is that every choice made by a consumer to opt out of a response to DSR signals reduces the value of their offering to the network. From the point of view of consumer acceptability it seems important to offer choice over response, while from the point of view of their business proposition it is in their interests to make sure that such choice is exercised as little as possible. Further research could usefully investigate the bounds within which consumers will tolerate DSR knowing that they have the option of opting out, but without choosing to do so.

The example of night-time overheating from the HomeTech trial is also pertinent to the concept of information as an antecedent of control. In this case the design of the controller was such that pressing the 'minus' button appeared to have no effect – essentially no feedback (a form of information) was given to the user. Furthermore, participants had no information on whether heat pump activity was due to their own timer settings, general background running to increase efficiency or to respond to DSR signals. It is clear from the interview data presented that participants were confused by this unscheduled activity, or attributed it to technical problems. In this case, this may largely be attributed to the principally technical nature of this trial. However, evidence was presented from focus groups in phase 1 that people on Economy 7 are unsure about the times between which rates apply and how exactly their storage and water heaters respond to this – sometimes resulting in misuse. This suggests that DSR operators will need to find ways to convey the information that consumers need in an appropriate manner. Future work could usefully investigate how this can be achieved. An example of a DSR operator conveying information about automated response to DSR is the Rush Hour Rewards[25] scheme from Nest, which shows a symbol on the thermostat when DSR activity is being taken, and giving the occupant the opportunity to overrule it.

[25] https://nest.com/support/article/What-is-Rush-Hour-Rewards, accessed 23 September 2015.

The experimental study confirmed that trust in electricity supplier is positively associated with DSR tariff acceptance. This was the case for all the offerings presented. Indeed, in the case of unautomated static and dynamic TOU tariffs, and of DLC, a person's trust in their electricity supplier has the single strongest association (of the variables measured, excluding the extended TAM variables) with tariff acceptance. This finding has important ramifications for how DSR offerings are designed, offered and communicated. Clearly, the high level of public distrust of energy suppliers in the UK (Which?, 2014) potentially presents a barrier to tariff acceptance where such tariffs are offered by those companies. It suggests a challenge to energy companies to focus even more strongly on building trust amongst their customer base, as well as an opportunity for more trusted companies operating in other sectors to enter or expand in the DSR market.

It is noteworthy that the proportion of people who said they distrust their energy company is lower for this study than for Which? (2014). This may be due to changes in the way in which the items were phrased. In particular, response options were amended in the current research to read, for example, 'fairly untrustworthy' and 'very untrustworthy' as compared to 'do not trust very much' and 'do not trust at all' in the original Which? responses[26]. This was done to improve consistency with the Likert-type response format presented for most of the other constructs measured. While this may appear to be a minor semantic difference, it is possible that participants interpreted the precise connotation of 'very untrustworthy' and 'do not trust at all' (for example) differently – as, indeed, the concepts of trust and distrust are different rather than one simply being the absence of the other (Hawley, 2014). It is permissible to trust an entity one believes to be untrustworthy (although it may be misguided). However, the concepts of trust and trustworthiness are closely related and often used almost interchangeably (Hardin, 1996) and this alteration is considered unlikely to have affected the substantive findings relating trust to acceptability of DSR.

It is interesting to note the range of effect sizes for trust. It is largest for the dynamic TOU tariff with no automation. Its importance here is unsurprising as someone on such a tariff is clearly making themselves quite vulnerable to the supplier's choice as to when to charge peak, medium or low rate prices, with no guarantee that they (the consumer) will be able to respond appropriately. However, it is somewhat surprising that trust was not still more important in the case of DLC. In this case the

[26] See http://www.populus.co.uk/wp-content/uploads/OmProfessional_Trust.pdf for examples of items.

vulnerability is to direct action affecting an individual's home heating system. It is probable that the very benign nature of the DLC tariff presented (with unlimited overrides and only a small possible effect on temperature) allayed concerns. It is striking that trust was less important where the possibility of an automated response to TOU pricing was offered. This may be because people feel assured that they are less likely to have to alter the way they live to fit the goals of their supplier; rather they can have a technology over which they have overall supervisory control optimize their cost performance (indeed, spending control was also significantly higher where there was the option of automation for the dynamic tariff). They may feel insulated by automated technology (which is under their control) from this novel exposure to the energy market.

The tariffs presented in the survey experiment all positioned the participant's own electricity supplier as the DSR operator. Had resources permitted, it would have been interesting to manipulate the identity of the DSR operator in the experimental stage of the research. For example, variants could have included a distribution network operator or community group – both of which could realistically be expected to be involved in offering DSR (see, for example, the NINES project mentioned in section 6.3.3 (SSEPD, 2013)). Community groups especially are becoming increasingly important in the British energy system (Seyfang et al., 2013) and are often seen as being more likely to be trusted by local residents, although this is by no means assured (Walker et al., 2010). Along with a measure of participants' trust in such organizations, such work could usefully inform who the best placed parties might be to offer and operate DSR programmes.

An important aspect of trust not examined in the experimental work was trust in automation. Trust in technology has been shown to be follow the same model as for trust in individuals and organizations, for example in expectations of benevolence, competence and integrity (see Li et al. (2008)). In the HomeTech trial, it is clear that some participants lost confidence in the ability of the new control system to function correctly – and furthermore they may have doubted whether it was acting in their own best interests or those of HomeTech or the registered social landlord (Valley Housing). The reliability of automation in performing its function is thought to be the most important factor in trust in automation (Wickens et al., 2015). In this case, this loss of confidence in reliability resulted in a demonstrable lack of trust in the control system on the part of some participants. To an extent this was based on their experience of the control system. However, the participants who reported such problems often also appeared to have a general mistrust of new technology (e.g. *'I*

*just wanna know that I can switch it on and off.'* [Christopher]). Careful attention will be needed on how to automate responses on behalf of consumers who are predisposed to be mistrustful of technology.

The various phases of the study provided several opportunities to investigate the role of familiarity with DSR on acceptance. In the survey experiment it was shown that people who are on an Economy 7 tariff were more likely than average to be willing to switch to the static TOU tariff and the dynamic tariff with automated response. There was also some evidence from the focus group stage of the research that people who are on an Economy 7 tariff would expect to lose control (in relation in spending on electricity) if they were to switch to a flat-rate tariff – suggesting that their experience of the time of use tariff was rather favourable. Chapter 2 has already cited evidence that British time of use tariff customers are generally happy with their time-based tariffs (if not with associated technologies such as night storage heaters) (Consumer Focus, 2012). This suggests that DSR operators could profitably target their communications at this sector of the consumer market.

It is informative to juxtapose this evidence on familiarity with other findings both from the focus group study in phase 1 of this research and from the HomeTech trial. In both cases, while participants were generally supportive in principle of the idea of time of use tariffs, their reports of their satisfaction with the main interdependent technology – various forms of night storage heating – are almost exclusively negative. The most common complaints were that heat was available at the wrong times – too much in the morning, too little later in the day. Furthermore, participants in the HomeTech trial who had experience of more modern automated heating system response to DSR signals reported similar problems. The situation may therefore be summarized as being that across all the phases of research presented here, participants with some familiarity with TOU tariffs appear to be favourably disposed towards them, but their experience of living with the technology required to make them effective from the DSR operator's point of view has generally been negative. This suggests that this should be an important focus for innovation.

## 7.3 The acceptability of external control

The finding in phase 2 of this research that a DLC tariff (with lower than average flat rate for electricity) was most acceptable was somewhat surprising given previous evidence of significant concerns around loss of control on such tariffs (see chapter 2). Indeed, the results indicated that people expected to have more general control

on the DLC tariff compared to the TOU tariffs (but not in relation to spending on electricity). There are a number of possible explanations for this.

Firstly, it is important to note that this is the first assessment of demand for various DSR tariffs, including both time of use tariffs and direct load control, to be conducted for a representative sample of the population of Great Britain. Where concerns have previously been voiced around loss of control in DLC programmes, it has mainly been in smaller scale qualitative studies or in other contexts, for example that look at the energy system as a whole. The strength with which concerns around loss of control have been expressed (e.g. as quoted in Rodden et al. (2013: 6): *'… we should have the choice of how we use energy in our home, at least that! Our home for crying out loud!'*) may have contributed to a sense that such concerns are more of a barrier to acceptance than the results of the survey study would suggest. It is pertinent to consider that a form of DLC has actually been in use in the UK for decades through the radio teleswitch for electric storage heaters with no outcry, although it is impossible to know how many people would choose to adopt such a system if it were offered to them (rather than inheriting it as a legacy product).

The DLC tariff presented to participants in the survey study was intentionally quite benign, allowing only a small ('less than 1 degree C') impact on internal temperature. Concerns expressed previously sometimes related to different or stronger forms of direct control. In the initial focus group study, for example, bounds in which temperature might change under DLC were not as tightly delimited (referred to in terms of 'a small amount' rather than a value in degrees Celsius). Other studies such as Mert (2008) and Rodden et al. (2013) included discussion of control of smart appliances such as washing machines, where other fears such as flooding, fire and noise (as highlighted by Mert) could be associated with concerns around loss of control. Related to this, there is clear prior evidence (e.g. Butler et al., 2013) that having an override function made, for some people, the unacceptable acceptable. It may be that inclusion of unlimited overrides meant that people perceived themselves to retain sufficient 'human supervisory control' – of which the ability to intervene in automated action is an important part (Sheridan, 2012) – for the idea of external control to become acceptable.

Previous findings regarding such concerns in small groups are not necessarily inconsistent with the findings of this and other studies at the national scale (some of which were published after the current research was planned). In this study, 37% of

participants were favourable towards switching to a tariff involving DLC, with 63% somewhat or strongly agreeing that the tariff presented was a good idea. Thirty per cent of people were found to be strongly or somewhat against switching to the DLC tariff, which is in line with the finding by Downing and iCaro Consulting (2009) that the same proportion of people were concerned by loss of individual control in sustainable community infrastructure involving remote control of appliances. There is also broad consistency with the proportion of people found to be in favour of limited cooker use by Oseni et al. (2013) (32-36%) and remote triggering of washing machines by Spence et al. (2015) (just under 30%).

It is interesting to note that the proportion of people accepting DLC in this study and those of Spence et al. (2015) and Oseni et al. (2013) were broadly similar despite the level and type of incentive being different in each case. This study offered a reduced flat rate, while Oseni et al. (2013) offered a rebate on bills and Spence et al. (2015) did not mention any compensation. There was evidence from the HomeTech trial that for some people the main concern was not that they should save money with DSR, but simply that they should feel confident it would not cost them extra (e.g. *'as long as it didn't … if it's dear I wouldn't be interested at all.'* [Maureen]). It is possible that some participants in all three studies interpreted the offerings in this way, contributing to that consistency. Further research specifically focusing on the effect of different incentives would be required to support this hypothesis.

Another factor that could help explain *prima facie* differences between the findings of the survey study and the initial focus groups (and previous results) is psychological distance. In this survey, participants were asked to take a relatively quick decision based on the available information about whether they would actually sign up to a tariff. Much of the previous research cited (e.g. Butler et al., 2013; Rodden et al., 2013; Mert, 2008) has asked in more general terms what people think about the idea of DLC taking place in a general future period. Construal level theory holds that in making decisions which will have temporally nearer outcomes, people focus more on detailed contextual factors (such as value for money and the precise terms of the tariff deal), while for more temporally distant outcomes more high-level and abstract factors (such as values and attitudes) come into play (Trope et al., 2007). It may be that when people consider DLC in the abstract, concerns about loss of control and autonomy are more salient than when faced with a tariff decision which (hypothetically at least) has a more immediate outcome. In the latter

case, more immediate concerns such as cost and whether people think they will get the energy services they need may take precedence.

It is worth re-emphasizing (as initially set out in chapter 3) that qualitative and quantitative approaches have very different goals, and the results of both can be valid while appearing at a glance somewhat at odds. For example, the focus group study presented here aimed to explore understandings of control in relation to energy and DSR. While the expectation was for these understandings (and the reasons for them) to be relevant and applicable to the wider population, there was no expectation of generalizing their priority or distribution (e.g. proportionally) to that population. The survey, on the other hand, was set up to do just that. Of course, ticking a survey box is different to actually switching tariff and it may be that other concerns (such as potentially more abstract concepts of autonomy) do indeed feature more prominently. This issue is discussed further towards the end of section 7.4 below.

Part of the aim of this study was to explore the acceptability of DLC in principle – that is, the direct influence by an external party on the action of technology within the home. Choosing a form of external control that would have limited direct impact on consumers was important in isolating the issue of third party control in itself from concerns that may follow directly from it (such as noise of running a washing machine overnight). What this study has shown is that the principle of external control in an important area such as heating is acceptable to many people, in a context where the limits of control are strictly defined and the option of overriding it clearly available. Some consensus appears to be emerging amongst nationally representative studies of GB that between a third and a half of people are open to the idea of external control. Further work could usefully test how varying the bounds of control and override potential affect acceptance.

The preceding paragraphs have dealt mainly with the absolute acceptability of the principle of DLC in Great Britain. It is also useful to explore its relative acceptability compared to the TOU tariffs, since this may also shed light on the relatively high ratings DLC received for the control variables which were measured. One clear difference between the DLC and TOU tariffs was that the TOU tariffs would affect all electricity use, while the DLC only applied to heating. It is perhaps not surprising that people would report an expectation of lower control over comfort, the timing of when they do things and their lives in general when activities such as cooking and watching television are affected in one case (TOU) and not in another (DLC). The

implication is that concerns around who is doing the controlling (e.g. a DSR operator in DLC) are subsidiary to fears that control will be lost over people's ability to do things that use electricity to the extent and at the times they want.

In the HomeTech trial participants were almost all completely unconcerned that their use of the heating system and its activities were being remotely monitored, and even controlled, by HomeTech. As discussed in chapter 6, it is possible that participants in the study (as residents of retirement properties) were more than usually accustomed to external intrusion into their homes (e.g. through wardens having keys for emergency access). It is also possible that participants felt it would be socially unacceptable to complain about this in interviews involving a HomeTech representative – although it is clear that they were happy to complain about other issues, so this seems improbable. Taken with the results of phase 2 of the study, their acceptance of external monitoring and control does not seem altogether inconsistent with the population more generally. Further experimental work that specifically manipulates precisely where control resides (i.e. the identical tariff with response actuated manually, by automation within the home or by an external agency) would be required to confirm this (and trust is likely to be an important factor in this (see section 7.2.2)).

Other structural differences between the DLC and TOU tariffs may have contributed to the relative acceptability of the former. Nicolson et al., (under review) show that a high proportion of the British population are loss averse – that is, they give greater weight to potential losses than gains. Pricing information was prominent in the tariff descriptions used here, and could therefore be expected to be quite salient when participants were making decisions about willingness to switch. Because it was based on a lower than average flat rate, the DLC tariff offers a guaranteed saving and no prospect of losing money compared to being on a standard flat rate tariff. On the contrary, while there is the potential to save money by exploiting low off-peak rates on TOU tariffs, there is also the possibility of being worse off if people find they are unable to do so. This may have contributed to the relatively high perceived usefulness rating of the DLC tariff, two items for which specifically focused on whether people thought they would save money on the tariff (and perceived usefulness was the strongest predictor of willingness to switch to the DLC tariff). To truly test the association between direct load control and autonomy (or on the basis of the preceding discussion, a sense of general control including aspects of autonomy), it would be necessary to design an experiment which precisely manipulated only this factor while holding all others constant. As explained in

chapter 5, this was not done here out of the need to balance testing a range of realistic DSR tariff options with pragmatic concerns such as sample size.

## 7.4 Privacy, locus of control and other factors

Research question 3 prompts exploration of how factors not considered part of the perceived control framework developed here are associated with DSR acceptance. The results of the survey experiment confirm that privacy concern is negatively associated with acceptance. These results are consistent with previous findings (e.g. Hoenkamp et al., 2011) that privacy is an important concern in relation to smart energy systems, and that acceptance can only be expected where people feel assured that they have appropriate control over their data and how it is used. Again, it is interesting to note that the association is not strongest for DLC, where there is the most direct 'intrusion' by an external agency into the home, but for the dynamic TOU tariff with automation – although it is unclear why this should be the case. It is possible that the explicit ability to override DLC was sufficient to allay concerns about such intrusion.

The only significant association with locus of control was for the DLC offering, where people who perceived themselves to have less personal control in relation to energy (i.e. a more external locus of control) were more likely to accept the tariff. Further testing revealed that people with external locus of control were more likely to think they would save money on the DLC tariff, but no more likely to feel positively towards it. This suggests that it is attractive to people with external locus of control mainly for its money saving potential rather than any greater acceptance of the idea of external control. As suggested in section 5.4, special attention should be paid to ensuring that people who consider themselves to have little other option to save money on energy are not exploited through being attracted to cede large amounts of control over comfort- and health-related energy services such as heating.

Some associations were found which cannot be explained with confidence on the basis of the data available, and suggest interesting future avenues for research. Trust in the supplier's ability to ensure a reliable electricity supply was negatively associated with acceptance of the dynamic TOU tariff (only). A possible explanation for this is that people for whom reliability of supply is a salient issue may be more likely to recognise the benefits of tariffs such as this which can adapt to the specific ever-changing needs of the grid. Were this the case, it may suggest that if the much-discussed tightening of capacity margins in the UK does result in increasing

power interruptions, people could increasingly see the value of DSR tariffs. However, since there was no association between lack of trust in a reliable supply and acceptance of the other tariffs, more focused research on this question would be required to establish whether this is a genuine issue.

Being a private tenant was positively associated with acceptance of the dynamic TOU tariff. This finding is in common with that of Stenner et al. (2015), who also found that renters prefer real-time pricing. It is possible that private tenants who want to save money on their energy bill viewed this as an option that was open to them to achieve this, where other options (such as fabric improvements) were not. If this were the case, it is possible that certain DSR tariffs could be viewed as giving some empowerment in relation to energy use for people who otherwise have little opportunity to act in this area – and therefore targeted in this area. However, it is not clear why this should only apply to the dynamic TOU tariff. Additionally, being a social tenant did not show an association here, and it was negatively associated with acceptance of the dynamic TOU tariff with automation. These findings are contradictory and would benefit from further research, especially in light of concerns that everyone should feel able to benefit from smart grid applications such as DSR. Being the sole occupant is significantly positively associated with acceptance of the static TOU tariff with automation. It is plausible that having some automated function would be important for certain lone occupants as they would not be able to rely on other household members to turn appliances of and on for them. However, it is – again – unclear why this should not also apply in the case of automated dynamic TOU.

Concern about future climate change was positively associated with acceptance of the dTOU and automated dTOU tariffs, but none of the others. This is interesting in the light of the finding by Spence et al. (2015) that concern about future climate was positively associated with acceptance of a range of automated DSR measures. There are a number of possible reasons for the difference in association with climate concern between different tariffs, and between this study and Spence et al. (2015). The key difference between this study and that of Spence et al. (2015) is that the latter formed a scale of DSR acceptance based on the participants' acceptance of the range of DSR offerings presented. It is not therefore possible to distinguish (on the basis of the data presented) the extent to which climate concern might have different associations with different measures. The current study, on the other hand, does allow association of climate concern with different tariffs to be observed separately. Possible reasons for such differences are considered below.

A key difference between the two studies is the context in which the questions were asked. Spence et al. (2015) posed questions on DSR as part of a long survey (median completion time 48 minutes as reported by Demski et al. (2013) covering the same piece of work) on energy system transformation in the UK, with questions throughout considering issues around affordability, security and sustainability of different energy options. While the full questionnaire does not appear to be available, the order in which the themes it covers are summarized in Demski et al. (2013) suggests that participants will have already been giving a lot of consideration to the climate implications of different energy options by the time they came to the questions on acceptability of DSR. The current study, on the other hand, asked first for participants' response to the DSR tariffs themselves, and only later measured climate concern. Evidence of an 'order effect' – that the response to questions may differ depending on the preceding questions – has long been found (Kalton & Schuman, 1982), and it is possible that this may also have contributed to the difference in findings in this case.

Turning to the difference in apparent associations between the different tariffs, it is possible that there were small associations between climate concern and acceptance of the static TOU tariffs and DLC but that the sample size was too small to detect it (suggesting the substantive effect would anyway be very small). It may also be that the inclusion of different variables in the regression model used by Spence et al. led to the difference in result. A possible substantive reason for the difference in climate concern association between the dynamic and static/DLC tariffs is that the descriptions of the dynamic tariffs specifically stated that these tariffs would be partly determined by 'predicted amounts of wind power'. This was done because some participants in the Low Carbon London trial objected to the seemingly random variation in dynamic tariff price they were charged as they were not informed of the reasons for changes (Carmichael et al., 2014). The inclusion of this information may have made the dynamic tariffs more attractive to those people who are concerned about climate change and support mitigating it through the use of renewable energy. It is notable that all the tariffs were briefly introduced in this study as follows:

> *Some electricity tariffs try to encourage people to use electricity at times of day when it is cheaper and cleaner to produce.*

This clearly did not have the effect of 'priming' climate concern for all of the tariffs. It is possible that participants skimmed over this information, or that they did not

connect the idea of being ‘cleaner’ with climate change, or that they did not believe in some of the tariffs’ potential to mitigate climate change. What this suggests is that it should not be presumed that consumers will necessarily see all DSR tariffs as environmentally friendly, or believe claims that it is, or will be attracted by such claims.

