FINANCIAL INCENTIVE APPROACHES FOR REDUCING PEAK ELECTRICITY DEMAND, EXPERIENCE FROM PILOT TRIALS WITH A UK ENERGY PROVIDER

1. Introduction

Reducing peak electricity usage to avoid the necessity of building and running expensive marginal capacity has long been a goal of the power sector (Faruqui et al, 2010), but is also potentially important for reducing carbon dioxide emissions (Bradley et al, 2013, Darby and McKenna, 2012, Ofgem, 2012) and increasing the reliability of renewable energy systems (DECC, 2012, Walawalkar et al, 2010). There are now increasing efforts to try to encourage demand side response as seen for example by Liu et al (2015). Tariff-based economic instruments tend to be the dominant approach to demand response in the residential sector (Ofgem, 2013), although incentive-based approaches are used in the commercial sector, particularly in the US (Albadi and El-Saadany, 2008). However, evidence from a number of different countries, especially in North America, suggest that: (a) where involvement is voluntary, participation rates in Time-of-Use tariffs tend to be low; and (b) the degree of response to such tariffs in terms of percentage reduction in peak usage of those who do participate, whilst variable, averaged only 5% in 15 trials from across the States (Faruqui and Sergici, 2010, Newsham and Bowker, 2010).

In terms of participation rates, Midwest Power's voluntary Time-of-Use (ToU) experiment attracted a 4% uptake (Baladi et al, 1998) and California's many voluntary time-of-use programmes just 1% in contexts where air-conditioning is a major feature (Braithwait and

Faruqui, 2001). Whilst 8% has been reported in one recent UK voluntary Time-of-Use trial, this involved direct marketing (Darby and McKenna, 2012), reflecting experience from energy conservation that effective marketing and communication can be a significant factor affecting participation rates (Stern et al, 1986). Participation in the UK "Economy 7" tariff has been reported at 15% (cited in Faruqui et al, 2001), but this form of semi-dynamic pricing is tightly connected with those homes which have night storage heaters (often because they are not connected to the natural gas infrastructure) and therefore high usage because of electricity-based heating. Indeed little data exists for contexts where electricity use for heating and cooling is not a feature; perhaps partly because it has been assumed there is less scope for load-shifting in such settings (AECOM, 2011).

Economics, psychology and sociology-based research on energy consumption has identified a number of what one can call 'consumer barriers' (Kim and Shcherbakova, 2011) that appear to influence the degree of participation and response in residential tariff-based approaches. These consumer barriers go beyond issues of design, communication and marketing of an energy-related measure and are summarised in Figure 1 below as six interlinking categories. The current authors assimilated this barriers framework to helped guide the design of the pilot study.

Figure 1: Consumer barriers to participation and response in tariff-based approaches to shifting residential peak electricity use

The first category of barriers relates to concern over potential disruption to existing habits and patterns of living (Ofgem, 2010). This includes issues related to the seeming temporal rigidity of certain forms of home-based electricity using practices (such as cooking an evening meal or

watching TV), and the temporal constraints imposed by work (Torriti, 2012). The shifting of particular energy-using practices to off-peak periods can be perceived or experienced as causing disruption and inconvenience, as well as possible reductions in comfort (Shove, 2003).

The second category is uncertainty over the scale of financial benefit (if any) that would be attained by moving to a semi-dynamic pricing tariff (Kim and Shcherbakova, 2011, Faruqui et al, 2010). The third category is access to and understanding of technology that can facilitate shifts through reducing 'asymmetries in information' (Torriti et al, 2010), that is, differences in information that the customers currently have and could have if technology (for instance, electricity monitoring equipment) were to be successfully implemented, or if timers on electricity-using devices and appliances were implemented and understood (Kim and Shcherbakova, 2011).

The fourth category is the issue of consumer knowledge and rationality (or apparent lack of it). Bounded rationality and relevant other factors linked to rationality can all be seen in the field of behavioural economics, which questions the overall assumption of consumer rationality[1]. Bounded rationality (Simon, 1957) is where time-poor consumers may make 'sufficing' decisions (Kim and Shcherbakova, 2011) based on a combination of inertia, incomplete or inaccurate knowledge about their electricity usage and the tariffs available (Kim and Shcherbakova, 2011; FERC, 2009) as well as their cognitive capabilities. In such situations 'rules of thumb' and other heuristics can replace rational choice. The invisibility of electricity use within energy-related routinised practices of consumption (Shove, 2003; Shove and Warde, 2002; Burgess and Nye, 2008; Hargreaves et al, 2010), and common behavioural biases such as

[1] Bounded rationality is also associated with a number of other economics disciplines.

'limited user capacity' in assessing options (e.g. issues with menu choice), 'loss aversion'[2] as opposed to valuing material gains (Kahneman and Tversky, 1979), discounting of the future[3] (as seen in Ofgem, 2011), and preferences for the 'status quo'[4] (Tversky and Kahneman, 1981), are possible associated factors.

The fifth category covers other psychological and social variables that have been shown sometimes to play a role in an individual's energy consumption decisions: the values, attitudes and beliefs they hold that relate to energy use (Gatersleben et a,l 2008; Abrahamse and Steg, 2011), the social norms they recognise and apply (Alcott, 2011; Bradley et al, 2015), their commitment to shifting (Heberlein and Warriner, 1983), and/or their social interactions and social orientation (Rasanen et al, 1995)[5].

The last category focuses on circumstantial factors which can make it difficult to participate or respond. Examples include the particular nature of household living arrangements (for instance, whether someone lives in a flat or a house, and with others or on their own) or whether a home uses electricity for space heating/cooling, as where residents do use electricity for at least some of their space heating or cooling (e.g. use of a fan when it is experienced as hot or a fan heater

[2] Loss aversion, is the situation where losses are weighted substantially more than objectively commensurate gains, when consumers are assessing trade-offs. With regards to demand response this is discussed in (Ofgem, 2011) and originally seen in (Kahneman and Tversky, 1979). This has to do with susceptibility of preferences to variations of how the decision is framed, i.e. framing the outcome for the decision as a loss or a gain, an excellent analysis and full discussion of framing is provided in (Thaler, 1981).

