



Residential consumer attitudes to time-varying pricing

Low Carbon London Learning Lab



Report A2

Authors

Richard Carmichael, James Schofield, Matt Woolf,
Mark Bilton, Ritsuko Ozaki, Goran Strbac

Imperial College London

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Executive Summary

The Low Carbon London programme is a technology demonstrator financed by customers via the Low Carbon Network Fund (LCNF), administered by the Office of Gas and Electricity Markets (Ofgem). As part of this programme, a residential dynamic time-of-use (dTOU) tariff was trialled with the aim of measuring consumer's willingness to engage with dynamic electricity pricing. This is the first trial of a dynamic time-of-use electricity tariff with UK households. It was conducted by a partnership of industry stakeholders organisations and academia. The London distribution network operator (DNO) and project coordinator was UK Power Networks. Key partners in the design and implementation of this trial included:

- Imperial College, London (ICL): report author and programme academic partner
- EDF Energy: retail energy supplier
- Siemens: information and communication technology (ICT) framework
- CGI: smart meter head end set-up and management

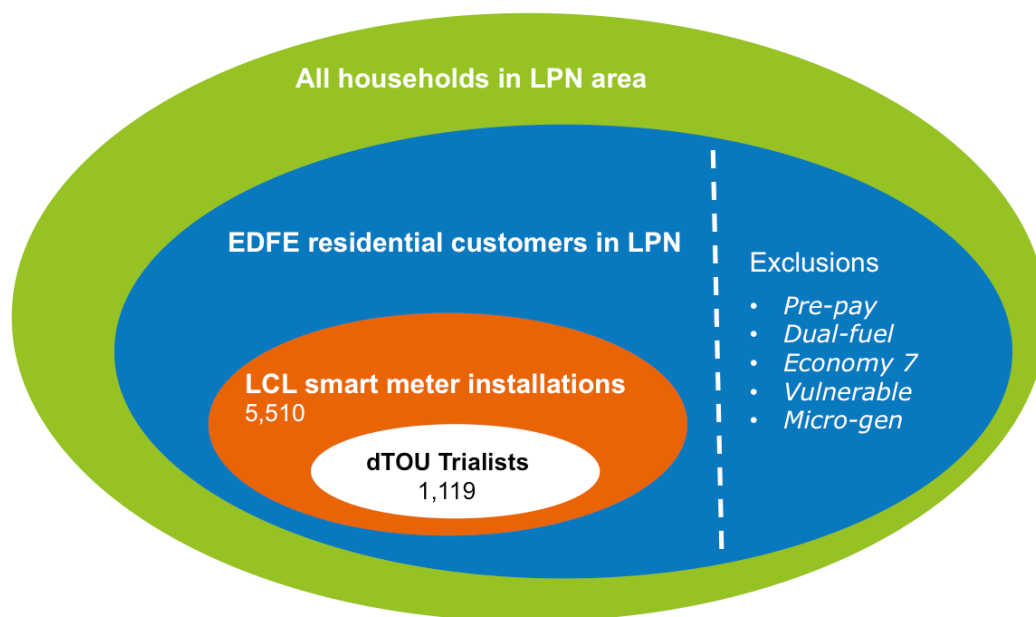
This report describes learning from the trial and is in many ways a complement to its companion report, A3, *Residential consumer responsiveness to time-varying pricing* [8]. The latter report addresses questions of responsiveness to the price signals by analysis of consumption data from smart meter data. This report, A2, addresses the experiences and attitudes of households on the residential dTOU trial. In some ways the separation of consumption practices/behaviour and attitudes is an artificial one; 'engagement' spans behaviour, attitudes and understandings. This report aims to add some understanding to what goes on inside the 'black box' of the home by looking at *how* responsiveness is achieved and how households *experience* this novel tariff. In doing so it relies heavily on trialists' self-reports from interviews and surveys.

The UK has a target of 15% of energy supply from renewable sources by 2020 [1]. This means that, according to the UK Renewable Energy Roadmap, more than 30% of UK electricity demand will be met by renewable generation by this date, largely through greatly increasing installed wind capacity. However, matching the residential electricity demand characterised by static peaks to the variable and irregular supply of wind power is a major challenge. In addition there is a huge economic value to reducing and delaying costly investments to reinforce the aging UK distribution network and this may be achieved in part by managing demand within the limits of network constraints. A key way to achieve this will be price signals through innovative tariffs aimed at making households more active and involved as energy consumers. Similarly price signals could also be used to incentivise load shifting away from times of network constraints. Whilst network constraints are to some extent predictable the unpredictable nature of renewables such as wind and solar will require time-of-use tariffs that are based on dynamic rather than static pricing.

The scheduled rollout of smart meters to all UK households by the end of 2020 opens the door to smart tariffs and dynamic electricity pricing. Domestic consumers are generally positive about smart meters [23] and previous trials of dynamic and time-of-use (TOU) tariffs have found public acceptance and responsiveness [3]. Most time-of-use pricing trials have, however, investigated static TOU to reduce fixed peaks in demand; the lack of predictable patterns in the price signals for wind-following is a potentially important difference for consumers. Such dynamic TOU tariffs have yet to be offered or trialled in the UK and debate and controversy over consumers' appetite for the perceived complexities, risks and fairness remain. The UK context for electricity demand and dynamic pricing also differs to that of less temperate North America where most dynamic pricing trials have been conducted. How would UK households respond

to price signals to follow wind energy? What are the challenges for such tariffs and how can engagement be maximised? This report begins to answer these questions.