One challenge common to all the phases of research presented here is that they have relied on participants’ reported intentions or experiences, rather than direct behavioural observation. The reason for this (considered in more detail in chapter 3) was principally that practical constraints prohibited actually offering participants the opportunity to sign up to a DSR tariff (or other offering). It is known that stated behavioural intention to act (which this study measured) does not closely relate to actual behaviour. As previously cited, a review by Sheeran (2002) found that, on average, 28% of variance in behaviour was explained by intention. There is even a substantial discrepancy between people’s self-reporting of behaviour and objective measures of that behaviour, with a meta-analysis indicating that 79% of variance in reported ‘environmental’ behaviours (e.g. recycling, cycling, etc.) is not explained by variance in objective measures (Kormos & Gifford, 2014). In the context of energy tariffs, actual switching rates are known to be low, with 62% of people saying they have never switched (Ofgem, 2014b), suggesting that the results obtained here are likely to overestimate real switching behaviour. The results presented should therefore be viewed as indicative rather than predictive of likely tariff acceptance. However, at a time when DSR tariffs are not widely offered, they can provide a useful insight into the factors that might ultimately affect adoption.

There are further questions around how the survey findings can be interpreted in terms of substantive importance in the real world. For example, what does it actually mean if 10% fewer people say they are strongly or somewhat against signing up to a dynamic tariff when it offers the option of automation? And are the many people who gave a ‘neither’ response implicitly against the tariffs, or just ambivalent (and does it make a difference if they do not ultimately engage)? Some tentative answers are possible. For example, in 2013 roughly 12% of consumers reported switching electricity supplier in last year, and 15% switched tariff or payment method (Ofgem, 2014b). Of the 26 million homes in GB, 15% represents approximately 3.9 million. If dynamic tariffs were commercially available, and if 10% of people go from negative to at least neutral towards such a tariff with the offer of automation, this would equate to 390,000 more consumers at least potentially in the market for such a tariff that year who may not otherwise have been. For reasons

described above it is impossible to say how this would translate into actual switching behaviour or, indeed, demand response potential, but on the face of it this appears to be a substantively as well as statistically significant effect.

The reasons for using the Technology Assessment Model to help guide this research – demonstrable relevant explanatory power, parsimony, ease of extensibility – were set out in chapter 2. However, it is clear that it does not include all factors which might be expected to impact on the ultimate acceptance of different DSR offerings. One important area that has received little attention here is related to social norms. The role of people's perceptions of what is socially acceptable is known to be an influential one, and alternative models of behaviour or behaviour change such as the Theory of Planned Behaviour (Ajzen, 1991) and Norm Activation Model (Schwartz, 1977) explicitly include it. This was apparent in the current research especially in the HomeTech trial, where participants often referred to nearby residents and their heating practices, sometimes in the context of justifying their own (e.g. *'Some of them have them full blast, which is like a sauna'* [Fiona], when discussing how they like to keep their heating quite low). It is reasonable to expect that changing social norms around DSR could impact upon its acceptance – this is an area of ongoing research elsewhere (e.g. Bradley et al., 2014).

Related to this is the concept of social networks and social capital. Social capital can be defined as *'resources embedded in a social structure which are accessed and/or mobilized in purposive actions'* (Lin, 2002: 40). For example, at its simplest, this might involve asking a neighbour to help out moving a piece of furniture. It has been demonstrated that approaches which leverage social capital to, for example, promote the diffusion of energy-reducing innovations, can be successful (McMichael & Shipworth, 2013). In that case, people were shown to go to others they knew for advice as well as to established sources of information such as organizations or the media. The HomeTech trial showed examples of social capital being mobilized, for example when Hector spoke of helping his father's neighbours set up their computers or when David called the housing association to fix a problem with a neighbour's heating. It is conceivable that technical and ease of use problems associated with automated DSR could be mitigated by leveraging this approach – but this remains an empirical question.

Finally, little attention has been paid here to intra-household dynamics, or the role that the actions or desires of different household members might have on whether a

household ultimately moves onto a DSR tariff. That this can have an important effect on energy-consuming practices and therefore overall energy use is well-established (e.g. Wilson et al. (2014) in the context of smart homes). It can be crudely observed in the results of the survey experiment presented here, where lone occupants were shown to the significantly more accepting of the static TOU tariff than those who lived with others. Approaches which take either households as the unit of enquiry (such as Hargreaves et al. (2015)), or social practices (such as Higginson et al. (2013), and as outlined in section 2.3), are essential to unpicking the underlying drivers for findings such as this.

This chapter set out answers to the research questions, considered limitations of the study and proposed areas for future research. The key conclusions and contributions of the work are presented in the next chapter along with their implications for research, policy and industry.

# 8 Conclusions

This programme of research set out to investigate how people understand 'control' in the context of home energy use, and how their perceptions of control may influence the future acceptability of domestic demand-side response (DSR). Such DSR is viewed as important to the sustainable, secure and affordable operation of Great Britain's electricity system (Ofgem, 2015b). This concluding section summarizes the key original contributions made by this research and outlines their significance for research, industry and policy.

## 8.1 Summary of key findings

The research was conducted in three stages. An initial set of focus groups, together with analysis of the literature, explored the different motivations people may have for wanting control, and the antecedents that influence whether or not they feel in control. The second stage of research deployed a survey to a representative sample of energy bill-payers in Great Britain. It operationalized an extended version of the Technology Acceptance Model (Davis, 1989) based on the focus group results to test whether (and which dimensions of) perceived control was related to acceptance of DSR. Using an experimental approach, it also allowed comparison between different forms of DSR (static and dynamic time of use (TOU) pricing, with and without automated response, and direct load control). Other attitudinal and demographic factors were also explored. Finally, a case study was conducted of a trial of a new 'intelligent' domestic heat pump control system capable of cost-optimizing response to DSR signals. Surveys and interviews were conducted with participants before and after the trial with the aim of exploring how people's experiences of DSR compared to their expectations.

Analysis of the focus group results revealed four key motivations for control – control over *quality of service* (for example comfort, in the case of heating), *timing of activity* (or when people do things), *spending on energy*, and *autonomy* (or a sense of control in one's own life with freedom from outside influence). Through a scale development exercise these were operationalized in a survey which, however, showed very high multicollinearity between the constructs concerning control of comfort and timing, and autonomy. In light of this, the control constructs were restructured resulting in two constructs – control over spending on energy, and a general sense of control reflecting aspects of comfort, timing and autonomy.

General control was shown to be significantly positively associated with acceptance of all the DSR tariffs presented, while spending control had no significant association with any tariff except for the static TOU tariff, with which it was negatively associated.

Key antecedents of control identified in the focus groups were information, familiarity, predictability, trust and choice. The effect of manipulating the predictability of DSR signals was investigated in the survey by including both static and dynamic TOU pricing, with or without the option of automated response. There was a significant interaction effect between predictability and automation, with the option of an automated response making the unpredictable dynamic tariff as acceptable as the predictable static tariff. Where automation was not offered, participants had a more favourable attitude towards the static tariff and viewed it as easier to use. Of the other antecedents that the survey was able to explore, trust in energy supplier was shown to be significantly positively associated with acceptance of all tariffs (especially so where the option of automation was not offered). Participants who reported being on an Economy 7 tariff were significantly more favourable to the idea of switching to a static TOU tariff, suggesting the possible role of familiarity in acceptance. It was not possible to measure the effect of information or choice directly.

The survey experiment found that 25-30% of energy bill-payers in Great Britain were strongly or somewhat favourable to the idea of switching to a time of use tariff, while 37% were favourable towards switching to a tariff allowing external control of their heating system in return for a discounted flat-rate tariff. As well as the above antecedents to control, acceptance was also found to be negatively associated with privacy concern for all tariffs, and acceptance of the direct load control tariff was associated with having an external locus of control in relation to energy. Older people were somewhat less likely to be accepting of the unautomated static tariff and the automated dynamic tariff than younger people, but there were no consistent associations with factors typically associated with vulnerability such as household income or being a social tenant.

The results of the final case study stage of the research provide a different perspective on these findings since they reflect people's experience of an innovative automated DSR offering. Again, the research was structured according to the understanding of control (and other factors for acceptance) established in the previous two phases of work. Participants experienced a range of problems with the

new control system, including technical issues, difficulty using the controller and issues with night-time overheating and noise. Despite this, most participants retained a positive view of DSR following the trial – but often with the caveat that it should work better than it did if they were to continue to use the system that was trialled. Technical and usability issues should be expected to improve based on the findings of the trial. However, longer heat pump operation, including overnight, is potentially integral to the ability to achieve DSR successfully. It is clear that where participants felt unable to override this they felt a diminished sense of general control and were unlikely to continue of the system (or indeed requested that it be removed). This suggests that when people's expectations of control are not met in reality, DSR is unlikely to be accepted.

## 8.2 Implications for research, practice and policy

While the importance of control is well recognised in research connected with energy use and DSR, no research has previously aimed to explore the separate motivations, antecedents, agents, means and ends of control in the way that is pursued here (following the recommendation of Skinner (1996)). It is hoped that qualitative researchers with an interest in control will be able to draw on these identified motivations and antecedents to structure their own enquiry (in the same way that they informed the design of the case study work presented here). The scale development and survey work has yielded items and a scale for acceptance of DSR that can be drawn on (with consideration to suggested amendments in chapter 7) by future quantitative researchers to investigate acceptance of different DSR offerings. In particular, the general control construct (which was significantly positively associated with acceptance of all tariffs and increased the explanatory power of the TAM, albeit slightly) with its reduced number of items could be included in survey instruments at little cost to resources or completion time. Overall, the findings should help give greater precision both to the process of enquiry in relation to control in DSR and the way in which results are discussed, reducing ambiguity and potentially facilitating more useful and specific recommendations.

The findings also suggest a range of avenues for future subjects of research. While the survey experiment presented here manipulated the predictability of DSR signals and where the response to them was actuated, it would be useful to investigate the effect of varying other factors such as ability to override, prices, identity of DSR operators and the type of appliances referred to. The results already presented here constitute an early point of comparison for such future work. As domestic DSR

becomes more viable with the introduction of smart meters, this will allow research to focus more on actual uptake rather than on statements of intention, which should increase the validity of the results.

One of the main implications for practice from this research is that direct load control of heating – one of the areas expected to account for most electricity demand in future – is acceptable in principle to many people. This, and the finding that having the option of an automated response to dynamic time of use pricing makes it more acceptable, are important for two main reasons. Firstly, they give the DSR operator flexibility in eliciting a demand response and therefore better permit responses to less predictable factors such as renewable (e.g. wind) generation or to faults on the system. Secondly, automated responses have been shown to be more enduring and reliable than those relying on manual response (Frontier Economics & Sustainability First, 2012b). This suggests that technology manufacturers and DSR operators should have confidence in concentrating their research and development efforts in these areas. In terms of communication with customers, automation should be promoted as a key accompaniment to dynamic tariffs, while for static tariffs it may serve better to focus on the simplicity of the tariff itself, with automation in a supporting role.

The findings from the case study provide an interesting counterpoint to this in that, while automated DSR was generally viewed positively by participants even after they experienced problems with it, there were suggestions that unless it could be operated in such a way that left much more control with the user, it would face difficulties in assuring acceptance. This challenge requires a whole system response, in that people's perceptions of control and ultimate acceptance will depend on the interaction between heating system and building, DSR operator and control system, and control system and user. Most pressingly, research is needed to determine what key factors that may pose problems for future DSR acceptance are locked in on system installation. Electric heating systems such as heat pumps are being incentivized by policy and, once fitted, should be expected to be in place for some time. Unless they can be installed in such a way that automated DSR can be 'retrofitted' without problems such as night-time overheating and noise, DSR will already be at a serious disadvantage. Factors to investigate should include fan positioning for air-source heat pumps, the possibility of better zoning to avoid overheating of bedrooms in particular, and how best to communicate with customers about the possible effects of DSR (and how they can be mitigated).

The findings specifically concerning control suggest that it is most important that people should feel a general sense of control over the level of energy service quality they receive. This means being able to access enough of that service, at the right time, with a sufficient sense of autonomy over these decisions. It is less important that people feel a sense of control over spending – although making a saving (or at least not perceiving a financial loss) appears to be a key condition of acceptance. This relates to the previous paragraph in that it is imperative that those developing DSR services should make retaining such control for their potential customers a driving goal. It is likely that retaining a sufficient level of 'supervisory' control over service level is an important contributing factor in acceptance of external control – but further research (e.g. varying the possibility of override as described above) could specifically test this. This is also likely to be important when communicating the benefits of these offerings – although further research would be required to determine precisely which framings are most effective in promoting DSR. Overall, the results suggest that people's perceptions of the savings (or other benefits) potential associated with DSR tariffs will be an important determinant of their decision to switch.

The proportion of 25-37% of survey participants indicating that they were somewhat or strongly favourable towards switching to the range of DSR tariff presented should be encouraging to UK policymakers as this is not inconsistent with Government's business case for the introduction of smart meters. This is predicated on 20% uptake of static time of use tariffs by 2030, in addition to those already on such tariffs (DECC, 2013b). However, tariff switching rates in the UK remain low (Ofgem, 2014b). Unless this issue can be addressed, it will be hard to convert favourable attitudes towards DSR into participation in practice. The findings also provide support for a smart meter roll-out approach which avoids mandatory implementation of DSR tariffs. Despite the encouraging levels of support, there remains significant opposition with more than twice as many people strongly against as strongly for all the tariffs. Such opposition could represent a general threat to uptake of smart meters, were DSR tariffs to be a mandatory accompaniment to them (as will be the case in Ireland (CER, 2014)).

Energy companies are known to have a problem with trust in Great Britain, with 40% of people expressing distrust in their supplier (Which?, 2014) (and a lower but still considerable figure of 29% in the second phase of this research). This work identified trust in supplier as an antecedent of control, and showed that it is the most important of the attitudinal and demographic predictors of acceptance of all

the tariffs (where framed as offered by the participant's current electricity supplier). This should add to other motivations to energy suppliers to build trust amongst their consumers if they are keen to offer DSR services. However, it also suggests an opportunity for trusted new entrants to the market. These may be from other sector such as home appliances, or different kinds of organization, such as those driven by communities. Further research could usefully establish the impact that who is offering DSR has on acceptance.

One potentially encouraging finding for energy companies is that when time of use tariffs were offered with automation in the current study, the association between trust and acceptance was smaller than when it was not. Viewed somewhat cynically, this suggests that automated solutions could be offered by such companies to mitigate lack of consumer trust. Viewed more positively, consumers may see the option of automation as a way of optimising their response to time of use tariffs, maximising savings and insulating them from uncertainty – with benefits for both consumers and suppliers. The lesson from the case study research, however, is that trust in technology (as well as the entity offering it) is also important. The findings suggest that where technical or design factors prevented the control system from working as the user expected, they lost trust in its ability to perform other functions such as automating response to DSR. This points to the need for rigorous testing in the field – not only of DSR-related services in isolation but alongside other technologies with which they are likely to interact in the real world.

The survey finding of a negative association between concern about privacy and willingness to switch reaffirms the vital importance of building public confidence in the security of system innovations and facilitating technologies such as smart meters. While the current research could not test this directly, perceived threats to privacy should be expected to harm uptake of demand-side response tariffs. Proponents of DSR should push for rigorously enforced privacy protection in the sector; regulators should continue to review how this can best be achieved. A further area of potential concern is that people with an external locus of control in relation to energy were more likely to accept direct load control. While they were no more likely to feel positive towards it than people with more internal locus, they were more likely to think it would save them money. While this is not *de facto* a bad thing, it does suggest that attention should be paid to the level of control which people are asked to hand over to third parties in return for financial reward. For example, large bill reductions in return for large internal temperature reductions

could be dangerous for more vulnerable people. Set against this, however, it is reassuring to note that factors traditionally more associated with being vulnerable (such as income or social tenancy) had no strong consistent association, suggesting that people who are more likely to be vulnerable should not be expected to miss out on the benefits of DSR by virtue of their willingness to participate.

The research has a range of implications for targeting of DSR services. The results of the survey suggest that people who are already on a DSR tariff such as Economy 7 might be more receptive to similar static offerings. As these consumers will already be known to some potential DSR operators (such as energy companies) they should be relatively easy to target. There were no consistent demographic differences in acceptance across the tariffs. However, it was found that younger people were more likely than older people to be accepting of an unautomated static TOU tariff and an automated dynamic tariff. The case study results suggest that older people who did not consider themselves to be particularly 'tech savvy' found the control system harder to use and considered it not to be 'for them'. The implications of this are two-fold. Firstly, younger people might be considered more likely to be early adopters of certain DSR offerings and could be targeted as such. Secondly, as a growing demographic sector, there appears to be an opportunity to develop offerings which increase the appeal of DSR to older people. While recognizing the diversity of this sector and its increasing technological proficiency, this is still, however, likely to involve making the operation as straightforward possible.

In conclusion, this has been the first work to focus explicitly on people's perceptions of control in the context of DSR, and has shed light on the different motivations and antecedents for control and their relative importance in DSR acceptability. The results paint a varied picture of the prospects for DSR in Great Britain. While levels of support for DSR may be viewed as encouraging given the very limited commercial availability of offerings currently in the market, there are challenges to face in ensuring that people get the levels of control they expect to have in relation to their energy use and the services that energy underpins. Implemented appropriately, DSR can take advantage of modern information and communications technology to make our electricity cleaner, more affordable and more secure. It is hoped that this research goes some way towards informing the next steps in its development.

# 9 References


Adams, D. A., Nelson, R. R. and Todd, P. A. (1992) 'Perceived Usefulness, Ease of Use, and Usage of Information Technology: A Replication', *MIS Quarterly*, 16(2), pp. 227–247, [online] Available from: http://www.jstor.org/stable/249577 (Accessed 22 June 2015).

Ajzen, I. (1991) 'The theory of planned behavior', *Organizational Behavior and Human Decision Processes*, 50(2), pp. 179–211, [online] Available from: http://dx.doi.org/10.1016/0749-5978(91)90020-T (Accessed 16 January 2013).

Ajzen, I. (2002) 'Perceived Behavioral Control, Self-Efficacy, Locus of Control, and the Theory of Planned Behavior', *Journal of Applied Social Psychology*, 32(4), pp. 665–683, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1559-1816.2002.tb00236.x/abstract (Accessed 8 October 2012).

Ajzen, I. and Fishbein, M. (1980) *Understanding attitudes and predicting social behavior*, Englewood Cliffs, NJ, Prentice-Hall.

Arteconi, A., Hewitt, N. J. and Polonara, F. (2013) 'Domestic demand-side management (DSM): Role of heat pumps and thermal energy storage (TES) systems', *Applied Thermal Engineering*, 51(1–2), pp. 155–165, [online] Available from: http://www.sciencedirect.com/science/article/pii/S1359431112006357 (Accessed 30 October 2013).

Ashok, S. (2006) 'Peak-load management in steel plants', *Applied Energy*, 83(5), pp. 413–424, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0306261905000681 (Accessed 9 November 2015).

Atkinson, R. and Flint, J. (2004) 'Snowball Sampling', In *Encyclopedia of Social Science Research Methods*, Thousand Oaks, CA, SAGE, [online] Available from: http://knowledge.sagepub.com/view/socialscience/n931.xml (Accessed 16 July 2015).

Bagozzi, R. P. (2007) 'The Legacy of the Technology Acceptance Model and a Proposal for a Paradigm Shift', *Journal of the Association for Information Systems*, 8(4), pp. 243–254, [online] Available from: http://search.proquest.com/docview/198793649/140DF4DE95BBD9BA6D/1?accountid=14511 (Accessed 2 October 2013).

Bailey, K. (2008) *Methods of Social Research, 4th Edition*, New York, NY, Simon and Schuster.

Balta-Ozkan, N., Amerighi, O. and Boteler, B. (2014) 'A comparison of consumer perceptions towards smart homes in the UK, Germany and Italy: reflections for policy and future research', *Technology Analysis & Strategic Management*, 26(10), pp. 1176–1195, [online] Available from: http://dx.doi.org/10.1080/09537325.2014.975788 (Accessed 12 November 2014).

Balta-Ozkan, N., Davidson, R., Bicket, M. and Whitmarsh, L. (2013) 'Social barriers to the adoption of smart homes', *Energy Policy*, 63, pp. 363–374, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421513008471 (Accessed 16 December 2013).