[3] With regards to time inconsistency it is stated that: "*In standard economic theory, consumers prefer to receive goods and services today than tomorrow. This preference for receiving things now more than in the future is constant over time. In practice, however, the amount that consumers discount the future by varies depending on how far in the future points are.*" (27, p. 8, identified first in Thaler, R., 1981) . Examples of this phenomenon in practice can be seen in (Ainslie and Varda 1983) as well as evidence that shows that people can overweigh certain outcomes compared with risky outcomes (McKenna 2013).

[4] Status quo bias comes from (Samuelson and Zeckhauser, 1988, p7): "*that is, doing nothing or maintaining one's current or previous decision*". Literature review of behavioural economics and demand response can be seen in (McKenna 2013 and Letzler, 2010).

[5] It should also be noted that behavioural economics sometimes also looks at social influences on decision making, so in this instance there can be some overlap.

when cold), changes in ambient temperature may be important in understanding electricity consumption patterns (Rasanen et al, 2005 and AECOM, 2011).

Drawing on this conceptual framework, a small-scale exploratory UK-based pilot study was designed to test two novel financial incentive approaches to encouraging the shifting of residential electricity consumption from peak to off-peak periods and explore barriers[6]. Whilst there are many studies that have analysed the implementation of dynamic and semi-dynamic pricing to shift electricity use, there are very few that trial financial incentives for this purpose. AECOM (2011) confirm there is 'little direct research evidence' on their use in energy demand management. This is despite evidence of strong economic and behavioural rational for their use and enormous potential value (Mizobuchi and Takeuchi, 2013; Letzler, 2010[7]). Two US and Canadian studies have trialled financial incentives. The California-Anaheim Critical Peak Pricing (CPP) Experiment was a critical peak pricing trial; it provided rebates (a financial reward) for each kWh reduction at critical times (e.g. just before a potential black out). The rebate was $0.35 for each kWh reduction below a base line level peak period consumption based on non-CPP days. Peak hours were 12a.m. – 6 p.m (Wolack, 2006). The Ontario/Canada-Ontario Energy Board's Smart Price Pilot (Ontario Energy Board, 2007) also trialled a critical peak rebate, providing participants with a $0.30 per kWh rebate for each kWh of reduction from estimated baseline consumption. Again, this was a straight rebate payment similar to that in California-Anaheim, with no variation of alternative incentive approaches. These financial

[6] The idea was that offering financial payments would be more attractive to users because it would reward participants for consuming electricity at off-peak periods, rather than penalising their peak usage with a higher price. As a result, it should allow for greater consumer flexibility in trading off priorities at different times according to their circumstances in ways that a rigid tariff-based system would not, and thus, it was hypothesised, encourage greater participation and response. The design of the incentive also looked to address framing effects and the issue of loss aversion.

[7] For critical peak pricing pilot programs, customers that receive significant incentives, participants report high satisfaction levels, use less power when prices electricity is more expensive, tend to stay on dynamic pricing and often save up to 10% or more. In Letzler (2010) a compelling case is made for the use of financial incentives.

incentive studies, have looked at load shifting but only for critical peak times and they only trial one broad approach, a straight rebate payment , without reference to the barriers that participants face in load shifting. The current paper builds a detailed classification of barriers, in order to design several different financial incentive approaches that are tested for every day of the trials, not just at critical peak times. The study represents a first attempt to look at and compare alternative financial incentive approaches and to explore the approaches in depth for efficacy, participant experience, preferences, and motivation. This is intended to help guide subsequent (larger scale) studies of this important topic in a way that simple quantitative response results cannot.

2. Methods

2.1 Study design

The pilot study was a small and exploratory 'real world' experiment with households in a large block of flats served by one energy company[8]. The, project was provided with two month of electricity data (April and May) by the energy company to provide a benchmark for the intervention and control groups[9]. Details of the meter implementation[10] and the two six week financial incentive trials are provided in Figure 2. The trials aimed to motivate participating households to shift electricity usage to off-peak hours (green shaded hours), which were determined as between 11pm and 7am and between 1pm and 5pm daily (see Table 1 below for a comparison with other common semi-dynamic pricing schemes, hours vary somewhat in

[8] In this accommodation hot water and heating were supplied by a central Combined Heat and Power system: individual household electricity consumption was therefore for other energy services and related social practices, such as cooking and washing clothes.

[9] The control group was constructed randomly based on 12 aggregated observations from the sample that the energy company provided.

[10] According to records, in total £184 was paid to participants in financial incentives over the two trials. Monitoring equipment costs are estimated to be £2010 for the ten participants (on most recent prices). Most of the cost was associated with the six smart plugs provided. If only overall electricity monitoring had been provided to each participant then the cost of the monitoring equipment would only have been £500.

different areas and tariffs[11]). The trials differed in terms of the level of incentive offered and the way benefits were allocated (see section 2.2).

Table 1: Comparison between peak and off-peak times of study and common ToU schemes

Before the two trials, electricity monitoring equipment was installed for each participating household as seen in Figure 2. Six plug-based on-off timers were also made available to each household to help them shift loads during the trials. Participants were able to access feedback on their usage through a website, in some cases at the individual appliance level. The first trial was implemented for six weeks at the start of July 2013, followed immediately by the second six-week trial in mid-August.