Over 1,100 households in the London Power Networks (LPN) area were recruited onto a three-rate dynamic tariff with day-ahead notification and monthly feedback. Half-hourly smart meter consumption data was collected from these households plus a comparison group of nearly 4,500 households on a standard rate tariff. Survey data was collected from the majority of these households and 37 semi-structured in-depth interviews were carried out to gain insight into the experiences of households on dTOU and to understand observed patterns in demand response.



Recruitment of dTOU trialists within the London Power Networks (LPN) area

Analyses show a large majority of households on the trial modified their consumption behaviour in response to the dynamic pricing signals and also made financial savings over the 12-month trial period. The interview and survey data on household engagement found that while the unpredictability of the price events was commented on by trialists, dTOU was not reportedly experienced day-to-day as complex. Findings shed light on the potential of dynamic pricing for wind-following and how such tariffs might be delivered and supported with appropriate technology to maximise take-up, engagement, and consumer benefit, and so can help to inform future trials and energy policy.

Further details about the measured responsiveness to the dTOU tariff is covered in LCL Report A3, *Residential consumer responsiveness to time-varying pricing* [8]. This report will summarise the aspects of engagement concerned with the attitudes and experiences of the households on the trial; these are summarised below, followed by specific recommendations for future trials.

Main findings on consumer attitudes to dTOU

1. **Very positive trialist reaction to dTOU:** Perhaps the stand-out finding is the degree of positive reaction to dTOU from trialists who were, it is worth emphasising, quite heavily incentivised to sign-up to *Economy Alert* (as the LCL dTOU tariff was known) and therefore not necessarily pre-disposed in favour of dTOU at the outset. The list below shows the range of these positive endorsements of the dTOU tariff by trialists. It will be interesting to see, in the future, if these figures are affected by alternative price points and rate schedules but there is no reason to believe that these aspects of the Economy Alert tariff design were especially attractive. Indeed, certain changes to the tariff design used in the LCL dTOU trial could result in even greater levels of satisfaction (e.g., lower High-rate, fewer evening peak-time High-rate events, and better on-going feedback about savings). Findings include original insights into some non-financial and more psychological benefits to consumers.

Two points worth emphasising from the table below are:

- **Strong acceptance and support of dTOU:** One of the most impressive findings from the survey was the very high rate of endorsement of this item (91%) and, moreover, agreement that dTOU “should be the standard tariff for everyone” (81%). This indicates strong potential support for cost-reflective pricing which is viewed as fairer and/or promoting efficiency. Awareness and debates about cost-reflective pricing have some way to go but this is an extremely encouraging starting point.
- **dTOU was not experienced as complex:** Despite the admission that calculating costs and comparing with other tariffs is far from simple, 79% reported that Economy Alert was not experienced as complex in the course of living day-to-day with the tariff. In the current UK context of efforts to make energy tariffs simpler and more transparent (under Ofgem’s Retail Market Review), findings suggest that greater consumer engagement supports greater acceptance of, or even an appetite for, some types of complexity and the two need to be seen in tandem. The importance of communicating to trialists the reasons underlying rate changes in the schedule (see below) further underscores that in some cases transparency is more important than simplicity.
- **dTOU helps households in planning and organizing (77%) and motivating them (80%) to get chores done.** This was one of the most striking survey results. In contrast to fixed TOU price signal occurring at the same time every day, it is possible that some of the motivating aspect of dTOU is linked to the unpredictability and complexity of the schedule. Many trialists spontaneously reported experiencing an element of fun, challenge or game-like aspects to fitting behaviour around the dynamic high and low rates suggesting that dTOU has greater potential than fixed TOU for subtle gamification.
- **Trialists valued the educational role of dTOU, especially for young household members.** 77% of survey respondents who had young household members to whom this could apply (n=85) agreed or strongly agreed that, “Being on Economy Alert was a valuable experience for the teenagers/young adults in our household to learn about the costs of energy before they leave home and pay bills themselves”.