Balta-Ozkan, N., Watson, T., Connor, P., Axon, C., Whitmarsh, L., Davidson, R., Spence, A., Baker, P., Xenias, D., Cipcigan, L. and Taylor, G. (2014) *Scenarios for the Development of Smart Grids in the UK: Synthesis Report*, London, UK, UKERC, [online] Available from: http://www.ukerc.ac.uk/support/tiki-index.php?page=RF3LSmartGrids (Accessed 25 February 2014).

Bandura, A. (1991) 'Social cognitive theory of self-regulation', *Organizational Behavior and Human Decision Processes*, 50(2), pp. 248–287, [online] Available from: http://linkinghub.elsevier.com/retrieve/pii/074959789190022L (Accessed 9 July 2015).

Barabas, J. and Jerit, J. (2010) 'Are Survey Experiments Externally Valid?', *American Political Science Review*, 104(02), pp. 226–242, [online] Available from: http://journals.cambridge.org/article_S0003055410000092 (Accessed 19 August 2015).

Barker, C. (2008) *Cultural Studies: Theory and Practice*, SAGE.

Battaglia, M. (2008) 'Convenience Sampling', In *Encyclopedia of Survey Research Methods*, Thousand Oaks, CA, SAGE, [online] Available from: http://knowledge.sagepub.com/view/survey/n105.xml (Accessed 16 July 2015).

Battaglia, M. P. (2008) 'Nonprobability Sampling', In *Encyclopedia of Survey Research Methods*, Thousand Oaks, CA, SAGE, [online] Available from: http://knowledge.sagepub.com/view/survey/n337.xml (Accessed 16 July 2015).

Bell, S., Capova, K. A., Barteczko-Hibbert, C., Matthews, P., Wardle, R., Bulkeley, H., Lyon, S., Judson, E. and Powells, G. (2015) *High Level Summary of Learning, Heat Pump Customers (Customer-Led Network Revolution)*, Durham, UK, [online] Available from: http://www.networkrevolution.co.uk/wp-content/uploads/2015/01/CLNR-L245-High-Level-Learning-Heat-Pump-Customers.pdf (Accessed 12 November 2015).

Bhattacherjee, A. (2002) 'Individual trust in online firms: Scale development and initial test', *Journal of management information systems*, 19(1), pp. 211–242, [online] Available from: http://www.jstor.org/stable/40398572?seq=1#page_scan_tab_contents (Accessed 1 November 2013).

Block, E. S. and Erskine, L. (2012) 'Interviewing by Telephone: Specific Considerations, Opportunities, and Challenges', *International Journal of Qualitative Methods*, 11(4), pp. 428–445, [online] Available from: http://ejournals.library.ualberta.ca/index.php/IJQM/article/view/6863 (Accessed 11 September 2015).

Borsboom, D., Mellenbergh, G. J. and van Heerden, J. (2003) 'The theoretical status of latent variables.', *Psychological Review*, 110(2), pp. 203–219, [online] Available from: http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-295X.110.2.203 (Accessed 4 November 2015).

Bradley, P., Leach, M. and Fudge, S. (2014) *The role of social norms in incentivising energy reduction in organisations*, Working Paper, Bristol, UK, University of the West of England, [online] Available from: http://www1.uwe.ac.uk/bl/research/bristoleconomics/research/economicspapers2014.aspx (Accessed 25 September 2015).

BRE (2013) *Energy Follow-up Survey 2011: Report 4: Main heating systems*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/274772/4_Main_heating_systems.pdf (Accessed 12 August 2015).

Broman Toft, M. and Thøgersen, J. (2015) 'Exploring private consumers' willingness to adopt Smart Grid technology', *International Journal of Consumer Studies*, p. n/a–n/a, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/ijcs.12201/abstract (Accessed 8 May 2015).

Brustad, M., Skeie, G., Braaten, T., Slimani, N. and Lund, E. (2003) 'Comparison of telephone vs face-to-face interviews in the assessment of dietary intake by the 24 h recall EPIC SOFT program—the Norwegian calibration study', *European Journal of Clinical Nutrition*, 57(1), pp. 107–113, [online] Available from: http://www.nature.com/ejcn/journal/v57/n1/full/1601498a.html (Accessed 11 September 2015).

Bryman, A. (2012) *Social Research Methods*, Oxford, UK, Oxford University Press.

Bryman, A. and Bell, E. (2015) *Business Research Methods*, Oxford, UK, Oxford University Press.

Bulkeley, H., Bell, S., Lyon, S., Powells, G., Judson, E. and Lynch, D. (2014) *Customer-Led Network Revolution Durham University Social Science Research: April 2014 Report*, Durham, UK, Durham University, [online] Available from: https://admin.networkrevolution.co.uk/Content/Uploaded/Downloads/a02e7e1d-6d56-4da9-bb50-89320b2d6c1c.pdf (Accessed 25 April 2014).

Bulkeley, H., Matthews, P., Whitaker, G., Bell, S., Wardle, R., Lyon, S. and Powells, G. (2015) *High Level Summary of Learning: Domestic Smart Meter Customers on Time of Use Tariffs*, Customer-Led Network Revolution, Durham, UK, Durham University, [online] Available from: http://www.networkrevolution.co.uk/wp-content/uploads/2015/01/CLNR-L243-High-Level-Summary-of-Learning-Domestic-Smart-Meter-Customers-on-Time-of-Use-Tariffs.pdf (Accessed 12 August 2015).

Burton-Jones, A. and Hubona, G. S. (2006) 'The mediation of external variables in the technology acceptance model', *Information & Management*, 43(6), pp. 706–717, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0378720606000504 (Accessed 22 June 2015).

Butler, C., Parkhill, K. and Pidgeon, N. (2013) *Deliberating energy transitions in the UK – Transforming the UK Energy System: Public Values, Attitudes and Acceptability*, London, UKERC, [online] Available from: http://www.ukerc.ac.uk/publications/transforming-the-uk-energy-system-public-values-attitudes-and-acceptability-deliberating-energy-system-transitions-in-the-uk.html (Accessed 1 September 2013).

Carifio, J. and Perla, R. (2008) 'Resolving the 50-year debate around using and misusing Likert scales', *Medical Education*, 42(12), pp. 1150–1152, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2923.2008.03172.x/abstract (Accessed 13 August 2014).

Carmichael, R., Schofield, J., Woolf, M., Bilton, M., Ozaki, R. and Strbac, G. (2014) *Residential consumer attitudes to time-varying pricing*, Report A2 for the 'Low Carbon London' LCNF project, Imperial College London, [online] Available from: http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-%28LCL%29/Project-Documents/LCL%20Learning%20Report%20-%20A2%20-%20Residential%20consumer%20attitudes%20to%20time%20varying%20pricing.pdf (Accessed 1 November 2014).

CER (2014) *CER National Smart Metering Programme  Smart Metering High Level Design: Decision Paper*, Dublin, Republic of Ireland, The Commission for Energy Regulation, [online] Available from: http://www.cer.ie/docs/000699/CER14046%20High%20Level%20Design.pdf (Accessed 13 November 2015).

Chang, L. and Krosnick, J. A. (2010) 'Comparing Oral Interviewing with Self-Administered Computerized Questionnaires: An Experiment', *Public Opinion Quarterly*, p. nfp090, [online] Available from: http://poq.oxfordjournals.org/content/early/2010/02/12/poq.nfp090 (Accessed 19 August 2015).

Chang, S.-J., van Witteloostuijn, A. and Eden, L. (2010) 'From the Editors: Common method variance in international business research', *Journal of International Business Studies*, 41(2), pp. 178–184, [online] Available from: http://www.palgrave-journals.com/jibs/journal/v41/n2/full/jibs200988a.html (Accessed 8 January 2015).

Chan, S.-H., Chen, J.-H., Li, Y.-H. and Tsai, L.-M. (2012) 'Gly1057Asp polymorphism of insulin receptor substrate-2 is associated with coronary artery disease in the Taiwanese population', *Journal of Biomedical Science*, 19, p. 100, [online] Available from: http://www.jbiomedsci.com/content/19/1/100 (Accessed 1 June 2015).

Chassin, D. P., Stoustrup, J., Agathoklis, P. and Djilali, N. (2015) 'A new thermostat for real-time price demand response: Cost, comfort and energy impacts of discrete-time control without deadband', *Applied Energy*, 155, pp. 816–825, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0306261915008065 (Accessed 6 July 2015).

Consumer Focus (2012) *From Devotees to the Disengaged: A summary of research into energy consumers' experiences of Time of Use tariffs and*

*Consumer Focus's recommendations*, London, UK, [online] Available from: http://www.consumerfocus.org.uk/publications/from-devotees-to-the-disengaged-a-summary-of-research-into-energy-consumers-experiences-of-time-of-use-tariffs-and-consumer-focuss-recommendations (Accessed 11 September 2015).

Coolican, H. (2014) *Research Methods and Statistics in Psychology*, Hove, UK, Psychology Press.

Costanza, E., Fischer, J. E., Colley, J. A., Rodden, T., Ramchurn, S. D. and Jennings, N. R. (2014) 'Doing the Laundry with Agents: A Field Trial of a Future Smart Energy System in the Home', In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, New York, NY, USA, ACM, pp. 813–822, [online] Available from: http://doi.acm.org/10.1145/2556288.2557167 (Accessed 5 March 2015).

Creswell, J. W. and Clark, V. L. P. (2011) *Designing and Conducting Mixed Methods Research*, London, UK, SAGE.

Culnan, M. J. and Armstrong, P. K. (1999) 'Information Privacy Concerns, Procedural Fairness, and Impersonal Trust: An Empirical Investigation', *Organization Science*, 10(1), pp. 104–115, [online] Available from: http://www.jstor.org/stable/2640390 (Accessed 9 July 2014).

Darby, S. (2006) *The effectiveness of feedback on energy consumption: a review for DEFRA of the literature on metering, billing and direct displays*, Oxford, UK, Environmental Change Institute, University of Oxford.

Darby, S. and Pisica, I. (2013) 'Focus on electricity tariffs: experience and exploration of different charging schemes', In *ECEEE 2013 Summer Study Proceedings*, Presqu'île de Giens, France, pp. 2321–2331, [online] Available from: http://proceedings.eceee.org/visabstrakt.php?event=3&doc=8-318-13 (Accessed 4 July 2013).

Davidoff, S., Lee, M. K., Yiu, C., Zimmerman, J. and Dey, A. K. (2006) 'Principles of Smart Home Control', In Dourish, P. and Friday, A. (eds.), *UbiComp 2006: Ubiquitous Computing*, Lecture Notes in Computer Science, Springer Berlin Heidelberg, pp. 19–34, [online] Available from: http://link.springer.com/chapter/10.1007/11853565_2 (Accessed 14 July 2015).

Davis, F. D. (1989) 'Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology', *MIS Quarterly*, 13(3), pp. 319–340, [online] Available from: http://misq.org/perceived-usefulness-perceived-ease-of-use-and-user-acceptance-of-information-technology.html?SID=ibq3sv0dkomuv0cug1abiruoj1 (Accessed 20 April 2012).

Davis, F. D., Bagozzi, R. P. and Warshaw, P. R. (1989) 'User Acceptance of Computer Technology: A Comparison of Two Theoretical Models', *Management Science*, 35(8), pp. 982–1003, [online] Available from: http://www.jstor.org/stable/2632151 (Accessed 3 October 2012).

DECC (2011) *The Carbon Plan: Delivering our low-carbon future*, London, UK, Department of Energy and Climate Change, [online] Available from:

http://www.decc.gov.uk/assets/decc/11/tackling-climate-change/carbon-plan/3702-the-carbon-plan-delivering-our-low-carbon-future.pdf (Accessed 30 January 2012).

DECC (2013a) *Electricity Market Reform: Capacity Market – Detailed Design Proposals*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209280/15398_TSO_Cm_8637_DECC_Electricity_Market_Reform_web_optimised.pdf (Accessed 9 November 2015).

DECC (2013b) *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB)*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/78666/IA-Feb.pdf (Accessed 18 September 2013).

DECC (2014a) *Digest of United Kingdom Energy Statistics 2014*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338750/DUKES_2014_printed.pdf (Accessed 6 July 2015).

DECC (2014b) *Energy Consumption in the UK (2014), Chapter 3: Domestic energy consumption in the UK between 1970 and 2013*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/338662/ecuk_chapter_3_domestic_factsheet.pdf (Accessed 15 July 2015).

DECC (2014c) *Smart Metering Implementation Programme: Third annual report on the roll-out of Smart Meters*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/384190/smip_smart_metering_annual_report_2014.pdf (Accessed 7 July 2015).

DECC (2014d) *Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB)*, Impact Assessment, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/276656/smart_meter_roll_out_for_the_domestic_and_small_and_medium_and_non_domestic_sectors.pdf (Accessed 7 July 2015).

DECC (2015a) *2010 to 2015 government policy: UK energy security*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/publications/2010-to-2015-government-policy-uk-energy-security/2010-to-2015-government-policy-uk-energy-security (Accessed 23 November 2015).

DECC (2015b) *Energy Consumption in the UK: Chapter 3*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449134/ECUK_Chapter_3_-_Domestic_factsheet.pdf (Accessed 14 September 2015).

DECC (2015c) *Quarterly Energy Prices June 2015*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/437328/QEP_June_15.pdf (Accessed 12 August 2015).

Deci, E. L. and Ryan, R. M. (1985) *Intrinsic Motivation and Self-Determination in Human Behavior*, New York, NY, Plenum Press.

Demski, C., Spence, A. and Pidgeon, N. (2013) *Transforming the UK Energy System: Public Values, Attitudes and Acceptability – Summary findings of a survey conducted August 2012*, London, UK, UKERC, [online] Available from: http://www.ukerc.ac.uk/publications/transforming-the-uk-energy-system-public-values-attitudes-and-acceptability-summary-findings-from-a-survey-conducted-august-2012.html (Accessed 12 November 2015).

Diamantopoulos, A. and Siguaw, J. A. (2006) 'Formative Versus Reflective Indicators in Organizational Measure Development: A Comparison and Empirical Illustration', *British Journal of Management*, 17(4), pp. 263–282, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1467-8551.2006.00500.x/abstract (Accessed 16 June 2015).

Downing, P. and iCaro Consulting (2009) *Understanding Consumer Attitudes to Sustainable Community Infrastructure*, Report for the UK Green Building Council and the Zero Carbon Hub, [online] Available from: http://www.zerocarbonhub.org/sites/default/files/resources/reports/Understanding_Consumer_Attitudes_to_Sustainable_Community_Infrastructure.pdf (Accessed 1 November 2013).

Druckman, J. N. and Nelson, K. R. (2003) 'Framing and Deliberation: How Citizens' Conversations Limit Elite Influence', *American Journal of Political Science*, 47(4), pp. 729–745, [online] Available from: http://www.jstor.org/stable/3186130 (Accessed 19 August 2015).

Eagly, A. H. and Chaiken, S. (2007) 'The Advantages of an Inclusive Definition of Attitude', *Social Cognition*, 25(5), pp. 582–602, [online] Available from: http://guilfordjournals.com/doi/abs/10.1521/soco.2007.25.5.582 (Accessed 23 July 2015).

Eastbury, D. (2014) 'Survey Methodology for the Reuters Digital News Report 2014', *Digital News Report 2014*, Reuters Institute for the Study of Journalism, [online] Available from: http://www.digitalnewsreport.org/survey/2014/survey-methodology-2014/ (Accessed 19 August 2015).

Element Energy (2012) *Demand side response in the non-domestic sector*, Final report for Ofgem, London, UK, [online] Available from: http://www.element-energy.co.uk/wordpress/wp-content/uploads/2012/07/Demand-Side-Response-in-the-non-domestic-sector.pdf (Accessed 4 December 2013).

Energy Networks Association (2014) *Demand Side Response Shared Services Framework Concept Paper*, London, UK, [online] Available from: http://www.energynetworks.org/modx/assets/files/news/consultation-responses/Consultation%20responses%202014/Demand%20Side%20Response%20Concept%20Paper_revised.pdf (Accessed 3 July 2015).

Energy Saving Trust (2010) *Getting warmer: a field trial of heat pumps*, London, UK, Energy Saving Trust, [online] Available from: http://www.heatpumps.org.uk/PdfFiles/TheEnergySavingTrust-GettingWarmerAFieldTrialOfHeatPumps.pdf (Accessed 12 November 2015).

Energy Saving Trust (2014) 'Ground source heat pumps', *Energy Saving Trust*, [online] Available from: http://www.energysavingtrust.org.uk/domestic/ground-source-heat-pumps (Accessed 12 November 2015).

Energy Saving Trust (2015) 'Our calculations', [online] Available from: http://www.energysavingtrust.org.uk/content/our-calculations (Accessed 12 August 2015).

Energy UK (2013) 'Power stations expected to close before 2025', [online] Available from: http://www.energy-uk.org.uk/common-questions/which-power-stations-are-due-to-close.html (Accessed 7 January 2014).

Evans, A. N. and Rooney, B. J. (2010) *Methods in Psychological Research*, London, UK, SAGE.

Farquhar, C. and Das, R. (1999) 'Are focus groups suitable for "sensitive" topics?', In *Developing Focus Group Research*, London, UK, SAGE, pp. 47–63, [online] Available from: http://srmo.sagepub.com/view/developing-focus-group-research/n4.xml (Accessed 9 November 2015).

Fawcett, T. (2011) 'The future role of heat pumps in the domestic sector', In *Proceedings of European Council for an Energy Efficient Economy, Summer Study 2011*, Presqu'ile de Giens, France, [online] Available from: http://www.eci.ox.ac.uk/publications/downloads/fawcett11b.pdf (Accessed 27 February 2012).

Feilzer, M. Y. (2010) 'Doing Mixed Methods Research Pragmatically: Implications for the Rediscovery of Pragmatism as a Research Paradigm', *Journal of Mixed Methods Research*, 4(1), pp. 6–16, [online] Available from: http://mmr.sagepub.com/content/4/1/6 (Accessed 14 September 2015).

Fell, M. J. and Chiu, L. F. (2014) 'Children, parents and home energy use: Exploring motivations and limits to energy demand reduction', *Energy Policy*, 65, pp. 351–358, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421513010215 (Accessed 17 December 2013).

Fell, M. J., Nicolson, M., Huebner, G. M. and Shipworth, D. (2015) *Is it time? Consumers and time of use tariffs*, Report to Smart Energy GB, London, UK, UCL Energy Institute, [online] Available from: http://www.smartenergygb.org/sites/default/files/UCL%20research%20into%20time%20of%20use%20tariffs.pdf (Accessed 10 March 2015).

Fishbein, M. and Ajzen, I. (1975) *Belief, attitude, intention, and behavior: an introduction to theory and research*, Boston, MA, Addison-Wesley Pub. Co.

Fogel, J. and Nehmad, E. (2009) 'Internet social network communities: Risk taking, trust, and privacy concerns', *Computers in Human Behavior*, 25(1), pp. 153–160, [online] Available from:

http://www.sciencedirect.com/science/article/pii/S0747563208001519 (Accessed 19 December 2014).

Frontier Economics (2012) *Domestic and SME tariff development for the Customer-Led Network Revolution*, [online] Available from: http://www.networkrevolution.co.uk/wp-content/uploads/2012/06/CLNR-L006-Domestic-and-SME-tariff-development-for-CLNR-June-2012.pdf (Accessed 20 May 2015).

Frontier Economics and Sustainability First (2012a) *Demand Side Response in the domestic sector- a literature review of major trials*, [online] Available from: http://www.decc.gov.uk/en/content/cms/meeting_energy/network/strategy/strategy.aspx (Accessed 19 November 2012).

Frontier Economics and Sustainability First (2012b) *Demand Side Response in the domestic sector - a literature review of major trials*, Report to DECC, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48552/5756-demand-side-response-in-the-domestic-sector-a-lit.pdf (Accessed 23 October 2013).

Fulgoni, G. (2014) 'Uses and Misuses of Online-Survey Panels in Digital Research: Digging Past the Surface', *Journal of Advertising Research*, 54(2), [online] Available from: https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwisjdTltKbJAhVDXBQKHWs4D8YQFgggMAA&url=https%3A%2F%2Fwww.comscore.com%2Fcontent%2Fdownload%2F25803%2F1319819%2Fversion%2F1%2Ffile%2FUses_and_Misuses_of_Online_Survey_Panels_in_Digital_Research.pdf&usg=AFQjCNETetNHCJKDQD-UUjCVPdyOJbPU7Q&sig2=0ey1EdBQ_r0oC2LEmH0iPQ (Accessed 1 August 2015).

Gaines, B. J., Kuklinski, J. H. and Quirk, P. J. (2007) 'The Logic of the Survey Experiment Reexamined', *Political Analysis*, 15(1), pp. 1–20, [online] Available from: http://pan.oxfordjournals.org/content/15/1/1 (Accessed 19 August 2015).

Gangale, F., Mengolini, A. and Onyeji, I. (2013) 'Consumer engagement: An insight from smart grid projects in Europe', *Energy Policy*, 60, pp. 621–628, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421513003637 (Accessed 31 July 2013).

Gaskin, J. (2015) 'Data screening', *Statwiki*, [online] Available from: http://statwiki.kolobkreations.com/wiki/Data_screening (Accessed 12 August 2015).