The research also involved two participant surveys in which respondents were asked to score how well various statements reflected their perspectives on a scale of seven points, often between strongly disagree to strongly agree (Likert, 1932). The first was administered just before the start of the first trial (as seen in Figure 2), and the second at the end of the two trials. The purpose of the first survey was to provide background information about each participant in relation to their attitudes, perspectives and self-reported behaviour in relation to the environment (Kaiser and Wilson, 2000; Pelletier et al, 1998; De Groot and Steg, 2008; Terry et al, 1999; Murtagh et al, 2013), their energy supplier, energy shifting, technology use, and lottery forms of risk-taking, as well as their general socio-economic position. The second survey repeated a number of the questions from the first in order to look for changes that might be attributable to participation in the trials, as well as asking about participant experience of inconvenience caused by attempting to shift electricity consumption. Full schedules/surveys for questionnaire and the

[11] https://customerservices.npower.com/app/answers/detail/a_id/179/~/what-are-the-economy-7-peak-and-off-peak-periods%3F

interviews can be seen in the appendix of the working paper (Bradley et al 2014a). All participants completed survey 1, and six out of ten completed survey 2. Their answers were used to assess self-reported pro-environmental behaviour, values and identity and comparisons were made of answers both within and between households, and how they are distributed following (Murtagh et al 2013)[12]. A questionnaire was also sent out to all those in the building who did not participate in the pilot study to ascertain their reasons for deciding not to be involved.

Participants were invited to take part in an interview towards the end of trial 2, seven out of ten of whom agreed. The aim was to gain a more in-depth understanding of participant experiences, particularly in relation to the barriers they encountered in attempting to make shifts in electricity consumption. The interviews were semi-structured in nature, with questions based on an interview guide to focus discussion, and were recorded digitally, played and transcribed as required. Following Braun and Clark (2006), they were then coded thematically in relation to concepts and hypotheses identified during the planning of the research, in particular the barriers participants faced in engaging in the financial structures piloted and how they felt such payment incentives compared with Time-of-Use tariffs.

A flow chart of the key methods used in the study is provided in Figure 2.

Figure 2: Diagram of study time-frame and methods

It should also be noted that participants were provided with the electricity monitoring equipment free-of-charge and were told that they could keep it at the end of the trails, should they wish.

2.2 Trials design

The site for the case pilot study was a large block of flats. The recruitment letter was sent to all 125 flats, from which 10 households participated in the trials (an overview of the socio-demographics of the main participants is provided in Table 2).

The design of the trials took account of evidence that suggests people are more motivated to act from fear of loss than expectation of gain (Ofgem, 2011) as well as framing (Tversky and Kahneman, 1981). Therefore, both trials involved the establishment of what was called an 'incentive account' for each household, holding a pot of money to be paid to the household at the end of the trial, dependent on their shifting activity. This allowed the payoff from energy use decisions to be 'framed' as a loss as opposed to a gain, as seen in subsequent explanations. The initial amount deposited in each account was intended to reflect their typical electricity expenditure for the period and hence was based on the household's total electricity consumption during the benchmark period, multiplied by 9p per kilowatt hour[13]: for a UK household with average consumption, this would mean the incentive account would contain £36 per six week trial.

The incentive account in the first trial represented how much a household would potentially 'earn' at the end of the trial if they shifted all their consumption to off-peak (without exceeding the total consumption of electricity they used in the benchmark period). The amount a participant actually received was proportionate to the percentage of their total electricity usage that had been consumed in off-peak periods: so if a third of their total electricity usage had been consumed in the off-peak period, the 'average' UK household would receive a third of the £36

[13] https://www.ofgem.gov.uk/ofgem-publications/64026/domestic-energy-consump-fig-fs.pdf

incentive account, i.e. £12. Thus, the hypothesis was that households would be incentivised to shift to off-peak electricity use in order to avoid losing part of the potential reward. The approach rewards customers consuming at off peak times, and does not penalise those that already have significant proportion of off-peak consumption[14]).

The second trial differed from the first in that, though the incentive accounts were calculated in the same way, the amounts remaining in each account at the end of Trial 2 were pooled and awarded to only one of the participating households, based on a draw. With 10 participants of average UK usage this would create a total pool of £360 if all the households involved managed to shift all their usage to off-peak. However, importantly, a participant's chance of winning the pool is increased as the proportion of their off-peak usage increases, similar to when someone buys more lottery tickets to increase their chances of winning[15]. This design was chosen to overcome the scale of benefit barrier (Figure 1). The pool that the participants could win was much higher than any individual incentive payment possible in Trial 1. In this sense it addresses the 'scale of the benefit' barrier. Households had the prospect of a much larger financial reward than in Trial 1, the hypothesis being that this would incentivise load-shifting both to keep the level of reward high, and to improve a participant's chances of winning it.

[14] Essentially, the approach rewards existing good behaviour as well as new efforts, but because of this could result in some of the following cases: 1. if a person already used 60% of their electricity off-peak prior to the intervention, and continued to do so, they would get the 60% of the incentive account even though their behaviour had not changed. Or if a person consumed 60% of their energy use at off-peak in the baseline but then moved 10% of their use to on-peak (worse behaviour) they would still get 50% of the reward, whereas another participant who used 80% on-peak before the intervention and moved 10% to off-peak afterwards would only get a 30% payment even though their behaviour improved. In this way, the approach rewards existing good behaviour as well as new efforts. The same situation applies to the incentives rewarded in the second trial, but here only one person gains the reward (whoever wins the pooled account).

[15] Each percentage point of total consumption a person has in the off peak period buys them one 'ticket'

3. Results and discussion

This section focuses on the response of participants to the financial incentives employed to encourage the shifting of consumption in relation to the barriers identified. What is encouraging is that the majority of participants shifted consumption from peak to off-peak in comparison with the benchmark period during the trials, with average percentage peak reductions that compare favourably with Time-of-Use experience. Just one household in Trial 1, and another in Trial 2 did not shift. Larger scale studies will be required to allow estimates of the potential for shifts for wider UK populations, but the study provides a valuable design template for such studies as well as 'proof of concept'. The section finishes with an exploration of participant experiences, providing new insights into barriers in relation to financial incentives and load-shifting more generally.

3.1 Participation

The participation rate for this pilot study was 10 out of a potential 125 households (8%)[16]. Table 2 below helps to show that whilst the residents who chose to participate were relatively diverse in age, ethnicity and income, they were largely wealthier than the UK average, and either lived alone or with one other adult. Although the research explored why some residents chose not to participate, less than 3% of non-participants filled in the questionnaire sent out and the energy supplier for the block, with whom the study was undertaken, was understandably averse to further questioning of those who had proved unwilling to engage. This makes it difficult to

[16] Though on very different scales, this is better than the 1% and 4% rates reported in Braithwait and Faruqui (2001) and Baladi et al (1998) respectively for different Time-of-Use trials in the US, where air-conditioning is a major feature. It is comparable to a recent UK voluntary Time-of-Use trial where direct marketing was used (Darby and McKenna, 2012), though less than the 15% participation rate for the UK Economy 7 tariff (cited in Faruqui et al, 2010).

ascertain the reasons for non-participation though some insights are provided by the respondents[17].

Table 2: Overview of socio-demographics of participants in study sample

3.2 Response

Table 3: Aggregate household electricity consumption during the study

As Table 3 above shows, aggregate household peak consumption fell and aggregate household off-peak electricity consumption rose during both Trial 1 and Trial 2 in comparison with the Benchmark period: peak electricity usage decreased from 1826 kWh (Benchmark) to 1156 kWh in Trial 1 and to 1250 kWh in Trial 2, whilst off-peak usage increased from 554 kWh to 911 kWh in Trial 1 and to 875 kWh in Trial 2. The control group saw peak electricity usage increase in trials 1 and 2 compared to the benchmark. Pre-intervention the control group's mean energy use was 222 kWh, the trial group's energy use was 238 kWh (means are used here, as the control group had 12 observations as opposed to 10 in the trial group). For the intervention group aggregate household total electricity consumption fell in trials 1 and 2 in comparison to the Benchmark period. It is important to note during each of the trials there was a household that was away for approximately 4 of the 6 weeks, and this may at least partly explain the lower overall energy use figures noted during the trials. Table 1 in Appendix 1 shows the absolute value for overall changes in energy use at the individual household level.

Table 4: Average household percentage of peak and off-peak electricity usage against total consumption during the study

[17] The responses of two of those who did reply hint at one potential issue: a lack of understanding of the incentives on offer. In addition, one of the participants mentioned he had not understood Trial 2, and another pointed to the complexity of the pooled approach of Trial 2 as a possible problem. Two other participants also appeared to have misunderstood what the second trial involved. The structure of the financial instrument in the second trial seems therefore not to have been communicated in a way that was understood by all; however, four other participants were positive about the pooled incentive approach.

Table 4 above illustrates the degree of the changes observed. Peak consumption fell to 56% in Trial 1 and 59% in Trial 2 in relation to total consumption in each of these periods. The study shows a 21 percentage point reduction in the proportion of peak electricity usage in Trial 1 and 18 percentage point reduction in Trial 2 in comparison with the benchmark peak consumption percentage[18]. These differences in percentage peak energy use going from the benchmark to intervention periods are reflected when looking at individual level changes for each participant later in Figures 3 and 4. These figures compare favourably with response rates found in voluntary Time-of-Use trials and previous financial incentives studies in literature. For example, the critical peak time rebate (incentive) trials: 1. In California (Wolak 2006) estimated that the intervention resulted in a 12% reduction in electricity on average during peak hours of CPP days; 2. The critical peak rebate (incentive) scheme in Canada (Ontario Energy Board 2007) saw a 8.5% shift as a percentage of all peak hours. The latter studies are not however directly comparable as they focus on critical peak pricing days, where as our incentive applied to every day of each of the two trials, more like the time of use tariffs and also our incentive approaches were organised differently as noted earlier in the study.

Overall, the average proportion of off-peak usage in the current study rose from 23% in the benchmark period to 44% in Trial 1 and 41% in Trial 2. Changes in the number of daylight hours were considered as an influence on results, but the control group results indicate that this was not responsible for the observed changes. The 'Hawthorne effect' of being observed in a trial (AECOM, 2011 and Ipakchi and Albuyeh, 2009) may have had some impact, although this

[18] Whilst it is tempting to conclude from the figures given earlier that Trial 1 was slightly more successful than Trial 2, it is important to note that 5 out of 10 (50%) of the households increased their off-peak consumption in the second trial in comparison to Trial 1, and that 'response fatigue' (Kim and Shcherbakova 2011) may mean the ordering of the trials played a role. There is also evidence that a few participants did not fully comprehend Trial 2, and this may have impacted on how they responded.

observation was done remotely through metering, and therefore should have reduced this influence.

The two charts of changes in electricity consumption during off-peak and peak periods (Figures 3 and 4 below, see absolute values in Appendix 1) for individual participants over the course of the study indicate that all of the households did reduce their electricity usage in peak periods in Trial 1, by shifting their electricity consumption at least partly to the off-peak periods. However, in both trials over half of the households also did so by reducing their total electricity usage, providing a double dividend of trial incentive payments and bill reductions.