Gillham, B. (2005) *Research Interviewing: The Range of Techniques*, Maidenhead, UK, McGraw-Hill Education (UK).

Gliem, R. R. and Gliem, J. A. (2003) 'Calculating, Interpreting, And Reporting Cronbach's Alpha Reliability Coefficient For Likert-Type Scales', [online] Available from: https://scholarworks.iupui.edu/handle/1805/344 (Accessed 2 November 2015).

Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T. and Spence, A. (2014) 'Smart grids, smart users? The role of the user in demand side management', *Energy Research & Social Science*, 2, pp. 21–29, [online] Available from: http://www.sciencedirect.com/science/article/pii/S2214629614000413 (Accessed 27 May 2014).

Greening, L. A. (2010) 'Demand response resources: Who is responsible for implementation in a deregulated market?', *Energy*, 35(4), pp. 1518–1525, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0360544209005337 (Accessed 3 July 2015).

Haase, R. F. and Ellis, M. V. (1987) 'Multivariate analysis of variance', *Journal of Counseling Psychology*, 34(4), pp. 404–413.

Hagger, M. S. (2014) 'Avoiding the "déjà-variable" phenomenon: social psychology needs more guides to constructs', *Frontiers in Psychology*, 5, [online] Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3907697/ (Accessed 9 July 2015).

Hair (Jr), J. F., Black, W. C., Babin, B. J. and Anderson, R. E. (2013) *Multivariate Data Analysis*, Pearson Education, Limited.

Hall, R. (2013) 'Mixed methods: In search of a paradigm', In *Conducting Research in a Changing and Challenging World*, Nova Science Publishers Inc., pp. 71–78, [online] Available from: http://www.researchgate.net/publication/259045135_Mixed_Methods_In_search_of_a_paradigm (Accessed 1 August 2015).

Hardin, R. (1996) 'Trustworthiness', *Ethics*, 107(1), pp. 26–42, [online] Available from: http://www.jstor.org/stable/2382242 (Accessed 4 November 2015).

Hargreaves, T., Coleman, M., Hauxwell-Baldwin, R., Wilson, C., Stankovic, L., Stankovic, V., Murray, D., Liao, J., Kane, T., Firth, S. and Hassan, T. (2015) 'Smart homes, control and energy management: How do smart home technologies influence control over energy use and domestic life?', In *ECEEE 2015 Summer Study Proceedings*, Presqu'île de Giens, France, pp. 1022–1032, [online] Available from: https://ueaeprints.uea.ac.uk/53923/ (Accessed 1 August 2015).

Hawley, K. (2014) 'Trust, Distrust and Commitment', *Noûs*, 48(1), pp. 1–20, [online] Available from: http://doi.wiley.com/10.1111/nous.12000 (Accessed 4 November 2015).

Hellwig, R. T. (2015) 'Perceived control in indoor environments: a conceptual approach', *Building Research & Information*, 43(3), pp. 302–315, [online] Available from: http://dx.doi.org/10.1080/09613218.2015.1004150 (Accessed 18 March 2015).

Hennink, M. M. (2013) *Understanding Focus Group Discussions*, New York, NY, Oxford University Press.

Hesmondhalgh, S., Owen, G., Pooley, M. and Ward, J. (2014) *GB Electricity Demand - 2102 and 2025. Impacts of demand reduction and demand*

*shifting on wholesale prices and carbon emissions. Results of Brattle modelling.*, GB Electricity Demand – realising the resource, London, UK, Sustainability First, [online] Available from: http://www.sustainabilityfirst.org.uk/docs/2014/Sustainability%20First%20-%20Paper%209%20-%20Updated%20Brattle%20Modelling%20-%20GB%20Electricity%20Demand%202012%20&%202025.%20January%202014.pdf (Accessed 7 July 2015).

He, X., Keyaerts, N., Azevedo, I., Meeus, L., Hancher, L. and Glachant, J.-M. (2013) 'How to engage consumers in demand response: A contract perspective', *Utilities Policy*, 27, pp. 108–122, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0957178713000593 (Accessed 11 December 2013).

Higginson, S., Thomson, M. and Bhamra, T. (2013) '"For the times they are a-changin": the impact of shifting energy-use practices in time and space', *Local Environment*, pp. 1–19, [online] Available from: http://www.tandfonline.com/doi/abs/10.1080/13549839.2013.802459 (Accessed 16 September 2013).

Hledik, R. (2014) 'Rediscovering Residential Demand Charges', *The Electricity Journal*, 27(7), pp. 82–96, [online] Available from: http://www.sciencedirect.com/science/article/pii/S104061901400150X (Accessed 6 July 2015).

Hoenkamp, R., Huitema, G. B. and de Moor-van Vugt, A. J. C. (2011) 'The Neglected Consumer: The Case of the Smart Meter Rollout in the Netherlands', *Renewable Energy Law and Policy Review*, 2011, p. 269, [online] Available from: http://heinonline.org/HOL/Page?handle=hein.journals/relp2011&id=277&div=&collection=journals.

Hornsby, G. (2010) 'The Secret Life of the National Grid', *BBC News*, [online] Available from: http://www.bbc.co.uk/news/uk-politics-11619751 (Accessed 14 September 2015).

Hsieh, H.-F. and Shannon, S. E. (2005) 'Three Approaches to Qualitative Content Analysis', *Qualitative Health Research*, 15(9), pp. 1277–1288, [online] Available from: http://qhr.sagepub.com/content/15/9/1277 (Accessed 2 November 2015).

Hu, P. J., Chau, P. Y. K., Sheng, O. R. L. and Tam, K. Y. (1999) 'Examining the Technology Acceptance Model Using Physician Acceptance of Telemedicine Technology', *Journal of Management Information Systems*, 16(2), pp. 91–112, [online] Available from: http://www.jstor.org/stable/40398433 (Accessed 22 July 2015).

IGI Global (2016) 'What is Technocentrism?', *IGI GLobal*, [online] Available from: http://www.igi-global.com/dictionary/technocentrism/29436 (Accessed 1 February 2016).

IHS Global Insight (2009) *Demand Side Market Participation Report*, Report to DECC, London, UK, Department of Energy and Climate Change, [online] Available from: http://webarchive.nationalarchives.gov.uk/20121217150421/http://decc.gov.

uk/assets/decc/Consultations/Electricity%20supply%20security/1_20090804144704_e_@@_DSMreportGlobalInsight.pdf (Accessed 7 July 2015).

Ipsos MORI (2012) *Consumer Experiences Of Time of Use Tariffs: Report prepared for Consumer Focus*, London, UK, [online] Available from: http://www.consumerfocus.org.uk/files/2012/09/Ipsos-MORI-report-on-Consumer-Experiences-Of-Time-Of-Use-Tariffs.pdf (Accessed 20 January 2015).

Irvine, A., Drew, P. and Sainsbury, R. (2013) '"Am I not answering your questions properly?"Clarification, adequacy and responsiveness in semi-structured telephone and face-to-face interviews', *Qualitative Research*, 13(1), pp. 87–106.

Israel, M. and Hay, I. (2006) *Research Ethics for Social Scientists*, London, UK, SAGE.

Jackson, T. (2005) 'Motivating sustainable consumption', *A review of evidence on consumer behaviour and behavioural change. A report to the Sustainable Development Research Network, Surrey: Centre for Environmental Strategies*.

Jamieson, S. (2004) 'Likert scales: how to (ab)use them', *Medical Education*, 38(12), pp. 1217–1218, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2929.2004.02012.x/abstract (Accessed 14 August 2015).

Kalton, G. and Schuman, H. (1982) 'The Effect of the Question on Survey Responses: A Review', *Journal of the Royal Statistical Society. Series A (General)*, 145(1), pp. 42–73, [online] Available from: http://www.jstor.org/stable/2981421 (Accessed 24 September 2015).

Kennedy, P. (2003) *A Guide to Econometrics*, Boston, MA, MIT Press.

Kim, Y. J., Chun, J. U. and Song, J. (2009) 'Investigating the role of attitude in technology acceptance from an attitude strength perspective', *International Journal of Information Management*, 29(1), pp. 67–77, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0268401208000157 (Accessed 7 August 2015).

Kinder, D. R. and Sanders, L. M. (1996) *Divided by Color: Racial Politics and Democratic Ideals*, Chicago, IL, University of Chicago Press.

King, W. R. and He, J. (2006) 'A meta-analysis of the technology acceptance model', *Information & Management*, 43(6), pp. 740–755, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0378720606000528 (Accessed 22 July 2015).

Kormos, C. and Gifford, R. (2014) 'The validity of self-report measures of proenvironmental behavior: A meta-analytic review', *Journal of Environmental Psychology*, 40, pp. 359–371, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0272494414000851 (Accessed 24 September 2015).

Kranz, J. (2011) ‘Studies on Technology Adoption and Regulation of Smart Grids’, Doctoral Thesis, Munich, Germany, LMU Munich.

Krauss, S. E. (2005) ‘Research Paradigms and Meaning Making: A Primer’, *The Qualitative Report*, 10(4), pp. 758–770, [online] Available from: http://www.nova.edu/ssss/QR/QR10-4/krauss.pdf (Accessed 14 September 2015).

Krueger, R. A. and Casey, M. A. (2000) *Focus groups: a practical guide for applied research*, London, UK, SAGE.

Lai, J.-Y., Ong, C.-S., Yang, C.-C. and Tang, W.-S. (2005) ‘Factors Influencing Employees’ Usage Behavior of KMS in e-business’, *PACIS 2005 Proceedings*, [online] Available from: http://aisel.aisnet.org/pacis2005/11.

Leaman, A. and Bordass, B. (1999) ‘Productivity in buildings: the “killer” variables’, *Building Research & Information*, 27(1), pp. 4–19, [online] Available from: http://www.tandfonline.com/doi/abs/10.1080/096132199369615 (Accessed 10 December 2012).

Leaman, A. and Bordass, B. (2007) ‘Are users more tolerant of “green” buildings?’, *Building Research & Information*, 35(6), pp. 662–673, [online] Available from: http://www.tandfonline.com/doi/abs/10.1080/09613210701529518 (Accessed 13 December 2012).

LeCompte, M. D. and Schensul, J. J. (2010) *Designing and Conducting Ethnographic Research*, Plymouth, UK, Rowman Altamira.

Lee, M.-C. (2009) ‘Factors influencing the adoption of internet banking: An integration of TAM and TPB with perceived risk and perceived benefit’, *Electronic Commerce Research and Applications*, 8(3), pp. 130–141, [online] Available from: http://www.sciencedirect.com/science/article/pii/S1567422308000598 (Accessed 5 November 2013).

Li, D., Aung, Z., Williams, J. and Sanchez, A. (2014) ‘P2DR: Privacy-Preserving Demand Response system in smart grids’, In *2014 International Conference on Computing, Networking and Communications (ICNC)*, pp. 41–47.

Lin, N. (2002) *Social Capital: A Theory of Social Structure and Action*, Cambridge, UK, Cambridge University Press.

Lipscomb, M. (2011) ‘Critical realism and realist pragmatism in mixed methods: Problematics of event identity and abductive inference (evolving paradigms in mixed methods research)’, In *Proceedings of the American Educational Research Association Annual Meeting, 2011*, New Orleans, Louisiana, USA, [online] Available from: http://eprints.uwe.ac.uk/14188/ (Accessed 4 November 2015).

Liu, L. (2009) ‘Technology acceptance model: A replicated test using TETRAD’, *International Journal of Intelligent Systems*, 24(12), pp. 1230–1242, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1002/int.20382/abstract (Accessed 8 June 2015).

Li, X., Hess, T. J. and Valacich, J. S. (2008) 'Why do we trust new technology? A study of initial trust formation with organizational information systems', *The Journal of Strategic Information Systems*, 17(1), pp. 39–71, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0963868708000036 (Accessed 23 September 2015).

Lund Research (2012) 'Convergent and divergent validity', *Lærd Dissertation*, [online] Available from: http://dissertation.laerd.com/convergent-and-divergent-validity.php (Accessed 29 October 2015).

Marsden, P. V. and Wright, J. D. (2010) *Handbook of Survey Research*, Bingley, UK, Emerald Group Publishing.

Martiskainen, M. and Nolden, C. (2015) '"Pro-savers": the role of community in energy demand reduction', In *ECEEE 2015 Summer Study Proceedings*, Presqu'île de Giens, France, pp. 2039–2047, [online] Available from: http://proceedings.eceee.org/visabstrakt.php?event=5&doc=9-121-15 (Accessed 9 November 2015).

Matsunaga, M. (2010) 'How to Factor-Analyze Your Data Right: Do's, Don'ts, and How-To's.', *International Journal of Psychological Research*, 3(1), pp. 97–110, [online] Available from: http://mvint.usbmed.edu.co:8002/ojs/index.php/web/article/view/464 (Accessed 7 August 2014).

Mayer, R. C., Davis, J. H. and Schoorman, F. D. (1995) 'An Integrative Model of Organizational Trust', *The Academy of Management Review*, 20(3), pp. 709–734, [online] Available from: http://www.jstor.org/stable/258792 (Accessed 2 December 2014).

McDaniel, P. and McLaughlin, S. (2009) 'Security and Privacy Challenges in the Smart Grid', *IEEE Security Privacy*, 7(3), pp. 75 –77.

McKenna, E., Ghosh, K. and Thomson, M. (2011) 'Demand response in low-carbon power systems: a review of residential electrical demand response projects', In *Proceedings of the 2nd International Conference on Microgeneration and Related Technologies*, Glasgow, UK, [online] Available from: https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/8709.

McKenna, K., Broome, K. and Liddle, J. (2007) 'What older people do: Time use and exploring the link between role participation and life satisfaction in people aged 65 years and over', *Australian Occupational Therapy Journal*, 54(4), pp. 273–284, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1440-1630.2007.00642.x/abstract (Accessed 12 November 2015).

McMichael, M. and Shipworth, D. (2013) 'The value of social networks in the diffusion of energy-efficiency innovations in UK households', *Energy Policy*, 53, pp. 159–168, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421512009202 (Accessed 16 December 2013).

Merriam-Webster (2015a) ‘automatic’, *Merriam-Webster*, [online] Available from: http://www.merriam-webster.com/dictionary/automatic (Accessed 9 November 2015).

Merriam-Webster (2015b) ‘consumer’, *Merriam-Webster*, [online] Available from: http://www.merriam-webster.com/dictionary/consumer (Accessed 9 November 2015).

Merriam-Webster (2015c) ‘control’, *Merriam-Webster*, [online] Available from: http://www.merriam-webster.com/dictionary/control (Accessed 9 July 2015).

Merriam-Webster (2015d) ‘convenience’, *Merriam-Webster*, [online] Available from: http://www.merriam-webster.com/dictionary/convenience (Accessed 23 November 2015).

Mert, W. (2008) *Consumer acceptance of smart appliances*, D 5.5 of WP 5 report from Smart-A project, [online] Available from: http://www.smart-a.org/WP5_5_Consumer_acceptance_18_12_08.pdf (Accessed 1 April 2014).

Moezzi, M. and Bartiaux, F. (2007) ‘Liberating energy analysis’, In *eceee 2007 Summer Study proceedings*, at La Colle sur Loup, France, [online] Available from: http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2007/Panel_1/1.337 (Accessed 1 February 2016).

Morgan, D. L. (1993) *Successful Focus Groups: Advancing the State of the Art*, London, UK, SAGE.

Murtagh, N., Gatersleben, B. and Uzzell, D. (2014) ‘A qualitative study of perspectives on household and societal impacts of demand response’, *Technology Analysis & Strategic Management*, 26(10), pp. 1131–1143, [online] Available from: http://dx.doi.org/10.1080/09537325.2014.974529 (Accessed 7 November 2014).

Mutz, D. C. and Reeves, B. (2005) ‘The New Videomalaise: Effects of Televised Incivility on Political Trust’, *American Political Science Review*, null(01), pp. 1–15, [online] Available from: http://journals.cambridge.org/article_S0003055405051452 (Accessed 19 August 2015).

National Grid (2015a) *Capacity Market Auction Guidelines*, [online] Available from: https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Auction%20Guidelines%20June%2029%202015.pdf (Accessed 7 July 2015).

National Grid (2015b) *National Grid and Statnett Agree to Proceed with UK-Norway Interconnector*, London, UK, [online] Available from: http://investors.nationalgrid.com/~/media/Files/N/National-Grid-IR/NSN%20RNS%2026%20March%202015%20final.pdf (Accessed 14 September 2015).

Nest (2015) ‘What is Rush Hour Rewards?’, *Nest*, [online] Available from: https://nest.com/support/articles/ (Accessed 17 September 2015).

Nicolson, M., Huebner, G. M. and Shipworth, D. (under review) ‘You’ve (Not) Been Framed: Loss- and Environmental-Framed Messages do not Boost Demand for Time-of-Use Electricity Tariffs’,.

OED Online (2013) ‘acceptance, n.’, *OED Online*, Oxford University Press, [online] Available from: http://www.oed.com/view/Entry/1011 (Accessed 7 January 2014).

Ofcom (2014) *The Communications Market Report*, London, UK, [online] Available from: http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr14/2014_UK_CMR.pdf (Accessed 9 September 2015).

Office for National Statistics (2014) *Internet Access – Households and Individuals 2014*, London, UK, [online] Available from: http://www.ons.gov.uk/ons/dcp171778_373584.pdf (Accessed 18 August 2015).

Office for National Statistics (2015) *Families and Households, 2014*, Statistical Bulletin, London, UK, [online] Available from: http://www.ons.gov.uk/ons/dcp171778_393133.pdf (Accessed 6 July 2015).

Ofgem (2008) *Energy Supply Probe - Initial Findings Report*, London, UK, Ofgem, [online] Available from: https://www.ofgem.gov.uk/sites/default/files/docs/2008/10/energy-supply-probe---initial-findings-report.pdf (Accessed 12 November 2015).

Ofgem (2010) *Demand Side Response: A discussion paper*, London, UK, Ofgem, [online] Available from: https://www.ofgem.gov.uk/ofgem-publications/57026/dsr-150710.pdf (Accessed 7 January 2014).

Ofgem (2013) *Creating the right environment for demand-side response: next steps*, London, UK, Ofgem, [online] Available from: https://www.ofgem.gov.uk/ofgem-publications/85129/creatingtherightenvironmentfordemandsideresponsenextsteps.pdf (Accessed 3 July 2015).

Ofgem (2014a) *Electricity settlement reform – moving to half-hourly settlement*, London, UK, Ofgem, [online] Available from: https://www.ofgem.gov.uk/ofgem-publications/87053/electricitysettlementlaunchstatement.pdf (Accessed 7 July 2015).

Ofgem (2014b) *State of the Market Assessment*, London, UK, Ofgem, [online] Available from: https://www.ofgem.gov.uk/ofgem-publications/86804/assessmentdocumentpublished.pdf (Accessed 2 October 2015).

Ofgem (2015a) *Low Carbon Networks Fund Governance Document v. 7*, London, UK, Ofgem, [online] Available from: https://www.ofgem.gov.uk/sites/default/files/docs/2015/04/lcnf_gov_doc_v7_-_final_clean_0.pdf (Accessed 9 November 2015).

Ofgem (2015b) *Making the electricity system more flexible and delivering the benefits for consumers*, London, UK, Ofgem, [online] Available from:

https://www.ofgem.gov.uk/sites/default/files/docs/2015/09/flexibility_position_paper_final_0.pdf (Accessed 13 November 2015).

Ofgem (2015c) 'RIIO-ED1 price control', *Ofgem*, [online] Available from: https://www.ofgem.gov.uk/network-regulation-riio-model/riio-ed1-price-control (Accessed 30 September 2015).

ONS (2012) '2011 Census, Population and Household Estimates for the United Kingdom', *Office for National Statistics*, [online] Available from: http://www.ons.gov.uk/ons/rel/census/2011-census/population-and-household-estimates-for-the-united-kingdom/index.html (Accessed 22 December 2014).

Opdenakker, R. (2006) 'Advantages and Disadvantages of Four Interview Techniques in Qualitative Research', *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 7(4), [online] Available from: http://www.qualitative-research.net/index.php/fqs/article/view/175 (Accessed 11 September 2015).

Oppenheim, A. N. (1992) *Questionnaire Design, Interviewing and Attitude Measurement*, London, UK, Continuum.

Ortega Egea, J. M. and Román González, M. V. (2011) 'Explaining physicians' acceptance of EHCR systems: An extension of TAM with trust and risk factors', *Computers in Human Behavior*, 27(1), pp. 319–332, [online] Available from: http://linkinghub.elsevier.com/retrieve/pii/S0747563210002530 (Accessed 19 December 2014).

Oseni, M. O., Pollitt, M. G., Reiner, D. M., Richter, L.-L., Chyong, K. and Baddeley, M. (2013) *2013 EPRG Public Opinion Survey: Smart Energy – Attitudes and Behaviours*, University of Cambridge, Energy Policy Research Group, [online] Available from: http://www.eprg.group.cam.ac.uk/wp-content/uploads/2013/11/1327-PDF.pdf (Accessed 18 November 2013).