Figure 3: Comparing household peak consumption in the benchmark, Trial 1 and Trial 2 periods

Figure 4: Comparing household off-peak consumption in the Benchmark, Trial 1 and Trial 2 period

Interview data also evidence that participants made deliberate attempts to shift and/or reduce their electricity consumption during the study. What is less clear is the role that the promise of financial rewards played in this. The evidence indicates that for many of the participants this was not the only reason they made changes in their energy consumption as illustrated in the quotation below:

"I like to use as little energy as I can myself….so, to me, it was helpful to know that not only am I doing that… which I plan to do anyway, but that effort has been sort of recognised in a way as well, and I'm getting something for it, so it's just… giving extra motivation" (Household 8)

Other motivations were also indicated in the survey data (see Figure 5 below), with eight out of ten participants agreeing strongly or very strongly that they had participated partly for reasons of societal economic and environmental benefits; four agreeing, to various degrees, that they were motivated by the financial payments (one strongly so); four agreeing that they were also partly motivated by the electricity monitoring equipment on offer (one strongly so); but none agreeing that the pooled (second trial) incentive had been an attraction. However, it is also important to note that one participant, who disagreed with the statement that he had become involved in the study because of the incentive offered in Trial 2, later admitted in his interview that in fact this had been a primary reason. This suggests that the questionnaire responses may, at least partially, reflect perceptions of social acceptability, and demonstrates the importance of mixed methods in such studies.

Figure 5: Responses to survey questions about motivations for participating in the study

Whilst the results indicate that the first trial was a little more successful than the second in incentivising load-shifting, the fact that half the households increased their off-peak consumption in the second trial in comparison to Trial 1, suggests this is not a straight-forward conclusion. It is possible, moreover, that if the trials had been ordered differently, the results may have differed, as there is some evidence that there was greater engagement with the electricity monitoring equipment early on, as has been noted in other research (Hargreaves et al 2010), and a problem of 'response fatigue' has been reported in some dynamic pricing trials (Kim and Shcherbakova 2011). This raises too possible issues with whether such response levels would be sustained over time, something these six week trials were not designed to test.

However a number of interviewees mentioned that they were planning on continuing some of the shifts and reductions in usage they had made during the trials. Four out of seven of those interviewed suggested that they had found the study useful or informative because the electricity monitoring equipment had allowed them to get a better understanding of their electricity usage. Supporting other research, this suggests that the monitoring element of the study was important for at least some of the participants in enabling both load-shifting and usage reductions, and that it was therefore the combination of provision of feedback facilities and financial incentives that helped deliver the participation and response rates detailed above.

3.3 Participant preferences for different trial designs of financial incentives and perceptions of Time of Use tariffs

The trial results indicate that some participants responded more to Trial 1, and others more to Trial 2. The interviews also show, however, that participants differed in their preferences for the trials and whether they felt they were better than Time-of-Use approaches.

The two participants below suggested that their preference in terms of the trials was partly a function of whether they enjoyed lottery-style risk, with the first preferring Trial 1, and the second Trial 2.

> *"… the first one… There was a clear, direct flow-through from [what I did] to what it would do to my energy bill. … I could internalise what I thought I was doing… The first one had clear incentives. The second one was…effectively gaming with other people, and that just struck me as… I was quite happy to do all the things I'd been doing during the first trial, but I wasn't going to go the extra… … if you've got a gambling instinct and you're basically sort of risk-taking, the second one had sufficient incentive. I know that I'm very risk-averse – everybody tells me I'm risk averse."* (Household 1).

> *"… once I saw a bigger figure in the second trial, that was a bigger incentive. … The fact that I saw, I think it was 300-odd quid, I've made a determined effort to do something. … I can play the lottery, and I bet I've got a better chance to win that 300 quid than I have the lottery, because I think, well, you know, there's fewer of us in it"* (Household 5)

However, the participant from Household 1 saw the first trial as a form of *gaming* with himself. The participant from Household 5, the only interviewee to express a definite preference for Trial 2, suggested that in time this preference might wane if he failed to win the pool[19].

All participants who were asked about whether they would accept a financial payment approach if offered by their supplier said they would consider it if on the basis of Trial 1. Four said they would consider participating in a pool-based financial incentive were it offered, with a couple saying: "*you have got nothing to lose"*. However, two said that they probably would not take up a financial incentive approach, if it was on the basis of Trial 2, because of the uncertainty of receiving any reward.

Two of those interviewed also said they would not be interested in a Time-of-Use rate, at least "*not at the moment"* in one of the participant's words. He explained this was because he lived in a small flat where it was too noisy to leave appliances on after he went to bed. There was therefore a risk that on a Time-of-Use tariff he would be "*penalised rather than rewarded"*, whereas with a financial incentives approach there is "*no risk to you"*. Whilst four said they were willing to consider a Time-of-Use tariff, two clarified that agreeing to one would depend on if they felt they could financially gain from the rates on offer, one suggested he would not want to feel like he was paying for it, and the other was concerned about needing to remain "*conscious of staying within that tariff"* in order not to go over budget.

[19] *"The pooled element makes it a bigger figure, and it certainly makes it a stronger incentive for me to want to do it, but I think, over time, if I wasn't achieving it and getting some kind of reward, in my world, there'd be a cut-off point of saying, do you know what, I've had enough of this now…*"

Yet, both the risk-averse and risk-taking participants from Household 1 and Household 5 respectively said that they would prefer a Time-of-Use tariff to that of a financial incentives approach, if their calculations suggested they would benefit from making savings. They both liked the clarity[20] and stability of the former: "*clear and permanent and transparent"* (Household 1).

This contrasts with the participant from Household 8 who said that he would not wish to be on such a tariff because he liked "*to have my flexibility…of being able to use what I want to use, when I want to use"*. He thought such flexibility would be particularly appealing to families who might find it more difficult to coordinate regular shifting.

The above suggests that whilst the categories of barriers identified for Time-of-Use remain for financial incentives, as indicated in the next section the height of barriers was perceived to vary according to approach (e.g. financial incentive design vs tariffs). The no-cost aspect of the financial incentives approach, which was recognised by a number of the participants, may overcome perceptions of disruption to existing living patterns and habits, a key potential load-shifting barrier according to the participants in this study. Households are able to dip in and out of load-shifting when convenient to them, and are not penalised if not always able to shift. On the other hand, the perceptions of Time-of-Use tariffs as being more simple and more permanent – "*black and white"* (Household 5) – than financial incentives may mean that they face lower barriers in terms of customer knowledge and uncertainty.

[20] *"I know what I am doing, so I would say, well, actually, I do need to do a wash this morning – how much more is it going to cost me if I do it at 11 o'clock or if I do it at 1 o'clock?"*

3.4 Barriers to response: exploring participant perspectives and experience

Participants identified the same categories of consumer barriers for incentive-based approaches as the literature suggests for tariff-based approaches, although seemingly to different degrees: potential disruption to existing patterns of living and habits, scale and uncertainty over benefit, availability and understanding of facilitating technology, consumer awareness and bounded rationality, individual psycho-social dimensions, and circumstances (for further discussion, see Bradley et al 2014a). However, what this study helps to highlight is that the height of these barriers varies not only according to how shiftable different electricity-using practices are perceived to be, as other research has indicated, but also according to the individual participants as identified in the last section, and their perceptions of what is "*practical"*.

3.4.1 Differences in the temporal rigidity of different electricity-using practices

The findings of this study echo findings from other studies that some electricity-using practices are easier to shift than others (Hargreaves et al 2010). Interviewees often referred to the structure of the working day and week as being a main reason for their existing patterns of electricity usage, and this was perceived as being largely beyond the control of the individual[21].

"I guess the main barriers would be time, kind of the morning, the morning routine, and the evening routine, and then, because none of us are stay at-home people, or none of us work from home, so we're unable to kind of shift the energy that we've always used at that time."(Household 10)

[21] *As other studies have found, cooking an evening meal was perceived as being especially immovable by those who were interviewed: "… you need to cook when you need to cook… you can't, you know, shift your dinner timing. That's harder to do" (Household 8). But there were other electricity-using domestic practices that interviewees were more amenable to shifting to off-peak periods. In particular, four interviewees mentioned that they had shifted doing the laundry to off-peak, facilitated in two cases by timers on the machine (they did the laundry late), and two by doing the washing late at night, in one case, or on a Saturday afternoon, in the other.*

Prior patterns of peak and off-peak usage may also have been a factor in determining how easy it was to shift usage. As Figure 6 below illustrates, the two households which started with the highest proportions of off-peak consumption (Households 4 and 10) were amongst those households that increased their proportion of off-peak consumption the least.

Figure 6: Household off-peak proportion of electricity usage in the Benchmark, Trial 1 and Trial 2 periods

What these findings show is that different practices have different temporal plasticity (i.e. the timing of some social practices seem more open to being modified) with some being perceived as easier to shift than others, depending on the equipment involved (whether it has a timer or not, for example), related social conventions (e.g. when dinner is eaten and that it is cooked), and the competencies required e.g. knowing how to use a timer on an appliance (Shove and Pantzar 2005).

3.4.2 Differences in individual trade-offs between inconvenience and expectations of reward

In addition to the temporal and technical control participants felt they had over the practice, it was an individual's assessment of the balance between "*hassle factor"* (Household 1) caused by moving a practice and the perceived benefits, which a couple of participants suggested was a key determinant of how much they shifted.

> *"It's got to work for me. … If I can save money from it, I will change my pattern… and I don't mind being inconvenienced, but not too much… when the financial aspect disappears, the convenience factor then comes in ... the washing will probably be nine o'clock in the morning, which is where it always used to be, just because it fits my lifestyle."* (Household 5)

"… it was the trade-off between, well, how much more can I do, how much is that actually going to inconvenience me…" (Household 1)

Such trade-offs appear to have been influenced by the way a participant constructed, measured and weighted inconvenience and benefit, and this seems to have differed from participant to participant. For example, the participant from Household 5 felt that he had gone a long way to try and win the pool in Trial 2 in that, he had put himself through what he experienced as quite a lot of inconvenience (see Figure 7 below).

Figure 7: Household responses to survey questions about level of inconvenience experienced in the trials

However, Household 5's shifts from peak time to off-peak time were not as great in either trial as those of Household 3 in Trial 1. Yet this latter participant reported very little feeling of inconvenience or disruption. Members of Household 3 worked at home and went to bed late, so they found it relatively easy to shift the timing of practices in comparison to those who worked elsewhere (the case for the participant from Household 5), and also partly by the fact that they were away for 4 weeks during the first trial. The participant from Household 3, however also scored highly in relation to pro-environmental measures (compared to the participant in household 5), so their rationale for the shifting was more aligned to her intrinsic values and identity.

Despite being a "*man of routine"* and the disruption he therefore experienced, the level of reward had been high enough to (extrinsically) incentivise the participant from Household 5 to shift his consumption: "… *So I would argue, in my case, if the*

incentive is big enough, I will change my lifestyle as much as I can. But the working bit, I can't change, unfortunately, so there will always be…that element of putting the oven on at a peak time because that's the time I get home."

Two of the other participants similarly felt that the financial payments on offer were "*good"* (Household 8). For two other participants (Households 1 and 7) they expressed that the financial incentive was not large enough to have incentivised them to shift in the longer term (Households 1 and 7). These mixed responses to whether the incentives on offer were sufficient enough to outweigh the inconvenience caused, and thus incentivise load-shifting, appear to have been independent of household income[22].