Owen, G., Pooley, M. and Ward, J. (2012) *What demand side services could household customers offer?*, GB Electricity Demand – realising the resource, London, UK, Sustainability First, [online] Available from: http://www.sustainabilityfirst.org.uk/docs/2012/Sustainability%20First%20-%20GB%20Electricity%20Demand%20-%20Paper%203%20-%20What%20demand%20side%20services%20could%20customers%20offer%20in%202010%20-%20Household%20demand-%20April%202012.pdf (Accessed 6 July 2015).

Paetz, A.-G., Dütschke, E. and Fichtner, W. (2012) 'Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions', *Journal of Consumer Policy*, 35(1), pp. 23–41, [online] Available from: http://link.springer.com/article/10.1007/s10603-011-9177-2 (Accessed 6 February 2013).

Palmer, J. and Cooper, I. (2013) *United Kingdom housing energy fact file 2013*, London, UK, Department of Energy and Climate Change, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/345141/uk_housing_fact_file_2013.pdf (Accessed 25 February 2015).

Parkhill, K., Demski, C., Butler, C., Spence, A. and Pidgeon, N. (2013) *Transforming the UK Energy System: Public Values, Attitudes and Acceptability – Synthesis Report*, London, UKERC, [online] Available from: http://www.ukerc.ac.uk/publications/transforming-the-uk-energy-system-public-values-attitudes-and-acceptability.html (Accessed 1 September 2013).

Pavlou, P. A. (2003) 'Consumer Acceptance of Electronic Commerce: Integrating Trust and Risk with the Technology Acceptance Model', *International Journal of Electronic Commerce*, 7(3), pp. 101–134, [online] Available from: http://www.jstor.org/stable/27751067 (Accessed 25 April 2012).

Peffer, T., Pritoni, M., Meier, A., Aragon, C. and Perry, D. (2011) 'How people use thermostats in homes: A review', *Building and Environment*, 46(12), pp. 2529–2541, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0360132311001739 (Accessed 29 October 2012).

Pettigrew, L. E. L., Wilson, J. T. L. and Teasdale, G. M. F. (2003) 'Reliability of Ratings on the Glasgow Outcome Scales from In-person and Telephone Structured Interviews', *Journal of Head Trauma Rehabilitation Focus on Clinical Research and Practice*, 18(3), pp. 252–258.

Platchkov, L., Pollitt, M. G., Reiner, D. and Shaorshadze, I. (2011) *2010 EPRG Public Opinion Survey: Policy Preferences and Energy Saving Measures*, EPRG Working Paper, Cambridge, UK, University of Cambridge, Energy Policy Research Group, [online] Available from: http://www.econ.cam.ac.uk/dae/repec/cam/pdf/cwpe1149.pdf (Accessed 8 July 2015).

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y. and Podsakoff, N. P. (2003) 'Common method biases in behavioral research: A critical review of the literature and recommended remedies', *Journal of Applied Psychology*, 88(5), pp. 879–903.

Pooley, M., Ward, J. and Owen, G. (2012) *What Demand Side Services Could Customers Offer - Industry Electricity Demand*, GB Electricity Demand – realising the resource, London, UK, Sustainability First, [online] Available from: http://www.sustainabilityfirst.org.uk/docs/2012/Sustainability%20First%20-%20GB%20Electricity%20Demand%20-%20Paper%203%20-%20What%20demand%20side%20services%20could%20customers%20offer%20-%20Industry%20electricity%20demand.%20Sep%202012.pdf (Accessed 6 July 2015).

Populus (2015) 'Polling', *Populus*, [online] Available from: http://www.populus.co.uk/Our-Methodology/Polling/ (Accessed 3 November 2015).

Raw, G. and Ross, D. (2011) *Energy Demand Research Project: Final Analysis*, Report to Ofgem, AECOM, [online] Available from: http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCgQFjAA&url=http%3A%2F%2Fwww.ofgem.gov.uk%2FSustainability%2FEDRP%2FDocuments1%2FEnergy%2520Demand%2520Research%2520Project%2520Final%2520Analysis.pdf&ei=yy1rT7e_G8nG8gO_g4HDBg&u

sg=AFQjCNH-nHMS8ouSEx7-lG3kqNRBmY2zzw (Accessed 22 March 2012).

Raworth, K., Sweetman, C., Narayan, S., Rowlands, J. and Hopkins, A. (2012) *Conducting semi-structured Interviews*, Oxford, UK, Oxfam.

Reckwitz, A. (2002) 'Toward a Theory of Social Practices A Development in Culturalist Theorizing', *European Journal of Social Theory*, 5(2), pp. 243–263, [online] Available from: http://est.sagepub.com/content/5/2/243 (Accessed 3 February 2016).

Redpoint and Element Energy (2012) *Electricity System Analysis – future system benefits from selected DSR scenarios*, London, UK, [online] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48551/5759-electricity-system-analysis--future-system-benefit.pdf (Accessed 7 July 2015).

Rodden, T., Fischer, J. E., Pantidi, N., Bachour, K. and Moran, S. (2013) 'At Home with Agents: Exploring Attitudes Towards Future Smart Energy Infrastructures', In *Proceedings of the CHI Conference on Human Factors in Computing Systems*, Paris, France, [online] Available from: http://www.orchid.ac.uk/eprints/106/ (Accessed 4 July 2013).

Rogers, E. M. (1962) *Diffusion of innovations*, Glencoe, IL, Free Press of Glencoe.

Rogers, E. M. (2003) *Diffusion of Innovations, 5th Edition*, New York, NY, Simon and Schuster.

Rogerson, P. (2001) *Statistical Methods for Geography*, London, UK, SAGE.

Rotter, J. B. (1966) 'Generalized expectancies for internal versus external control of reinforcement', *Psychological Monographs: General and Applied*, 80(1), pp. 1–28.

Russell, C. (1999) 'Interviewing Vulnerable Old People: Ethical And Methodological Implications Of Imagining Our Subjects', *Journal of Aging Studies*, 13(4), pp. 403–417, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0890406599000183 (Accessed 2 September 2015).

Sale, J. E. M., Lohfeld, L. H. and Brazil, K. (2002) 'Revisiting the Quantitative-Qualitative Debate: Implications for Mixed-Methods Research', *Quality and Quantity*, 36(1), pp. 43–53, [online] Available from: http://link.springer.com/article/10.1023/A%3A1014301607592 (Accessed 14 September 2015).

Schade, J. and Schlag, B. (2003) 'Acceptability of urban transport pricing strategies', *Transportation Research Part F: Traffic Psychology and Behaviour*, 6(1), pp. 45–61, [online] Available from: http://www.sciencedirect.com/science/article/pii/S1369847802000463 (Accessed 15 July 2015).

Schwartz, S. H. (1977) *Normative Influences on Altruism*, Advances in Experimental Social Psychology.

Sewell, W. H. (1992) ‘A Theory of Structure: Duality, Agency, and Transformation’, *American Journal of Sociology*, 98(1), pp. 1–29, [online] Available from: http://www.jstor.org/stable/2781191 (Accessed 4 February 2016).

Seyfang, G., Park, J. J. and Smith, A. (2013) ‘A thousand flowers blooming? An examination of community energy in the UK’, *Energy Policy*, 61, pp. 977–989, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421513005156 (Accessed 24 September 2015).

Sheeran, P. (2002) ‘Intention—Behavior Relations: A Conceptual and Empirical Review’, *European Review of Social Psychology*, 12(1), pp. 1–36, [online] Available from: http://dx.doi.org/10.1080/14792772143000003 (Accessed 22 December 2014).

Sheldon, R. (2013) ‘Hands off our homes!’, *Utility Week*, 30th August, [online] Available from: http://www.utilityweek.co.uk/news/news_story.asp?id=199176&title=Hands+off+our+homes!

Sheridan, T. B. (1992) *Telerobotics, Automation, and Human Supervisory Control*, Boston, MA, MIT Press.

Sheridan, T. B. (2012) ‘Human Supervisory Control’, In Salvendy, G. (ed.), *Handbook of Human Factors and Ergonomics*, John Wiley & Sons, Inc., pp. 990–1015, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1002/9781118131350.ch34/summary (Accessed 11 February 2015).

Shove, E., Pantzar, M. and Watson, M. (2012) *The Dynamics of Social Practice: Everyday Life and how it Changes*, SAGE.

Skinner, E. A. (1996) ‘A guide to constructs of control’, *Journal of Personality and Social Psychology*, 71(3), pp. 549–570, [online] Available from: http://www.ncbi.nlm.nih.gov/pubmed/8831161 (Accessed 14 December 2012).

Skinner, E. A., Chapman, M. and Baltes, P. B. (1988) ‘Children’s Beliefs about Control, Means-ends, and Agency: Developmental Differences during Middle Childhood’, *International Journal of Behavioral Development*, 11(3), pp. 369–388, [online] Available from: http://jbd.sagepub.com/content/11/3/369 (Accessed 10 July 2015).

Skinner, J. (2014) *The Interview: An Ethnographic Approach*, London, UK, A&C Black.

Slater, M. R. (2008) ‘Pragmatism, Realism, and Religion’, *The Journal of Religious Ethics*, 36(4), pp. 653–681, [online] Available from: http://www.jstor.org/stable/40378026.

Smart Energy GB (2015) *Transforming Great Britain’s relationship with gas and electricity*, London, UK, [online] Available from: http://www.smartenergygb.org/sites/default/files/SmartE_AnnualRep_A4_V5_HR_Small_SinglePage.pdf (Accessed 20 July 2015).

Spence, A., Demski, C., Butler, C., Parkhill, K. and Pidgeon, N. (2015) 'Public perceptions of demand-side management and a smarter energy future', *Nature Climate Change*, advance online publication, [online] Available from: http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2610.html (Accessed 28 April 2015).

Spence, A., Venables, D., Pidgeon, N., Poortinga, W. and Demski, C. (2010) *Public Perceptions of Climate Change and Energy Futures in Britain: Summary Findings of a Survey Conducted from January to March 2010*, Cardiff University, [online] Available from: http://psych.cf.ac.uk/understandingrisk/docs/final_report.pdf (Accessed 28 November 2013).

Spence, J. (2014) *Settlement of Dynamically Switched Meters*, PSRG Consultation, Elexon, [online] Available from: https://www.elexon.co.uk/wp-content/uploads/2014/02/PSRG-Dynamic-Switching-Consultation-v0_3.pdf (Accessed 6 July 2015).

Spiekermann, S. (2005) *Perceived Control: Scales for Privacy in Ubiquitous Computing*, SSRN Scholarly Paper, Rochester, NY, Social Science Research Network, [online] Available from: http://papers.ssrn.com/abstract=761109 (Accessed 25 January 2013).

Spiekermann, S. (2008) *User control in ubiquitous computing: design alternatives and user acceptance*, Aachen, Germany, Shaker Verlag, [online] Available from: http://docbox.etsi.org/erm/Open/RFIDWorkshop200712/RFID02_03.pdf (Accessed 7 January 2014).

SSEPD (2013) *NINES – Northern Isles New Energy Solutions: Customer Engagement Plan*, [online] Available from: http://www.ninessmartgrid.co.uk/wp-content/uploads/2013/11/Northern-Isles-New-Energy-Solutions-CEP-v0.6.pdf (Accessed 17 September 2015).

Statistics Norway (2014) 'Energy consumption in households, 2012', *Statistics Norway*, [online] Available from: http://www.ssb.no/en/energi-og-industri/statistikker/husenergi/hvert-3-aar/2014-07-14 (Accessed 14 September 2015).

Stenner, K., Frederiks, E., Hobman, E. V. and Meikle, S. (2015) *Australian Consumers' Likely Response to Cost-Reflective Electricity Pricing*, Australia, CSIRO, [online] Available from: https://publications.csiro.au/rpr/pub?pid=csiro:EP152667 (Accessed 7 November 2015).

Stern, P. C. (2000) 'New Environmental Theories: Toward a Coherent Theory of Environmentally Significant Behavior', *Journal of Social Issues*, 56(3), pp. 407–424, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/0022-4537.00175/abstract (Accessed 17 January 2013).

Stragier, J., Hauttekeete, L. and De Marez, L. (2010) 'Introducing Smart grids in residential contexts: Consumers' perception of smart household appliances', In *2010 IEEE Conference on Innovative Technologies for an Efficient and Reliable Electricity Supply (CITRES)*, pp. 135 –142.

Strbac, G. (2008) ‘Demand side management: Benefits and challenges’, *Energy Policy*, 36(12), pp. 4419–4426, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421508004606 (Accessed 31 July 2013).

Strengers, Y. (2010) ‘Air-conditioning Australian households: The impact of dynamic peak pricing’, *Energy Policy*, 38(11), pp. 7312–7322, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421510005926 (Accessed 8 August 2012).

Strengers, Y. (2013) *Smart Energy Technologies in Everyday Life: Smart Utopia?*, Basingstoke, UK, Palgrave Macmillan.

Strickland, B. R. (1989) ‘Internal-External Control Expectancies: From Contingency to Creativity’, *American Psychologist*, 44(1), pp. 1–12.

Swanborn, P. (2010) *Case Study Research: What, Why and How?*, London, UK, SAGE.

Tao Zhou (2011) ‘The impact of privacy concern on user adoption of location-based services’, *Industrial Management & Data Systems*, 111(2), pp. 212–226, [online] Available from: http://www.emeraldinsight.com/doi/full/10.1108/02635571111115146 (Accessed 19 December 2014).

Tavani, H. T. (2007) ‘Philosophical Theories of Privacy: Implications for an Adequate Online Privacy Policy’, *Metaphilosophy*, 38(1), pp. 1–22, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9973.2006.00474.x/abstract (Accessed 8 December 2014).

Terwel, B. W., Harinck, F., Ellemers, N. and Daamen, D. D. L. (2011) ‘Going beyond the properties of CO2 capture and storage (CCS) technology: How trust in stakeholders affects public acceptance of CCS’, *International Journal of Greenhouse Gas Control*, 5(2), pp. 181–188, [online] Available from: http://www.sciencedirect.com/science/article/pii/S1750583610001507 (Accessed 19 December 2014).

Thompson, S. C. and Spacapan, S. (1991) ‘Perceptions of Control in Vulnerable Populations’, *Journal of Social Issues*, 47(4), pp. 1–21, [online] Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1540-4560.1991.tb01831.x/abstract (Accessed 9 November 2015).

Tolmie, P., Pycock, J., Diggins, T., MacLean, A. and Karsenty, A. (2002) ‘Unremarkable Computing’, In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI ’02, New York, NY, USA, ACM, pp. 399–406, [online] Available from: http://doi.acm.org/10.1145/503376.503448 (Accessed 17 July 2015).

Tourangeau, R., Conrad, F. and Couper, M. (2013) *The Science of Web Surveys*, New York, NY, Oxford University Press.

Triandis, H. C. (1977) *Interpersonal behavior*, Monterey, CA, Brooks/Cole Pub. Co.

Trope, Y., Liberman, N. and Wakslak, C. (2007) ‘Construal Levels and Psychological Distance: Effects on Representation, Prediction, Evaluation,

and Behavior', *Journal of consumer psychology*, 17(2), pp. 83–95, [online] Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3150814/ (Accessed 16 September 2014).

Turner, M., Kitchenham, B., Brereton, P., Charters, S. and Budgen, D. (2010) 'Does the technology acceptance model predict actual use? A systematic literature review', *Information and Software Technology*, TAIC-PART 2008TAIC-PART 2008, 52(5), pp. 463–479, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0950584909002055 (Accessed 22 July 2015).

Tversky, A. and Kahneman, D. (1974) 'Judgment under Uncertainty: Heuristics and Biases', *Science*, 185(4157), pp. 1124–1131, [online] Available from: http://www.jstor.org/stable/1738360 (Accessed 4 February 2016).

U.S. Department of Energy (2006) *Benefits of demand response in electricity markets and recommendations for achieving them*, A report to the united states congress pursuant to section 1252 of the energy policy act of 2005, [online] Available from: http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/DOE_Benefits_of_Demand_Response_in_Electricity_Markets_and_Recommendations_for_Achieving_Them_Report_to_Congress.pdf (Accessed 3 July 2015).

U.S. Department of Energy (2015) *Interim Report on Customer Acceptance, Retention and Response to Time-Based Rates from the Consumer Behavior Studies*, Smart Grid Investment Grant Program, [online] Available from: https://www.smartgrid.gov/document/CBS_interim_program_impact_report_FINAL.html (Accessed 22 June 2015).

Valentine, G. (1999) 'Doing Household Research: Interviewing Couples Together and Apart', *Area*, 31(1), pp. 67–74, [online] Available from: http://www.jstor.org/stable/20003952 (Accessed 9 November 2015).

Vallely, L. (2015) 'Tempus launches offer to reward flexible customers', *Utility Week*, [online] Available from: http://utilityweek.co.uk/news/tempus-launches-offer-to-reward-flexible-customers/1112972#.VgQFDGuLnqU (Accessed 24 September 2015).

Vaus, D. de (2013) *Surveys in Social Research*, Didcot, UK, Routledge.

Vaus, D. and Vaus, P. D. de (2001) *Research Design in Social Research*, London, UK, SAGE.

Venkatesh, V. (2000) 'Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model', *Information Systems Research*, 11(4), pp. 342–365, [online] Available from: http://www.jstor.org/stable/23011042 (Accessed 12 October 2012).

Venkatesh, V., Morris, M. G., Gordon B. Davis and Davis, F. D. (2003) 'User Acceptance of Information Technology: Toward a Unified View', *MIS Quarterly*, 27(3), pp. 425–478, [online] Available from: http://www.jstor.org/stable/30036540 (Accessed 10 June 2012).

Walker, G., Devine-Wright, P., Hunter, S., High, H. and Evans, B. (2010) 'Trust and community: Exploring the meanings, contexts and dynamics of community

renewable energy', *Energy Policy*, The Role of Trust in Managing Uncertainties in the Transition to a Sustainable Energy Economy, Special Section with Regular Papers, 38(6), pp. 2655–2663, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421509003541 (Accessed 8 December 2014).

Walliman, N. (2006) *Social Research Methods*, London, UK, SAGE.

Walter, G. (2014) 'Determining the local acceptance of wind energy projects in Switzerland: The importance of general attitudes and project characteristics', *Energy Research & Social Science*, 4, pp. 78–88, [online] Available from: http://www.sciencedirect.com/science/article/pii/S2214629614001121 (Accessed 19 August 2015).

Warren, P. (2014) 'A review of demand-side management policy in the UK', *Renewable and Sustainable Energy Reviews*, 29, pp. 941–951, [online] Available from: http://www.sciencedirect.com/science/article/pii/S1364032113006680 (Accessed 14 November 2013).

Which? (2013a) *The Imbalance of Power: Wholesale costs and retail prices*, London, UK, [online] Available from: http://press.which.co.uk/wp-content/uploads/2013/08/The-Imbalance-of-Power-Wholesale-Costs-and-Retail-Prices-LOW-RES-July-2013.pdf (Accessed 2 December 2014).

Which? (2013b) *UCL-Energy seminar: 'The Imbalance of Power: consumers and energy affordability'*, [online] Available from: https://www.youtube.com/watch?v=1g5bIVxSYSI&feature=youtube_gdata_player (Accessed 6 March 2015).

Which? (2014) 'Which industry sectors / organisations do people most trust and distrust?', [online] Available from: http://consumerinsight.which.co.uk/tracker?utf8=%E2%9C%93&d%5bage_band%5d%5b%5d=&d%5bincome_band%5d%5b%5d=&d%5bregion%5d%5b%5d=&d%5bdata_month%5d=1410&d%5bfrom_month%5d=&d%5bsort_by%5d=default&d%5bopen_in%5d=trust&d%5bv%5d=78 (Accessed 19 December 2014).

Wickens, C. D., Hollands, J. G., Banbury, S. and Parasuraman, R. (2015) *Engineering Psychology & Human Performance*, Psychology Press.

Wilhite, H., Nakagami, H., Masuda, T., Yamaga, Y. and Haneda, H. (1996) 'A cross-cultural analysis of household energy use behaviour in Japan and Norway', *Energy Policy*, 24(9), pp. 795–803, [online] Available from: http://www.sciencedirect.com/science/article/pii/0301421596000614 (Accessed 16 August 2012).

Wilkinson, S. (1998) 'Focus groups in feminist research: Power, interaction, and the co-construction of meaning', *Women's Studies International Forum*, 21(1), pp. 111–125, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0277539597000800 (Accessed 9 November 2015).

Wilkinson, S. (1999) 'How useful are focus groups in feminist research?', In *Developing Focus Group Research*, London, UK, SAGE, pp. 64–78, [online]

Available from: http://srmo.sagepub.com/view/developing-focus-group-research/n5.xml (Accessed 9 November 2015).

Wilson, C., Hargreaves, T. and Hauxwell-Baldwin, R. (2014) 'Smart homes and their users: a systematic analysis and key challenges', *Personal and Ubiquitous Computing*, 19(2), pp. 463–476, [online] Available from: http://link.springer.com/article/10.1007/s00779-014-0813-0 (Accessed 11 June 2015).

de Winter, J. C. F., Dodou, D. and Wieringa, P. A. (2009) 'Exploratory Factor Analysis With Small Sample Sizes', *Multivariate Behavioral Research*, 44(2), pp. 147–181, [online] Available from: http://dx.doi.org/10.1080/00273170902794206 (Accessed 11 July 2014).

Wüstenhagen, R., Wolsink, M. and Bürer, M. J. (2007) 'Social acceptance of renewable energy innovation: An introduction to the concept', *Energy Policy*, 35(5), pp. 2683–2691, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421506004824 (Accessed 16 July 2015).

# 10 Appendices

## 10.1 Documents included in the analysis of 'control' in the literature

Balta-Ozkan, N., Amerighi, O. and Boteler, B. (2014) 'A comparison of consumer perceptions towards smart homes in the UK, Germany and Italy: reflections for policy and future research', Technology Analysis & Strategic Management, 0(0), pp. 1–20, [online] Available from: http://dx.doi.org/10.1080/09537325.2014.975788 (Accessed 12 November 2014).

Balta-Ozkan, N., Davidson, R., Bicket, M. and Whitmarsh, L. (2013) 'Social barriers to the adoption of smart homes', Energy Policy, 63, pp. 363–374, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421513008471 (Accessed 16 December 2013).

Breukers, S., Mourik, R. and DuneWorks, B. (2013) 'The end-users as starting point for designing dynamic pricing approaches to change household energy consumption behaviours.', Report for Netbeheer Nederland, Projectgroep Smart Grids (Pg SG)., [online] Available from: http://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/DutchDSO_Report.pdfhttp://www.leonardo-energy.org/sites/leonardo-energy/files/documents-and-links/DutchDSO_Report.pdf (Accessed 18 November 2013).

Broman Toft, M. (2014) 'Consumer Adoption of Sustainable Energy Technology – The Case of Smart Grid Technology', Doctoral Thesis, Aarhus, Denmark, Aarhus University, [online] Available from: http://badm.au.dk/fileadmin/Business_Administration/PhD/PhD_thesis_Madeleine_Broman_Toft.pdf (Accessed 4 July 2015).

Bulkeley, H., Bell, S., Lyon, S., Powells, G., Judson, E. and Lynch, D. (2014) Customer-Led Network Revolution Durham University Social Science Research: April 2014 Report, Durham, UK, Durham University, [online] Available from: https://admin.networkrevolution.co.uk/Content/Uploaded/Downloads/a02e7e1d-6d56-4da9-bb50-89320b2d6c1c.pdf (Accessed 25 April 2014).

Butler, C., Parkhill, K. and Pidgeon, N. (2013) Deliberating energy transitions in the UK – Transforming the UK Energy System: Public Values, Attitudes and Acceptability, London, UKERC, [online] Available from: http://www.ukerc.ac.uk/publications/transforming-the-uk-energy-system-public-values-attitudes-and-acceptability-deliberating-energy-system-transitions-in-the-uk.html (Accessed 1 September 2013).

Carmichael, R., Schofield, J., Woolf, M., Bilton, M., Ozaki, R. and Strbac, G. (2014) Residential consumer attitudes to time-varying pricing, Report A2 for the 'Low Carbon London' LCNF project, Imperial College London, [online] Available from: http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-%28LCL%29/Project-Documents/LCL%20Learning%20Report%20-%20A2%20-%20Residential%20consumer%20attitudes%20to%20time%20varying%20pricing.pdf (Accessed 1 November 2014).

Costanza, E., Fischer, J. E., Colley, J. A., Rodden, T., Ramchurn, S. D. and Jennings, N. R. (2014) 'Doing the Laundry with Agents: A Field Trial of a Future Smart Energy System in the Home', In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '14, New York, NY, USA, ACM, pp. 813–822, [online] Available from: http://doi.acm.org/10.1145/2556288.2557167 (Accessed 5 March 2015).

Darby, S. J. and McKenna, E. (2012) 'Social implications of residential demand response in cool temperate climates', Energy Policy, 49(0), pp. 759–769, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421512006076 (Accessed 20 December 2012).

Darby, S. and Pisica, I. (2013) 'Focus on electricity tariffs: experience and exploration of different charging schemes', In ECEEE 2013 Summer Study Proceedings, Presqu'île de Giens, France, pp. 2321–2331, [online] Available from: http://proceedings.eceee.org/visabstrakt.php?event=3&doc=8-318-13 (Accessed 4 July 2013).

Downing, P. and iCaro Consulting (2009) Understanding Consumer Attitudes to Sustainable Community Infrastructure, Report for the UK Green Building Council and the Zero Carbon Hub, [online] Available from: http://www.zerocarbonhub.org/sites/default/files/resources/reports/Understanding_C

onsumer_Attitudes_to_Sustainable_Community_Infrastructure.pdf (Accessed 1 November 2013).

Gangale, F., Mengolini, A. and Onyeji, I. (2013) ‘Consumer engagement: An insight from smart grid projects in Europe’, Energy Policy, 60, pp. 621–628, [online] Available from: http://www.sciencedirect.com/science/article/pii/S0301421513003637 (Accessed 31 July 2013).

Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T. and Spence, A. (2014) ‘Smart grids, smart users? The role of the user in demand side management’, Energy Research & Social Science, 2, pp. 21–29, [online] Available from: http://www.sciencedirect.com/science/article/pii/S2214629614000413 (Accessed 27 May 2014).

Mert, W. (2008) Consumer acceptance of smart appliances, D 5.5 of WP 5 report from Smart-A project, [online] Available from: http://www.smart-a.org/WP5_5_Consumer_acceptance_18_12_08.pdf (Accessed 1 April 2014).

Murtagh, N., Gatersleben, B. and Uzzell, D. (2014) ‘A qualitative study of perspectives on household and societal impacts of demand response’, Technology Analysis & Strategic Management, 0(0), pp. 1–13, [online] Available from: http://dx.doi.org/10.1080/09537325.2014.974529 (Accessed 7 November 2014).

Oseni, M. O., Pollitt, M. G., Reiner, D. M., Richter, L.-L., Chyong, K. and Baddeley, M. (2013) 2013 EPRG Public Opinion Survey: Smart Energy – Attitudes and Behaviours, University of Cambridge, Energy Policy Research Group, [online] Available from: http://www.eprg.group.cam.ac.uk/wp-content/uploads/2013/11/1327-PDF.pdf (Accessed 18 November 2013).

Paetz, A.-G., Dütschke, E. and Fichtner, W. (2012) ‘Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions’, Journal of Consumer Policy, 35(1), pp. 23–41, [online] Available from: http://link.springer.com/article/10.1007/s10603-011-9177-2 (Accessed 6 February 2013).

Rodden, T., Fischer, J. E., Pantidi, N., Bachour, K. and Moran, S. (2013) ‘At Home with Agents: Exploring Attitudes Towards Future Smart Energy Infrastructures’, In Proceedings of the CHI Conference on Human Factors in Computing Systems,

Paris, France, [online] Available from: http://www.orchid.ac.uk/eprints/106/ (Accessed 4 July 2013).

Sheldon, R. (2013) ‘Hands off our homes!’, Utility Week, 30th August, [online] Available from: http://www.utilityweek.co.uk/news/news_story.asp?id=199176&title=Hands+off+our+homes!

## 10.2 Information and consent form used in ‘Exploring control’ study

See next page.

# Research study into people's views on future electricity tariffs

## Hello!

My name is Mike Fell and I'm a PhD researcher at University College London (UCL) Energy Institute. I'm running a study to find out what people think about a range of possible new electricity tariffs that we could see introduced in the coming years. The aim is to find out what people like and don't like about them to help improve their design.

To do this I'm going to be putting together a questionnaire – which is where you come in. To make sure the questionnaire asks the right questions (and asks them clearly) I'm talking to a few groups of people first to get their views on different possible tariffs and on home energy use in general. In particular, I'm interested in how "in control" people feel of their energy use. I'd like you to take part in one of these discussions.

*What's involved?*

Each discussion (focus group) will last about an hour and include around six people. I'll lead the group through a number of subjects and, so that I can review what was said afterwards, I'll be making a recording. In reporting this work I'll be using quotes from the discussion, but it is important for you to know that **these will be kept entirely anonymous**. Participation is voluntary, and you are free to pull out at any time without giving a reason. If you'd like to see a copy of the final report, please let me know.

*Any other questions?*

Please feel free to get in touch with me (Mike Fell) at any time on michael.fell.11@ucl.ac.uk.

*If you would like to participate…*

Please confirm that you agree to the following:

- I've read this information sheet and understand to my satisfaction what the study involves.
- I agree to take part in the study, knowing that I can pull out at any time.
- I agree to the processing of my personal information, and understand that this information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
- I understand that my participation will be audio-recorded, and agree to this.

Print name ……

Signature …….  Date ……

## 10.3 Focus group guide sheet used in 'Exploring control' study

<table>
<tr><td colspan="2">Overall objective:<br>To inform questionnaire design by seeing how people talk about control of energy use, to get feedback on DSR scenarios, to see how they rank these programmes in terms of control.</td></tr>
<tr><td>(approx. 5 mins)<br><br>Aim: To introduce the topic, encourage participation and explain the shape of the session.</td><td>Introduction/Warm Up<ul><li>Welcome to the session</li><li>Introduction by researcher to discussion</li><li>Explanation of rules of engagement of group discussion: take part; not a test; no right or wrong answers; respect each other's views; non-judgemental; confidential; OK to change mind, not something we often think or talk about.</li><li>If I say provocative things it's to tease out detail.</li><li>Introduction to topic: talking about thoughts on different future home energy use scenarios, to inform a wider study. Particular interest on whether you feel in control of energy use.</li><li>Introduction to participants: first name, if you could only have one gadget/appliance, what would it be?</li></ul></td></tr>
<tr><td>(approx. 10 mins)<br><br>Aim: Get idea of people's attitudes towards energy saving, locus of control of energy use</td><td>General background (locus of control of energy use)<ul><li>General talk about staying on top of energy use – something you think about much? Have you done / can you do anything specific? Why / why not?</li><li>Anything you would like to do but can't? Why not?</li><li>Is there much people can do to alter how much you use, or what you pay? What affects this?</li></ul></td></tr>
<tr><td>(approx. 15 mins)<br><br>Aim: Establish if/how people see continuum of control in DSR</td><td>Scenarios:<ul><li>Explain problems with peaks (higher cost, high carbon), about variable renewables and electric cars, grid overloading.</li><li>Is that something you've thought about?</li><li>One response to this DSR. Here are four scenarios – please read.</li><li>Mark on line.</li><li>Ask people to show where they put (bring together on board) and explain why.</li><li>What difficulties in doing this? Control over what?</li><li>Use energy when want, or larger about sanctity of home, or money, others?</li><li>How much in control of energy now?</li><li>What think of different scenarios (acceptance)?</li></ul></td></tr>
</table>

| | |
|---|---|
| (approx. 10 mins)<br><br>*Aim: To look in detail at the more extreme forms of DSR and difference between mediated/consented* | Talking about DLC in particular:<br>• What think about this? What actually is the problem (if any)? What if no change in performance whatsoever? Does anyone have problem with that?<br>• Difference between HEM and DLC?<br>• What would make it more acceptable to you? |
| (approx. 10 mins)<br><br>*Aim: To see what range of antecedents people mention, and how strongly they seem to feel about them.* | Antecedents:<br>• Which way would control shift if following was the controlling party: council, M&S, community group. Why?<br>• What about if you could go online and see details of when automation kicking? Or even on appliance? Or just see with a light when something happening? On state of local/national grid?<br>• Does option of override make a difference?<br>• Convenience – how does this come in?<br>• Smart appliance have things like remote control from smartphone – how does this affect view? |
| (approx. 10 mins)<br><br>*Aim: To elicit attitudes towards automation/convenience in the context of energy use* | Home heating/appliances<br>• How do people control their home heating?<br>• Happy with temperature in home? Why? Can they control it? How? What difficult?<br>• Thermostats/timers – if so, why? Give more or less control?<br>• What about other appliances? Dishwashers, ovens, etc.?<br>• Control over what? |
| (approx. 5 mins)<br><br>*Aim: To clarify key points that emerged from the group and wrap up* | Summing up<br>• Summarize discussion and what seemed to be the main points.<br>• Any general comments on the discussion?<br>• Anyone any questions they would like to ask me<br>• FILL IN QUESTIONNAIRE |

## 10.4 Focus group materials used in ‘Exploring control’ study

### Background explanation (read to group)

The UK’s demand for electricity varies throughout the day – it is often at its highest in the evening in winter when people have lights on, might be cooking and heating with electricity and so on, and lowest overnight when people are sleeping.

When demand is high electricity costs more to supply because extra power stations have to be powered up and down.

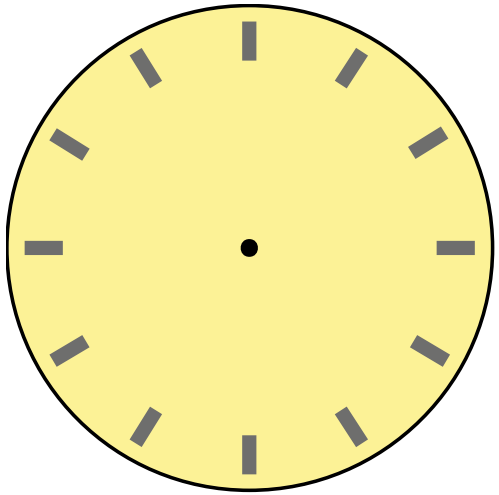
If people were rewarded with lower prices for using electricity away from peak times, everyone can benefit. Any questions?

You might already be familiar with Economy 7 tariffs, where people pay less for electricity overnight.

In the next few years all homes in the UK will be getting smart meters, which will make it easier to have tariffs which charge different prices for electricity at different times of day.

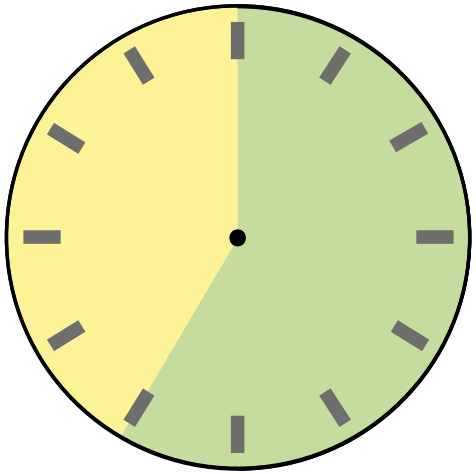
You’ll also be able to see real-time energy use on a monitor, and potentially do things like set appliances with smartphones.

Electric cars and heating systems are also likely to be more common.

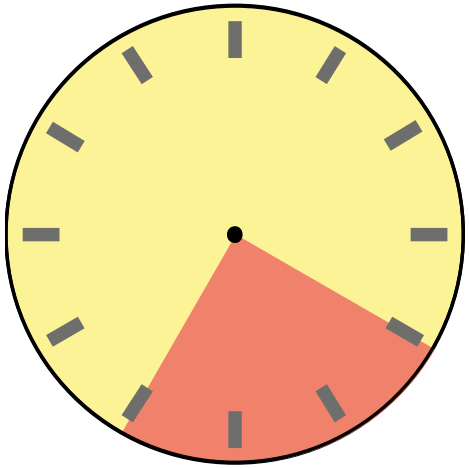


You pay the same for electricity at all times of day (this is the standard tariff for most people in the UK at present).

AM

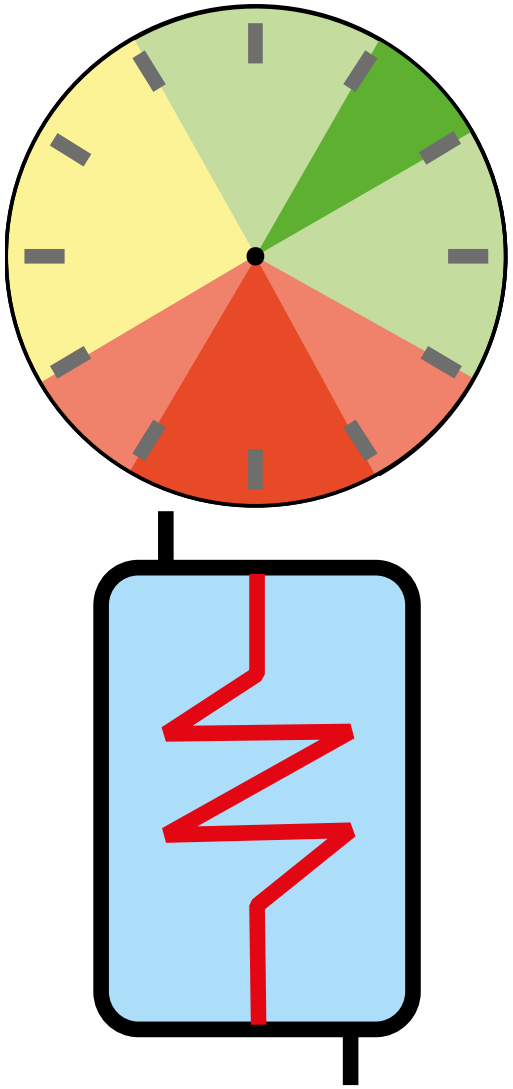


PM



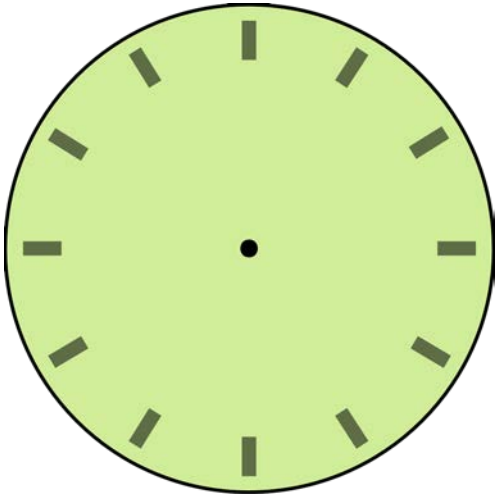
You pay a different price for electricity at different times of day, but the prices and time periods are the same from day to day (except on weekends).

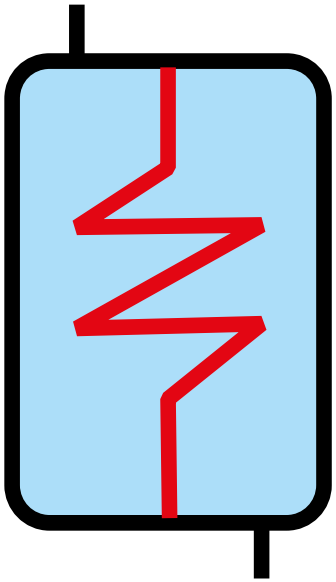
For example, on weekdays you might pay a high rate between 4pm and 7pm (e.g. 20p/unit), a low rate between 12am and 7am (e.g. 8p/unit), and a medium rate at all other times (e.g. 12p/unit). Weekends are the same but without the high rate period.



The price of electricity changes every hour depending on the cost to the supplier. For example, it will be higher when there is a lot of demand for electricity, and lower when there is little demand. Hourly prices are available online from the day before.

Because the price changes so often and is difficult to predict, you have a box in your home which you can set to run some energy using devices depending on price. For example, you can set it so that electric water heating only runs once price drops below a specified point (and you can always override if you choose).



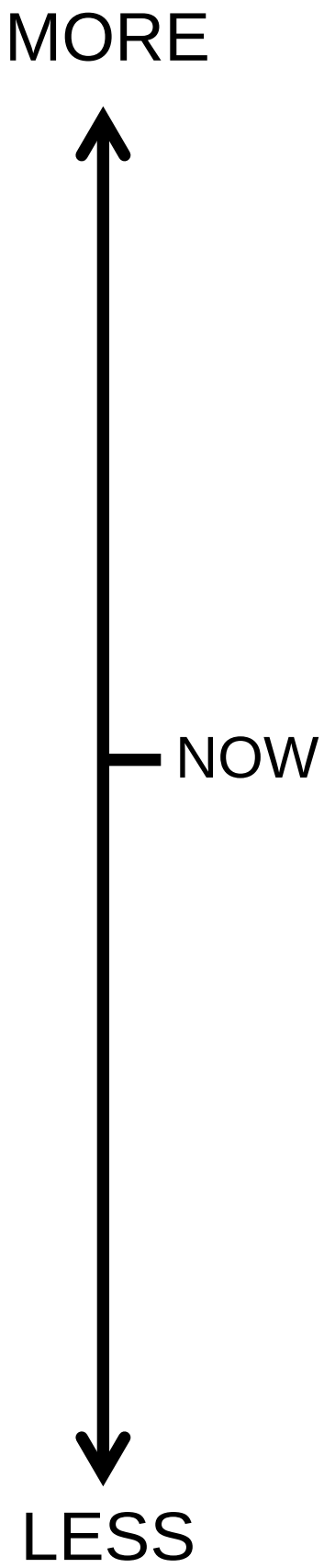


You pay the same for electricity at all times of day, but at a lower rate than in the standard (Δ) tariff.