The importance of differences in people's perceptions in determining response were acknowledged within interviews, with comments about how it depended "*on the person, you know, the personality"* (Household 7), "*you as a character"* (Household 5), or "*the state of mind of the individual"* (Household 10). This is seen again in the example below:

> *"I'm sort of independently saying, well, actually, I'm not sufficiently bothered…to go all out to win this particular prize* [the pool in Trial 2]. *... if all I can see is I'm changing my habits and somebody else benefits from it, I'm sufficiently selfish to say, well, how can I trust somebody else to do the things that will enable me to benefit?"* (Household 1)

[22] Whilst Household 1 reported an annual income of above £60,000, Household 7 reported an income level of between £20,000 and £39,999, as did Household 10; Households 3 and 5 both reported income levels of between £40,000 and £59,999.

"… If you're very much into saving the planet and reducing consumption of electricity and stuff like that, financial incentive shouldn't matter – it becomes part of life. …. I'm not driven like that. I'm driven in what I believe is reality and what my bills are each month. So, for me, it's a case of is there an opportunity to save some money and reduce my outgoings in the month, and if there is, I'm up for it. So, I think it depends on the individual… and it's different for everyone." (Household 5)

3.4.3 The development of new load shifting habits:

A number of participants mentioned that being involved in the study had led to the formation of what they called *new* energy-saving and shifting *habits* which they hoped to maintain even once the incentives stopped for example: "… *I'll keep on doing all the things I have been doing, which I have been doing beyond the trial time as well, because that becomes a force of habit… irrespective of the financial incentive".* (Household 1) This latter point is an important area for further research: what percentage of respondents continue load-shifting habits once the financial incentive is withdrawn?

Two of the participants mentioned that the study had allowed them to see how much they were willing and able to shift (and provide self efficacy). In essence, therefore, the study had facilitated them to test whether they could alter pre-existing habits, one of the barriers identified for Time-of-Use tariffs.

5 Conclusions with policy implications

This paper presents one of the few studies of financial incentive approaches for reducing peak residential energy demand. The financial incentive approaches explored were innovative in that they seek to address the issues of 'loss aversion' and scale of financial benefit identified from looking at barriers to consumer participation with time of use tariffs. The paper then went on to report on barriers to the current financial incentive approaches for demand response; these are key research gaps that the paper addresses.

This study showed that both incentive approaches trialled saw shifts in electricity use from peak to off peak. In combination, the interview and energy data of this study indicates that the majority of participants made deliberate attempts to reduce and/or shift[23] their electricity usage, adopting such a strategy creates a double dividend for consumers: in addition to financial payments for the proportion of usage that is off-peak, they also receive a lower electricity bill. Environmental motivations were also important for some participants in their shifting. What was particularly encouraging was that a number of participants formed new habits and routines related to electricity usage as a result, which they intend to continue beyond the study.

The quantitative findings of this study cannot be generalised to the larger UK population however as households recruited for the study tended to be small, childless and working. With wider UK relevance, what the study does however show is that that different incentive structures appeal to different people based on their perceptions, priorities and circumstances.

[23] For six out of the 10 of the households in both trials, the changes in proportion of off-peak usage were the result of reducing peak consumption, not just shifting electricity usage to off-peak, which echoes findings from Sweden for a recent Time-of-Use study.

Barriers identified in the literature for semi-dynamic tariff-based approaches were also identified for participants in this study[24], but height of the barriers differed (a) in relation to the temporal flexibility of different practices, and (b) according to participant preferences and perspectives[25]. For example, the question of whether the incentive on offer was perceived as sufficient for participants was integrally related to – and traded off with – their perception of the 'scale of financial incentive', alignment with intrinsic motivations and the extent to which disruption to existing living arrangements was experienced as problematic.

What was most interesting however, and of high relevance to policy and decision makers in industry and government, is that the study indicates that the height of perceived barriers (such as uncertainty in scale of benefit/perceived disruption to habits and patterns of living) depend on the financial incentive or tariff approach applied. This is a new finding as far as the authors are aware, with relevance to policy, as different incentivising structures (various financial incentives or tariffs) for demand response see differences in the extent of barriers experienced, even if offering very similar financial benefits.

What was also very clear from the pilot study, and with real policy relevance, is that when participants were asked about their perspectives on the two trials and on Time-of-Use tariffs, their preferences differed. This is an important finding and suggests that there is unlikely to be one form of load-shifting measure that appeals to all, and

[24] Disruption to existing habits and patterns of living, scale and uncertainty of benefit, access to facilitating technology, consumer knowledge and bounded rationality, and psycho-social aspects such as values, priorities and norms.

[25] As other studies have suggested, participants were more willing to shift use of washing machines and dish-washers to off-peak times, although noise and social norms were identified as issues; in contrast, as other researchers have found (Hargreaves et al 2010 and Dutschke and Paetz 2013), cooking an evening meal was perceived as immoveable. Additional smart plug data showed that devices commonly used for shifting were Kettles; irons; toasters; lamps as well as microwaves (Kidd 2014).

therefore offering a range of options may be most successful in incentivising load-shifting.

Future research:

Larger and longer-term trials are needed to generalise the sort of quantitative findings of this study to the UK population, and to answer questions that this pilot study was not designed to address: whether any shifts generated are maintained over time and once incentives are removed; whether any intrinsic participant motivations for load-shifting are gradually eroded by the use of financial incentives (AECOM, 2011: Ipakchi and Albuyeh, 2009); whether there are any issues related to equity and fairness (and potential for negative gaming spill over effects form the second trial approach, e.g. a rise in expenditures on the national lottery); and what the electricity 'producer barriers' (Kim and Shcherbakova, 2011) might be of implementing such an incentive-based approach.

It is also recommended that future studies aim to understand which segments and proportions of the population (by different income group and household sizes/types) will find different financial incentive approaches preferable, and the extent of perceived barriers for each approach by income group and household size/type. This is important future work as it would help inform energy companies' recruitment and marketing strategies and identify the length of time that incentives need to be applied in order to maximise demand response, with the lowest cost and maximum benefits to society, as discussed in (Bradley et al 2013).