Your electricity supplier has permission to remotely turn off and on high power devices such as electric water heating and room heating systems. They are limited in the amount they can do this and you can choose to override it (although if you do this too much, you don't qualify for the cheaper tariff).

All things considered, how much control would you have, compared to now?

(mark shapes next to line)



Please fill in your seat number: ……

**Please tick the box which describes you:**

Age: ☐ 16-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64

☐ 65-74 ☐ 75 and over

Housing: ☐ I **own** the house/flat I live in

☐ I **rent** the house/flat I live in

☐ Other (please describe briefly)

…….

**I pay for my electricity by:**

☐ Prepay ☐ Quarterly payment ☐ Direct debit ☐ Other/not sure

**I heat my house/flat mainly with:**

☐ Gas ☐ Electricity ☐ Don't know

**I am on an Economy 7, 10 or other "time of use" tariff for electricity:**

☐ Yes ☐ No ☐ Don't know

**I have (tick any that apply):**

☐ Solar electric (PV) panels ☐ A heat pump ☐ An electric car

☐ None of these

**I switched supplier or tariff for my electricity or gas in the last year:**

☐ Yes ☐ No ☐ Not sure

# 10.5 Feedback provided to focus group participants in 'Exploring control' study

*Thanks again for taking part in the focus groups I ran in late 2013. Your contributions were very useful, and I wanted to send you a quick summary of initial results – please see below. At the moment I'm using this data to inform the design of a questionnaire which I'll be sending out to a larger sample of people. I'm also involved in a project with one of the electricity distribution companies (UK Power Networks) which is researching the use of one of the types of tariff I was looking into, so that will be a great opportunity to see what people think of it in practice.*

*Thanks!*

*Mike*

## Initial results – focus groups about control and future energy tariffs

I held a number of focus groups in the autumn of 2013 to get people's views on a number of possible future energy tariffs. This document provides a short overview of the results. I'll be carrying out more analysis which will be reported in future papers.

As set out in the information sheet provided to group participants, all contributions are reported anonymously. In the following sections participants are identified by a two- or three-letter group code (PIL = pilot group, DH = district heating, GCH = gas central heating, TOU = time of use tariff) followed by a number for each participant in the group (e.g. TOU2 is participant 2 in the time of use tariff group).

**Control relating to energy use in general**

People talked about control in relation to a wide range of different subjects in the wider context of home energy use. Most commonly they referred to bills, or spending on energy. As well as this there was a lot of discussion of control of temperature, both in terms of actual control over heating systems and more generally of homes. Related to this was the general idea of having control over one's comfort. Another important control concept was time – that is, being able to do things with electricity when you want to do them (*"we like to do things when we want to do them and I doubt very much whether we'd change that", GCH2*). Allied to this were ideas of flexibility and predictability. Overarching it all was a general sense of energy being tied to control over one's home or life in general (e.g. in a discussion about direct load control: *"That means they're controlling your life basically"*, *TOU2*). There was very little mention of control of energy or electricity themselves. Different people viewed control in some of these areas as more important than in others.

The perception across the groups was that energy use wasn't something people have a great deal of control over, although the reasons for this sometimes varied from group to group. There was a strong feeling that certain energy services, such as heating, were non-negotiable – in a sense, people felt themselves hostage to their own requirements in this respect (e.g. *"I try and work with it with what I've got, the heat I can't live without"*, *TOU2*). This effect was increased when other occupants such as housemates or children were mentioned (e.g. *"if you had a baby it'd be different, but that baby determines the timing rather than you determine the timing"*, *TOU3*). People differed in the options they had available to them to reduce energy use. The most marked difference was between people who owned their own homes (houses) and people who rented, or owned in blocks. The former group spoke more about possibilities for installing insulation or replacing boilers themselves, while the latter spoke more about behavioural measures (or even unsuccessful attempts to get landlords to take more permanent measures). Participants with storage heaters or district heating often spoke at their frustration at the lack of personal control these systems gave them over their heating *("there is no fine control at all so. So people open windows, that's the control", DH1*). Such frustrations were in little evidence with participants with gas central heating.

Lack of information was a notable factor in people feeling a lack of control over certain appliances. For example, some participants on Economy 7/10 tariffs were not completely confident of the times between which the night-time tariff was in operation or how much the difference in price was between tariffs. One participant had requested to go onto a prepay meter so as to more easily be able to track their expenditure on energy, and several others expressed interest in using energy monitors (although often cited reasons with they had not, such as lack of access to the meter to attach the monitor).

**Responses to different tariffs**

A clear majority of people considered fixed time of use tariffs to increase their level of control over fixed rate tariffs (or in the case of those already on TOU tariffs, flat rates were associated with loss of control). In this case control was mainly thought of as being over costs. Factors such as simplicity, predictability and familiarity (e.g. with existing Economy 7/10 tariffs) were highlighted as adding to the feeling of control.

The picture was somewhat more varied in relation to time of use tariffs where the price changed frequently throughout the day. Here there was a relatively even spread of people who thought these would give them more or less control. Where people felt their control would increase this was generally in relation to costs – the impression being that these could really be minimized by carefully planning when to use certain appliances (*"you have got some more control cause you can look at the, 'oh right OK let's put the washing machine on now'", GCH4*). Where people thought they would lose control this was generally due to the complexity of such arrangements and the lack of predictability (*"the prices change so often it's difficult to predict, I just thought I'd never understand it", GCH7*). There were also concerns about the level of automation required. Concerns about shifting

certain practices such as cooking came out most strongly here, and it was pointed at the demand was high at certain times for a reason, and that you couldn't control when everyone else decided to use electricity.

Almost everyone associated direct load control (where third parties such as energy companies take an element of direct control over certain appliances) with loss of control. The main reasons cited for this were people's desire to have electricity when it is needed (not when someone else decides you need it), and a general association of this approach with others controlling your life in general (e.g. "Big Brother" or "Soviet" style control was often cited). Often there was a feeling that people would unexpectedly be cut off, reflecting concerns about lack of information. Where people thought they would gain control, or lose only a little, this was generally to do with convenience – either of managing costs or of managing appliances themselves (*"If it's … something that happens in the background and doesn't actually affect your usage … for me personally I don't think I have an issue with them controlling it", PIL3*).

Where people were concerned about losing control in possible future energy tariffs this was often associated with lack of trust in either third parties or technology. Participants related stories of energy companies and other comparable bodies (e.g. phone companies) acting without their interests at heart as a basis for this concern (*"wait till you get over the limit and they charge you whatever they want", PIL4*). It was pointed out that even though technology might work the majority of times, concern about the possibility of failure loomed quite large. People recognised a misalignment between their own motives (e.g. keeping warm, using appliances) and those of energy companies (e.g. making a profit), causing them to be doubtful as to which the energy company would prioritize. However, there were mixed views as to whether other bodies (for example community groups) would be more trusted to take on roles in DSR.

## 10.6 Initial item pool for extended TAM development, ‘Measuring control’ study

| Variable | Item |
|---|---|
| ATTITUDE | Generally, I have a positive attitude towards this plan. |
| ATTITUDE | I think that this plan is a good idea. |
| ATTITUDE | I think that using this plan would make sense for me. |
| ATTITUDE | I would be comfortable using this plan. |
| AUTONOMY | This plan would be a case of Big Brother taking over. |
| AUTONOMY | This plan would make me too much like a robot. |
| AUTONOMY | With this plan I would be free to live as I choose. |
| AUTONOMY | With this plan I would be living according to a programme. |
| AUTONOMY | With this plan I would be too dependent on automation. |
| AUTONOMY | With this plan I would have enough control over my life. |
| AUTONOMY | With this plan the energy company would basically be controlling my life. |
| AUTONOMY | With this plan the energy company would be telling me what I can and can’t do. |
| BEHAVIOURAL INTENTION TO USE | I would not use this plan. |
| BEHAVIOURAL INTENTION TO USE | If it was offered to me now, I would sign up to this plan. |
| BEHAVIOURAL INTENTION TO USE | If my electricity supplier introduces an equivalent to this plan, I intend to use it. |
| CHOICE | On this plan it would be up to me whether or not appliances operate in my home. |
| CHOICE | This plan would not give me enough choice how my appliances operate. |
| CHOICE | With this plan I would always have the option to use my appliances as I want. |
| CHOICE | With this plan, it would ultimately be my decision when to use electricity. |
| COMFORT CONTROL | This plan would make it difficult for me to heat my home enough. |
| COMFORT CONTROL | This plan would prevent me from creating the conditions I want in my home. |

| | |
|---|---|
| COMFORT CONTROL | This plan would prevent me from making my home comfortable. |
| COMFORT CONTROL | With this plan I could be sure of a pleasant environment in my home. |
| COMFORT CONTROL | With this plan I could create the conditions I want in my home. |
| COMFORT CONTROL | With this plan I could make sure my home is warm enough. |
| COMFORT CONTROL | With this plan I would be able to control the temperature of my home. |
| COMFORT CONTROL | With this plan I would be able to heat my home as I like. |
| COMFORT CONTROL | With this plan I would have enough control over the comfort of my home. |
| COST CONTROL | I could really make the most of this plan in order to save money. |
| COST CONTROL | This plan would help me stay on top of my spending on electricity. |
| COST CONTROL | This plan would help me take charge of my spending on electricity. |
| COST CONTROL | This plan would just be a way of charging me more money for electricity. |
| COST CONTROL | With this plan I would be in charge of my spending on electricity. |
| COST CONTROL | With this plan I would be in direct control of how much I spend on energy. |
| COST CONTROL | With this plan I would have enough control over my spending on electricity. |
| INFORMATION | From what I know of this plan, I would have the information I need to get the best from it. |
| INFORMATION | On this plan I would always know when my appliances are running. |
| INFORMATION | On this plan I would have enough information about the operation of my heating system. |
| INFORMATION | With this plan, I could always find out when my appliances are in operation. |
| PERCEIVED EASE OF USE | Being on this plan would not require a lot of mental effort. |
| PERCEIVED EASE OF USE | I would find this plan easy to use. |
| PERCEIVED EASE OF USE | I would find this plan to be flexible to interact with. |
| PERCEIVED EASE OF USE | Learning to live with this plan would be easy for me. |
| PERCEIVED EASE OF USE | This plan is clear and understandable. |

| | |
|---|---|
| PERCEIVED EASE OF USE | This plan is too complicated. |
| PERCEIVED EASE OF USE | This plan sounds too much like hard work. |
| PERCEIVED USEFULNESS | Being on this plan would save me money. |
| PERCEIVED USEFULNESS | I can really see the benefits of this plan. |
| PERCEIVED USEFULNESS | I could see myself saving money with this plan. |
| PERCEIVED USEFULNESS | I don't think I'd really end up saving any money on this plan. |
| PERCEIVED USEFULNESS | My power supply would be more reliable on this plan. |
| PERCEIVED USEFULNESS | Overall, I would find this plan useful. |
| PERCEIVED USEFULNESS | This plan would be beneficial for me. |
| PERCEIVED USEFULNESS | This plan would be valuable to me. |
| PERCEIVED USEFULNESS | This plan would give me a worthwhile saving on my energy bills. |
| PERCEIVED USEFULNESS | This plan would have clear benefits for me. |
| PERCEIVED USEFULNESS | This plan would help me save money. |
| TIMING CONTROL | This plan would force me to do things at times I don’t want to do them. |
| TIMING CONTROL | This plan would make it hard for me to do things when I want to do them. |
| TIMING CONTROL | This plan would unacceptably limit my flexibility. |
| TIMING CONTROL | This plan would, overall, give me enough flexibility to do things when I want. |
| TIMING CONTROL | With this plan I would be able to do things when I want to do them. |
| TIMING CONTROL | With this plan I would be able to heat my home at the times I want to heat it. |
| TIMING CONTROL | With this plan I would be free to follow my own schedule. |
| TIMING CONTROL | With this plan I would be worried about having to change when I do things. |
| TIMING CONTROL | With this plan I would have enough control over when I do activities which use electricity. |
| TIMING CONTROL | With this plan, if I needed electricity, I feel confident I would be able to use it. |

## 10.7 Construct definitions used in item sorting exercise from ‘Measuring control’ study

USEFULNESS: “How useful someone thinks the plan would be (for themselves).”

EASE OF USE: “How easy someone thinks it would be to understand and use the plan.”

COMFORT CONTROL: “How much control someone thinks they would have over their comfort (e.g. temperature in their home)”

SPENDING CONTROL: “How much control someone think they would have over how much money they spend on energy.”

TIMING CONTROL: “How much control someone thinks they would have over WHEN they can do things.”

AUTONOMY: “How much someone thinks they are in overall control in their life.”

CHOICE: “How much choice someone thinks they have in a given situation.”

INFORMATION: “How much information someone thinks they will be given (for example, on cost of energy or whether appliances are running).”

OVERALL ATTITUDE: “Whether someone thinks the plan is a good or bad idea overall.”

INTENTION TO USE: “Whether someone says they would actually sign up to a plan.”

# 10.8 Summary of demographic variables for the experimental groups, ‘Measuring control’ study

| | | sTOU | Automated sTOU | dTOU | Automated dTOU | DLC | Total |
|---|---|---|---|---|---|---|---|
| **Age** | **18-24** | 30 | 25 | 27 | 39 | 37 | 158 |
| | **25-44** | 111 | 106 | 116 | 103 | 105 | 541 |
| | **45-64** | 154 | 145 | 167 | 131 | 160 | 757 |
| | **65-74** | 119 | 89 | 96 | 76 | 90 | 470 |
| | **75+** | 19 | 15 | 10 | 16 | 16 | 76 |
| **Gender** | **Male** | 231 | 214 | 212 | 195 | 212 | 1064 |
| | **Female** | 202 | 166 | 204 | 170 | 196 | 938 |
| **Tenure** | **Homeowner** | 304 | 242 | 277 | 249 | 281 | 1353 |
| | **Social tenant** | 64 | 58 | 71 | 60 | 78 | 331 |
| | **Private tenant** | 61 | 76 | 64 | 55 | 45 | 301 |
| | **Other tenure** | 4 | 4 | 4 | 1 | 4 | 17 |
| **Household income** | **<£14k** | 84 | 61 | 79 | 68 | 85 | 377 |
| | **£14<28k** | 162 | 157 | 159 | 145 | 147 | 770 |
| | **£28<48k** | 132 | 124 | 123 | 97 | 132 | 608 |
| | **£48k+** | 32 | 25 | 33 | 28 | 26 | 144 |
| | **Income not declared** | 23 | 13 | 22 | 27 | 18 | 103 |
| **Households with children 15 and under** | | 76 | 89 | 88 | 84 | 91 | 428 |
| **Single-person households** | | 109 | 81 | 86 | 76 | 99 | 451 |
| **Households on a TOU tariff** | | 81 | 73 | 79 | 66 | 75 | 374 |
| **Switching energy supplier** | **Switched in last year** | 96 | 87 | 103 | 96 | 96 | 478 |
| | **Switched, not in last year** | 254 | 210 | 231 | 206 | 228 | 1129 |
| | **Never switched** | 83 | 83 | 82 | 63 | 84 | 395 |

# 10.9 Questionnaire used in 'Measuring control' study

**Qa Are you the person responsible for paying your energy bill, that is, electricity and mains gas (if you have it)**

**CODE ONE**

1. Yes - Solely responsible
2. Yes - Jointly responsible
3. No - Not responsible

**Q1 Which of the following companies supplies your electricity?**

**CODE ONE**

1. British Gas
2. EDF Energy
3. E.ON UK
4. npower
5. Scottish Power
6. SSE
7. Don't know
8. Other (Please specify)

**[NEW PAGE]**

Some electricity tariffs try to encourage people to use electricity at times of day when it is cheaper and cleaner to produce.

The next three pages ask for your thoughts on one such tariff. Please read the description and imagine that **it is being offered to you by your present electricity supplier**. A couple of points to note:

- People on standard flat-rate tariffs pay on average **14p per unit of electricity** (enough to run a fridge-freezer for a day, a PC for three hours or half a cycle of a washing machine).
- More people are expected to use electric heating in future. If you have a non-electric heating system, please imagine that **your heating system works exactly as it does now except that it runs on electricity**.

**[NEW PAGE]**

**RANDOMLY SELECT ONE OF THE 5 PLANS**

**SHOW PLAN ON SCREEN**

**Q2 How much do you agree or disagree with the following statements?**

**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. With this plan I would have enough control over my spending on electricity
B. This plan would make it hard for me to do things when I want to do them
C. With this plan I could be sure of a pleasant environment in my home
D. I would find this plan easy to use

E. With this plan I would be free to live as I choose
F. I could see myself saving money with this plan
G. With this plan I would have enough control over the comfort of my home

**CODE ONE PER STATEMENT**

1. Strongly agree
2. Somewhat agree
3. Neither agree nor disagree
4. Somewhat disagree
5. Strongly agree

**SHOW PLAN ON SCREEN**

**Q3 How much do you agree or disagree with the following statements?**

**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. Being on this plan would require a lot of mental effort
B. With this plan I would be in charge of my spending on electricity
C. This plan would be beneficial for me
D. With this plan I would be able to heat my home at the times I want to heat it
E. I think this plan is a good idea
F. With this plan I would be in direct control of how much I spend on energy
G. With this plan I would be too dependent on automation

**CODE ONE PER STATEMENT**

1. Strongly agree
2. Somewhat agree
3. Neither agree nor disagree
4. somewhat disagree
5. Strongly agree

**SHOW PLAN ON SCREEN**

**Q4 How much do you agree or disagree with the following statements?**

**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. Generally, I have a positive attitude towards this plan
B. With this plan I could make sure my home is warm enough
C. Being on this plan would save me money
D. With this plan I would have enough control over my life
E. Learning to live with this plan would be easy for me
F. With this plan I would be able to do things when I want to do them
G. If it was offered to me now, I would sign up to this plan

**CODE ONE PER STATEMENT**

1. Strongly agree
2. Somewhat agree
3. Neither agree nor disagree
4. somewhat disagree
5. Strongly agree

**Q5 In which of the following ways do you pay for the electricity you use?**
**CODE ONE**

1. Monthly direct debit
2. Quarterly direct debit
3. Cheque, cash, card or bank transfer on receipt of your bill
4. Prepayment meter
5. Other (Do not specify)
6. Don't know

**Q6 Are you currently on a time of use tariff such as Economy 7 or Economy 10 (i.e. you pay less for electricity at certain times of the night or day)?**
**CODE ONE**

1. Yes - Economy 7
2. Yes - Economy 10
3. Yes - other time of use tariff
4. No
5. Don't know

**Q7 How likely or unlikely is it that there is at least one member of your household at home during the following times.**
**DISPLAY ONE ROW AT A TIME**

A. Mornings in the week (roughly 6am-9am)
B. Daytime in the week (roughly 9am-5pm)
C. Evening in the week (roughly 5pm-11pm)
D. Night-time in the week (roughly 11pm-6am)
E. Mornings on the weekend (roughly 6am-9am)
F. Daytime on the weekend (roughly 9am-5pm)
G. Evening on the weekend (roughly 5pm-11pm)
H. Night-time on the weekend (roughly 11pm-6am)

**CODE ONE**

1. Very likely
2. Fairly likely
3. Neither likely nor unlikely
4. Fairly unlikely
5. Very unlikely

**Q8 When was the last time you switched your gas or electricity supplier?**
**CODE ONE**

1. In the last month
2. 2-6 months ago
3. 7-12 months ago
4. 1-2 years ago
5. 3-5 years ago
6. Over 5 years ago
7. Never switched my gas or electricity supplier

**Q9 If you wanted to switch your electricity supplier today do you know if this would or would not be possible?**

**CODE ONE**

1. Yes – would be possible [GO TO Q10]
2. No – would not be possible [GO TO Q9]
3. Don't know [GO TO Q9]

**ASK ALL WHO CODE 2 AT Q9 (No)**

**Q10 Which of the following describe why you believe it would be possible to switch your electricity supplier?**

**CODE ALL THAT APPLY**

1. I am on a fixed-term contract
2. I am unsure about where to get information to help me make a good choice
3. I am in debt with my current supplier so don't think I could switch if I wanted to
4. I live in rented accommodation and don't think my landlord would allow me to switch
5. I wouldn't know how to switch
6. My supplier has told me I can't switch
7. I live with other people and it wouldn't be up to me
8. Other (Please specify)

**ASK ALL**

**Q11 To what extent do you think your electricity supplier is trustworthy or untrustworthy with regard to the following…**

**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. Ensuring you always have a reliable electricity supply
B. Providing information that you can easily understand
C. Charging a fair price for your electricity
D. Acting in your best interest