The price elasticity of demand for electricity is normally reported at a highly aggregated level and typically shows that the demand for residential electricity is inelastic, although with some differences in the short term and longer term (see Duerinck, 2009 and Narayan et al, 2007). This study's findings indicate however that the price elasticity of demand should ideally be measured at the energy service/appliance level (i.e. looking at how price or incentive changes alter the electricity use by different appliances or electricity uses) and for different household groups. This is a new and important finding for policy makers and energy companies and deserves further research. One study that can help with potential approaches in this area is Reiss and White (2005).

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Appendix 1

Table A: Changes in participant energy use going from the benchmark to intervention periods

Appendix 2: Initial letter sent to participants.

Invite to take part in the energy shift study with [company name].

Dear Sir/Madam,

We are writing to invite you to take part in an energy study being conducted by [company name] and the Centre for Environmental Strategy, University of Surrey. The study is looking at the role of financial incentives in encouraging shifts in household electricity use to different times of the day. The research is part of a larger study exploring the potential environmental and economic benefits for the UK (and benefits for individual energy consumers) from such shifts in demand. In relation to the environment, shifts in electricity use can help accommodate greater contributions from renewable power. In terms of the economy, shifts in electricity demand can help the electricity system run more efficiently.
The study will consist of:

- Two brief participant surveys (5/10 mins) which provide information about your situation, experience and values;
- The collection of the electricity used by your major household appliances (collected autonomously with no input required from yourselves). A portable 'smart meter' display screen installed and supported by [company name] will provide energy feedback to you (*The technology is easily installed and does not require physical alteration of existing fixtures, fittings and walls etc).* The metering will collect just electricity use data for 5 months. The equipment will be collected from participants at the end of the study, by [company name] at the next standard metering visit. However, you have the option to keep the monitoring equipment after the study, if you manage to complete the two questionnaires;
- A three month trial where financial payments are available from [company name] for electricity shifting at the end of each month, this will start in May. Payments will depend on the proportion of electricity consumption that is off peak (off peak is between11pm to 7 am and 1pm till 5pm).

It is your decision whether to respond to financial incentives available. Participating in the study will not affect your current electricity tariff, so you don't need to worry about this.
Benefits of the study for participant are as follows:

- Financial payment for shifts you make in the timing of electricity consumption;
- Provision of the metering plugs, screen and software that you can keep: The kit provides you with easy to understand information on where in your house (e.g. appliances) electricity is being used. The information in easily accessible. On completion of the study (and two questionnaires) you have the chance to keep this electricity monitoring equipment.
- Information that can help you reduce your electricity bills.

Further detail on the trials and incentive payments is provided on the application form. Your participation or withdrawal will have no bearing on the electricity prices that you pay in future from [company name] or your relationship with them. If you would like to take part in the study please fill in the attached application form and return to [company name] in the addressed envelope provided, or send the application form by email to ……. Thank you for your co-operation.

Yours faithfully,

Application form
In order to take part and continue participation in the study you will need to:

- Keep the electricity metering in place when consuming electricity (for as long as you are participating in the study).
- Agree to provide permission for [company name] to supply information to the University of Surrey on: a.) your monthly electricity consumption over the last year to inform the researchers of the study Surrey. b.) your contact details, so that the researcher can liaise with you when required;
- Have access to the internet.

All data will be held and processed in the strictest of confidence and in compliance with the Data Protection Act. No information that could identify an individual from the study will be disseminated outside the Surrey research team. Due to small size of the study it may be possible that your identity may become known to the researchers working on the project at the University of Surrey. Please note that any electricity use data collected will not be analysed until a week after the time of energy consumption. Any information which could identify an individual, including an email address, will be held separately so that the data are anonymous. If you wish to ask further questions about the study, please contact [company name], who can direct you to the relevant researchers at the University of Surrey.
If you would like to take part in the study please provide answers to the following questions: If you work/study, what are the numbers of days that you work/study and typical hours on an average day (please estimate)? Number of days..... Number of hours.....

Further information: The study will last five months in total. For three of these months you will have the ability to attain money based on the extent to which you consume at off peak times. Off peak times are 11pm to 7 am (night) and 1pm till 5pm (daily). In the first month where financial rewards are available, an incentive account will be created for you. Each participant will continue on their current tariff and pay their electricity bill as normal. The money to be put in the incentive account at the start of the month will be estimated based on your long term monthly average figure of electricity use multiplied by 6 pence (this value will treble in the second and third months). For the average household the amount of money put in the incentive account at the start of the first month would be £17 (275kWh of electricity use multiplied by £0.06), and £50 in the second and third months (275kWh of electricity use multiplied by £0.18).
Incentive accounts can only be accessed at the end of the month. The extent of money in the account and available to you at the end of month will depend on how much electricity you consume at off peak times (11pm to 7 am and 1pm till 5pm daily). If all of your consumption is off peak you will receive the full financial incentive account.
When it comes to paying rewards at the end of the third month of incentives, all accounts will be pooled and one of the participants in the study will win the joint account at the end of the month based on a draw (at the start of the month each participant will have at least a 1 in 25 chance of winning – as there is a maximum of 25 people in the study). Each person's chance of winning will change by the end of the month, depending on how much consumption is off peak. Higher proportions of off peak consumption will improve your chances of winning the pool account.

We now need you to read the following text and confirm your participation with the project: I have read and understood the information provided and have been given the opportunity to ask questions on all aspects of the study and have understood the advice and information given. I agree to take part in the study and consent to my data (as outlined in the letter and application form) being used for this study. I understand that I am free to withdraw from the study at any time, without needing to justify my decision.

Signature..... Date..... Email contact……

Appendix 3: Mean and standard deviation - supplementary information for Figures 5 and 7