**CODE ONE PER STATEMENT**

1. Very trustworthy
2. Fairly trustworthy
3. Neither trustworthy nor untrustworthy
4. Fairly untrustworthy
5. Very untrustworthy

**Q12 How much do you agree or disagree with the following statements?**

**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. The amount of money my household spends on energy is largely out of my control

B. There are external factors that make it difficult for me to take actions to reduce my energy bills
C. It is hard to reduce your energy bills even if you want to

**CODE ONE PER STATEMENT**

1. Strongly agree
2. Somewhat agree

3. Neither agree nor disagree
4. Somewhat disagree
5. Strongly agree

**Q13 How concerned or not concerned are you about each of the following:**
**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. About climate change, sometimes referred to as 'global warming'
B. That in the future, electricity will become unaffordable
C. That in the future there will be power cuts

**CODE ONE PER STATEMENT**

1. Very concerned
2. Fairly concerned
3. Neither concerned nor unconcerned
4. Not very concerned
5. Not at all concerned

**Q14 Please indicate if each of the following statements apply to you**
**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. I have refused to give information to a company because I thought that information was too personal
B. I have signed up to TPS (Telephone Preference Service, which allows people to opt out of receiving sales or marketing calls)
C. I have asked an organization to take my name off of a mailing or email list

**CODE ONE PER STATEMENT**

1. Yes
2. No

**Q15 What type of accommodation does your household occupy?**
**CODE ONE**

1. Detached whole house or bungalow
2. Semi-detached whole house or bungalow
3. Terraced whole house or bungalow (including end terrace)
4. Flat or maisonette in a purpose built block
5. Flat or maisonette in a converted or shared house
6. Flat or maisonette in a commercial building (for example: in an office building, or hotel, or over a shop)
7. A caravan or mobile home or other temporary structure
8. Other (Please specify)

**Q16 In what year was your home first built?** ***Please write the year, for example 1980. If you are not sure, please give your best estimate.***
**ENTER NUMERIC (1000 - 2014)**

**Q17 What is the main system you use to heat your home?**
**CODE ONE**

1. Gas boiler with hot water tank
2. Gas combiboiler (provides heating and hot water, no tank)
3. Electric night storage heaters
4. Other type of electric heaters
5. Community heating system
6. Don't know
7. Other (Please specify)

**Q18 Are the walls of your home insulated?**
**CODE ONE**

1. Yes – I have cavity wall insulation
2. Yes – my solid walls are insulated on the outside
3. Yes – my solid walls are insulated on the inside
4. Yes – I know they are insulated, but don't know how
5. No
6. Don't know

**Q19 Does your home have loft insulation?**
**CODE ONE**

1. Yes – I have a loft and it is insulated
2. No – I have a loft but it is not insulated
3. Not applicable – I don't have a loft
4. Don't know

**Q20 How much do you agree or disagree with the following statements?**
**ROTATE ORDER – SHOW ONE ROW AT A TIME**

A. On cold winter days it is easy to heat my home up to the temperature I want
B. On cold winter days, once my home is at the temperature I want, it is easy to keep it warm
C. My home is expensive to heat

**CODE ONE PER STATEMENT**

1. Strongly agree
2. Somewhat agree
3. Neither agree nor disagree
4. Somewhat disagree
5. Strongly agree

## 10.10 Tests for equivalence of experimental groups in 'Measuring control' study

**Group comparisons: Chi square tests (for variables treated as categorical)**

| | Chi-Square | df | p value |
|---|---|---|---|
| Sole/joint billpayer | 4.32 | 4 | 0.365 |
| Supplier name | 35.82 | 28 | 0.147 |
| Payment method | 29.57 | 16 | 0.020 |
| Current TOU customer | 7.41 | 16 | 0.965 |
| Last switch | 21.91 | 24 | 0.585 |
| Option to switch | 9.80 | 8 | 0.279 |
| Privacy - refuse | 5.05 | 4 | 0.283 |
| Privacy - TPS | 5.87 | 4 | 0.209 |
| Privacy - remove | 1.63 | 4 | 0.804 |
| House type | 27.26 | 28 | 0.504 |
| House year | 52.37 | 48 | 0.308 |
| Heating system | 18.16 | 24 | 0.795 |
| Wall insulation | 26.52 | 24 | 0.327 |
| Loft insulation | 21.66 | 12 | 0.042 |
| Tenure | 25.79 | 20 | 0.173 |
| Education | 27.36 | 28 | 0.499 |
| Urban/rural | 6.90 | 12 | 0.864 |
| Working status | 25.50 | 24 | 0.379 |
| Occupation | 33.11 | 44 | 0.885 |
| Gender | 2.58 | 4 | 0.631 |
| ITV area | 36.62 | 44 | 0.777 |
| Region | 30.99 | 40 | 0.846 |
| Marital status | 17.67 | 28 | 0.934 |
| City | 83.04 | 76 | 0.272 |
| Household income | 52.60 | 52 | 0.451 |
| Age | 20.50 | 20 | 0.427 |
| Social grade | 28.38 | 20 | 0.101 |
| Household size | 15.72 | 20 | 0.734 |
| People under 18 in household | 26.44 | 24 | 0.331 |
| People 18 or over in household | 15.23 | 20 | 0.763 |

**Group comparison: Analysis of Variance (for variables treated as continuous)**

| | Sum of Squares | df | Mean Square | F | p value |
|---|---|---|---|---|---|
| Weekday morning | 8.505 | 4 | 2.126 | 3.82 | 0.004 |
| Weekday | 4.590 | 4 | 1.148 | 0.80 | 0.522 |
| Weekday evening | 1.146 | 4 | 0.287 | 0.94 | 0.438 |
| Weeknight | 1.832 | 4 | 0.458 | 1.43 | 0.222 |
| Weekend morning | 3.023 | 4 | 0.756 | 1.87 | 0.113 |
| Weekend day | 7.115 | 4 | 1.779 | 2.56 | 0.037 |
| Weekend evening | 1.110 | 4 | 0.278 | 0.54 | 0.704 |
| Weekend night | 2.130 | 4 | 0.533 | 1.52 | 0.194 |
| Trust (supply) | 1.459 | 4 | 0.365 | 0.48 | 0.753 |
| Trust (info) | 6.958 | 4 | 1.739 | 1.88 | 0.112 |
| Trust (price) | 3.771 | 4 | 0.943 | 0.84 | 0.501 |
| Trust (best interests) | 2.796 | 4 | 0.699 | 0.64 | 0.632 |
| Locus item a | 7.263 | 4 | 1.816 | 1.39 | 0.233 |
| Locus item b | 8.234 | 4 | 2.059 | 1.86 | 0.116 |
| Locus item c | 6.132 | 4 | 1.533 | 1.44 | 0.218 |
| Climate concern | 6.016 | 4 | 1.504 | 1.09 | 0.357 |
| Cost concern | 0.953 | 4 | 0.238 | 0.26 | 0.902 |
| Power cuts concern | 6.675 | 4 | 1.669 | 1.63 | 0.164 |
| Heat up house | 6.311 | 4 | 1.578 | 1.25 | 0.286 |
| Maintain heat | 14.593 | 4 | 3.648 | 3.13 | 0.014 |
| Expensive to heat | 1.674 | 4 | 0.419 | 0.38 | 0.820 |

## 10.11 Full pre-trial questionnaire used in 'Experiencing control' trial

By completing this questionnaire you will help us understand how your household uses your heating and system and how well it meets your needs so that we can make sure your new controls best meet your needs.
Once you have completed this questionnaire please return it using the stamped addressed envelope provided.

Name:

Phone Number:

1 How many people live in your home aged:

| | |
|---|---|
| Under 9 years old | |
| From 10 to 17 years old | |
| From 18 to 64 years old | |
| From 65 to 74 years old | |
| Over 75 years old | |

Please enter a number in each box.

2 During the week, how likely is it that there will be at least one member of your household at home during the following times:

| | Very Unlikely | Unlikely | Likely | Very Likely |
|---|---|---|---|---|
| Overnight - between 12am and 8am | | | | |
| Daytime - between 8am and 3pm | | | | |
| Afternoon - between 3pm and 6pm | | | | |
| Evening - between 6pm and 11.59pm | | | | |

Please select one option on each

3 On a typical day in winter does your heating system always keep you (and everyone in your household) comfortable?

- ☐ Yes - Always
- ☐ Yes - Sometimes
- ☐ No - Too Hot
- ☐ No - Too Cold

Please select one option.

4 During the summer are you (and everyone in your household) comfortable?

- ☐ Yes - Always
- ☐ Yes - Sometimes
- ☐ No - Too Hot
- ☐ No - Too Cold

Please select one option.

5 How much thought, if any, would you say you give to saving energy in your home?

- ☐ A lot
- ☐ A fair amount
- ☐ Not very much
- ☐ None at all
- ☐ Don't know

Please select one option.

6 As far as you know, how worried has the person who is responsible for paying the energy bills been about this in the last three months?

- ☐ Very worried
- ☐ Fairly worried
- ☐ Not very worried
- ☐ Not at all worried
- ☐ Don't know

Please select one option.

FORM CONTINUES OVERLEAF....

7 How do you control what times of day your heating is on?

| | |
|---|---|
| We control the heating manually, by switching it on and off | |
| We set the thermostat and let it control when the heating comes on and off | |
| We use the thermostat to turn the heating on and off whenever we need to | |
| We control when the heating is on using a timer or programmer | |
| We can't control when the heating is on | |
| Our landlord adjusts our heating controls | |

Please select all that apply.

8 How easy is it to use your heating controls to:

| | 1 - Very Easy | 2 | 3 | 4 - Very Difficult | Not Applicable |
|---|---|---|---|---|---|
| Set the times when the heating is on? | | | | | |
| Turn the heating off for when you are going out for a few hours? | | | | | |
| Turn the heating off when you are going away for a few days? | | | | | |
| Turn the temperature up if you feel cold? | | | | | |
| Turn the temperature down to save energy? | | | | | |

Please select one option on each row.

9 How often do you find that:

| | Often | Sometimes | Rarely |
|---|---|---|---|
| There is not enough hot water. | | | |
| There is more hot water than you need. | | | |
| The water is not hot enough | | | |
| The water is too hot | | | |

Please select one option on each row.

10 Have you got any comments on your current heating system that you would like to share with us?

11 Do you have a pay-as-you go electricity meter (also known as a key or prepayment meter)

| Yes | No |
|---|---|
| | |

12 Have you ever been on an Economy 7 or Economy 10 electricity tariff, where the price of electricity changed depending on the time of the day?

| Yes | No |
|---|---|
| | |

If yes, would you have been interested in technology that could help reduce your bills by automatically moving your electricity demand to the cheaper periods?

| Yes | No |
|---|---|
| | |

FORM CONTINUES OVERLEAF....

13 The PassivSystems heating controller that we are trialling is designed to run your heating more cheaply and efficiently. For example, it can turn down the heating when no-one is at home and use weather forecasts to work out just how much heat will be needed. It can also help reduce "peaks" in electricity use on the national grid (these peaks make electricity more expensive and polluting for everyone). It can do this by heating more when demand for electricity is low, and less when demand is high - while always sticking to the temperatures that you have set.

Based on what you know about the new controller, how much do you agree or disagree with the following statements? With the new controller, I think:

| | 1. Strongly Agree | 2 | 3 | 4 | 5. Strongly Disagree |
|---|---|---|---|---|---|
| I will be in charge of my spending on electricity for heating | | | | | |
| I will be able to do things when I want to do them | | | | | |
| I will be too dependent on automation | | | | | |
| I will be able to make sure my home is warm enough | | | | | |
| I can see myself saving money | | | | | |
| I would find it easy to control my heating | | | | | |
| Overall, the controller is a good idea | | | | | |

Please select one option on each row.

---

14 If you had the option to have the following features of the controller turned on or turned off, which would you choose? (tick either "on" or "off" for each feature)

| | ON | OFF |
|---|---|---|
| Ability to turn down heating when no-one is at home | | |
| Ability to respond to weather forecasts | | |
| Ability to reduce peaks in electricity demand on the grid | | |

Please select one option on each row.

---

15 We are keen to talk in more detail about your expectations and experiences of the new control system, if you are happy to be contacted about this please tick here. ☐

---

**Thank you very much for your time.**
**Please return this form in the enelope provided.**

## 10.12 Full post-trial questionnaire used in 'Experiencing control' study

By completing this questionnaire you will help us understand how well our controls have met your needs which will allow us to improve them for the future.
Once you have completed this questionnaire please return it using the stamped addressed envelope provided.

Name:

Phone Number:

1 Has there been any changes to the way you occupy your home since PassivSystems' controls have been installed?

Yes ☐ No ☐

**If you answered yes:** during the week, how likely is it that there will be at least one member of your household at home during the following times:

| | Very Unlikely | Unlikely | Likely | Very Likely |
|---|---|---|---|---|
| Overnight - between 12am and 8am | | | | |
| Daytime - between 8am and 3pm | | | | |
| Afternoon - between 3pm and 6pm | | | | |
| Evening - between 6pm and 11.59pm | | | | |

Please select one option on each

2 Since you received the PassivSystems controls, does your heating system always keep you (and everyone in your household) comfortable?

☐ Yes - Always
☐ Yes - Sometimes
☐ No - Too Hot
☐ No - Too Cold

Please select one option.

3 How often do you find that:

| | Often | Sometimes | Rarely |
|---|---|---|---|
| There is not enough hot water. | | | |
| There is more hot water than you need. | | | |
| The water is not hot enough | | | |
| The water is too hot | | | |

Please select one option on each row.

4 Since you've had the new PassivSystems heating controls, how easy has it been to?

| | 1 - Very Easy | 2 | 3 | 4 - Very Difficult | Not Applicable |
|---|---|---|---|---|---|
| Read the information on the screen? | | | | | |
| Interact with the screen? | | | | | |
| Set the times when the heating is on? | | | | | |
| Turn the heating off for when you are going out for a few hours? | | | | | |
| Turn the heating off when you are going away for a few days? | | | | | |
| Turn the temperature up if you feel cold? | | | | | |
| Turn the temperature down to save energy? | | | | | |

Please select one option on each row.

FORM CONTINUES OVERLEAF....

6 What would you like your heating controls to do that currently is not possible?

_____

_____

7 Would you recommend PassivSystems' controls to your friends? | Yes | No |

8 Have you got any other feedback that you would like to share with us?

_____

_____

9 The new PassivSystems heating controller that we are trialling was designed to run your heating more cheaply and efficiently. For example, it turned down your heating if you told it no-one was at home, and used weather forecasts to work out just how much heat was needed. It also helped reduce 'peaks' in electricity use on the national grid (these peaks make electricity more expensive and poluting for everyone). It did this by occasionally heating more when demand for electricity was low, and less when it was high - while always sticking to the temperatures you set.

Based on your experience of the new controller, how much do you agree or disagree with the following statements? With the new controller:

| | 1. Strongly Agree | 2 | 3 | 4 | 5. Strongly Disagree |
|---|---|---|---|---|---|
| I felt in charge of my spending on electricity for heating | | | | | |
| I felt able to do things when I wanted to do them | | | | | |
| I felt too dependent on automation | | | | | |
| I felt able to make sure my home was warm enough | | | | | |
| I saved money | | | | | |
| I found it easy to control my heating | | | | | |
| Overall, the controller is a good idea | | | | | |

Please select one option on each row.

10 If you had the option to have the following features of the controller turned on or turned off, which would you choose?

| | ON | OFF |
|---|---|---|
| Ability to turn down heating when no-one is at home | | |
| Ability to respond to weather forecasts | | |
| Ability to reduce peaks in electricity demand on the grid | | |

Please select one option on each row.

**Thank you very much for your time.**
**Please return this form in the enelope provided.**

## 10.13 Cover slip included with pre-trial questionnaire in ‘Experiencing control’ study

[HomeTech logo]

UCL ENERGY INSTITUTE

Thank you for agreeing to try out the new [HomeTech] heating controller.

Before we install your new controls we’d like to find out a little more about your household and how you use your heating. This will help us to better understand how well our system works for you.

We have enclosed a short questionnaire and a stamped/addressed return envelope. We would be very grateful if you would fill in the questionnaire and use the return envelope to post it back to us in [Town].

Thank you again for your time and for taking part. As always, if you have any questions please feel free to give us a call (details below).

Kind Regards,

_____ _____

Representative, HomeTech Mike Fell, UCL Energy Institute

[HomeTech contact details]

## 10.14 Pre-trial telephone interview schedule/record sheet used in 'Experiencing control' study

| **Interviewee reference number:** | |
|---|---|
| - Introduce – still OK to take part in interview – should take about 15 minutes?<br>- UCL working with [HomeTech] – help us understand more about what people expect from the new controller.<br>- This info will be fed back to [HomeTech] and may also use quotes from interviews when reporting the work – but these will be ANONYMOUS.<br>- Recording the phone call – is this all OK?<br>- No right or wrong answers, don't worry about criticizing because all useful, just interested in your honest opinion. | |
| **Can I ask how you heard about the trial?** | |
| **Why did you decide to take part?** | |
| **What do you hope the new controller will be able to do for you?**<br>o **Can you give a specific example?**<br>o **Any problems at the moment?** | |
| • **I'd like to move along now if possible.** | |
| **Do you know if you are on Economy 7?**<br>o **Aims to get people to use electricity when lower demand to avoid overloading the National Grid.** | |
| **One of the things smart controllers like this do is work in a way that tries to avoid peaks in demand on the Grid, like by pre-heating when fewer people are using electricity so they need to use less later.**<br>o **What do you think about that function of the controller?**<br>o **Would you have any specific concerns?** | |

| | |
|---|---|
| **That's everything, is there anything else you would like to add?**<br><br>**Do you have any questions for me?** | |
| **Available for follow-up interview in early April?** | |

## 10.15 Post-trial interview confirmation letter and consent form used in 'Experiencing control' study

Thanks for agreeing to take part in a follow-up interview for the [HomeTech] heating controller trial. We will come and visit you at your home at the time/date below:

We would be grateful if you could read and sign the enclosed interview consent form for us to collect when we visit. If you need to get in touch, please see the contact details below.

We have allowed a one-hour slot for the interview, and will be interested to hear what you thought about the new controller. If other household members would like to join you in the interview, that would be great as we are interested in a range of views. If you would like to ask a friend or family member to sit in, that is also fine.

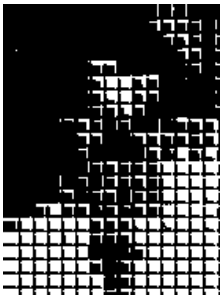
We will both be carrying University College London identification, and both [HomeTech] and your landlord know we will be visiting you so you are welcome to give them a call.

We look forward to meeting you soon.

**Mike Fell**
**University College London**

Tel: [number]
[email]@ucl.ac.uk

**[Representative]**
**[HomeTech]**



Tel: [number]
[email]

# Interview for [HomeTech] heating controller trial

## Thank you for taking part in the [HomeTech trial].

As well as measuring things like energy use and temperature in your home with the new controller, we are also keen to find out what you thought about using it. For this reason we are carrying out some in-home interviews.

The interview will last up to an hour and include Mike Fell of UCL, [Representative] of [HomeTech], yourself, and any other household members or other friends/family you would like to join you. So that we can review what was said afterwards, we'll be making a recording. In reporting this work we'll be using quotes from the discussion, but it is important for you to know that **these will be kept entirely anonymous**. Participation is voluntary, and you are free to pull out at any time without giving a reason.

*Any other questions about the interview?*

Please feel free to get in touch with Mike Fell at any time on [email] or call on [number].

*If you are happy to participate in the interview…*

Please confirm that you agree to the following:

- I've read this information sheet and understand to my satisfaction what the interview involves.
- I agree to take part in the interview, knowing that I can pull out at any time.
- I agree to the processing of my personal information, and understand that this information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
- I understand that my participation will be audio-recorded, and agree to this.

Print name ……

Signature …….. Date ……

(Please hold onto this form and we will pick it up when we visit you.)

## 10.16 Post-trial interview guide used in 'Experiencing control' study

***Aim:*** Understand how perceptions have changed. Overall satisfaction. Pick up any issues uncovered in previous interviews/questionnaires.

- Overall, have you been happy with the control?
- Was it easy to learn how to use the control at first?
- What was good/bad about actually using it – then and now?
    - What did you do when you first got it?
    - Any difference now?
- Thinking about warmth – were you warm enough, too warm?
- Was the system flexible – did it fit around your schedule?
- Did you interact much with the controller?
    - If so, to what end?
    - Were you happy with the results?
    - Did it give you enough information about what it was doing?
- Do you have a feeling for how the controller has worked out for you spending-wise?
- System was reacting to your settings and to changes in national demand for electricity – what do you think about that?
- Did you feel you were in control of your heating system?
    - More or less than before, and why?
    - Are you happy with that?
- Overall, are do you think systems like this are a good idea?
- [Depending on whether they do DLC] If sudden savings needed to be made, in theory system could be turned down at short notice in return for a credit on your bill.
    - What would you think about that?