Survey statements about dynamic-TOU tariff	% Agree or Strongly Agree	% Disagree or Strongly Disagree *
Greater sense of control	71	24
Worth the hassle	67	28
Enjoyed some aspects	55	39
No reduction in quality of life	75	19
Do not find tariff complex	79	16
Effort sustainable long-term	79	15
Good for motivating us to get chores/activities done	80	7
Helped planning/organizing/remembering activities/chores	77	10
Taught young about the cost of energy	71	14
We miss some things about being on dTOU	53	13
Some new practices persisting beyond end of trial	70	30
Reduced overall electricity consumption	63	30
Renewables link would make me more likely to sign up	59	32
Renewables link would make me more likely to adapt behaviour	60	31
Would want to stay on dTOU	77	18
dTOU should be offered to everyone	91	5
dTOU should be the standard tariff for everyone	81	14

Summary of trialists' pro-dTOU attitudes and perceived benefits (n=708)

(* 'No Replies' and 'Neither agree nor disagree' not shown)

2. Explanation of the reasons behind dynamic TOU is required:

- **Ambivalence about unpredictability:** The characteristic of dTOU for supply following that distinguishes it from fixed TOU is that the times of rate changes are unpredictable. It appears a potentially serious issue that having more predictable timing of rate changes was the most commonly endorsed suggestion (from a list of seven) of things that might help their household respond better in the future. 68% reported that they would be more likely to sign-up to dTOU if the rate changes were more predictable. But this must be seen alongside other survey responses – both the predominant wish to remain on dTOU and also more positive interpretations of superficially negative aspects of dTOU such as unpredictability and complexity.
- **Communicating the reasons behind the rate changes will increase engagement.** The schedule of rate changes on the dTOU trial was unpredictable and no clear explanation was provided to trialists for why the rate was higher at some times than at others. In interviews and surveys some trialists reported irritation with the schedule and its lack of transparency and the suspicion that the rate changes were scheduled to benefit the supplier. This is unsurprising in a context of consumer mistrust of suppliers [4]

and scepticism that the benefits of the smart grid will be shared with consumers [2] but the unpredictability of dynamic TOU schedules brings these issues of trust to the fore. A strong piece of learning from the LCL dTOU trial is that consumers are likely to engage more with dTOU 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, and frustration to be expressed in the absence of explanations. If the rate changes are seen as happening at certain times for a good reason (“I just need to know that it's been done for an efficient reason”), then tolerance of the unpredictability, complexity, limited notice period, etc. appears to follow.

- **Efficiency, citizenship and support for renewables all have significant potential to engage consumers in dTOU**, as evidenced by the survey findings in this trial: 60% of survey respondents said they would be more likely to sign-up to dTOU and more motivated to be flexible if there was a link with renewables; almost 70% would be motivated by “helping society use energy more efficiently”. Earlier work on UK households’ attitudes towards energy system change also points to the importance of initiatives being seen as consistent with consumers’ values [5]. Survey responses also indicated that stimulating debate about fairness and efficient usage of resources would be a valuable step towards public acceptance and support for dTOU. This potential for engaging with households on the basis of their “civic relationship with the grid”[6], rather than purely narrow financial interests also has support from qualitative work for the another LCNF project, the Customer-Led Network Revolution.

3. Insights into what helped and limited households respond to rate-changes:

- **Feedback was well-received but improvements possible:** the In-home-display (IHD) was found to be clear and useful for acting on rate-changes but suggestions for improvements were also common. Similarly, the monthly feedback letter was generally well-received but highlights even more the variation in preferences between different households. On-going feedback about financial savings made benchmarked against a flat-rate tariff was not given to trialists and this is considered essential for future trials (as it would undoubtedly be for a real-world commercial dTOU tariff). The most prominent suggestion for improvements to the IHD for dTOU were for it to have a traffic light display for present tariff rate as well as, or instead of, for present load.

- **The use of timers for shifting was limited.** Timer functions/devices were reportedly used by only a small minority of households; even in households who owned appliances with timers, approximately 40% never used that function. Reasons for limited use of timers included their perceived complexity of use and the noise from wet appliances during the night. This suggests more user-friendly design, and improvements in acoustic insulation of appliances and or buildings could support greater use of night-time surplus electricity.

- **Flexibility in who uses appliances is limited:** Although 21% of responding households on the trial reported making changes to who uses appliances in order to better respond to dTOU, approximately 20% of households agreed that having fixed roles for who uses appliances were a limiting factor and the fact that they were not able or willing to adapt these roles is potentially very interesting, both sociologically and from the point of view of increasing demand response (DR) in the future.

4. The reported most/least flexible practices were as expected:

- **Most flexible:** Wet appliances were reported to be the easiest to shift. Lighting, cooking and showering were reported as the hardest to shift, however some shifting of even these was reported.

- **Least flexible:** Interestingly, the supposedly hard-to-shift **cooking practices** are reported to be flexible (more than ‘occasionally’) onto Low-rate for 35–40% of trialists who owned electric oven or hob.

However, further analysis will aim to check if these self-reports corresponds to actual shifting/ consumption behaviour.

5. **Reduction in overall consumption commonly reported but not yet assessed:** Further work is needed to corroborate this with actual consumption data but it is interesting in broadening-out the impact of dTOU beyond load-shifting practices and into a wider interest in greater efficiency, reduction/curtailment. Indeed, it is interesting that using less lighting came out as the most commonly-reported action to take advantage of rate-changes. This is a curtailment/reduction behaviour, not a shifting behaviour, which suggests potential links between dTOU and future take-up of low-energy (LED) lighting and other energy-efficient products and appliances.
6. The **self-reported data seems to be in agreement with the measured DR**, e.g., about which days/times were preferred for alerts but more cross-comparison of measured DR with survey responses will be carried out.
7. **DR on future trials should be greater.** For a number of reasons to do with trial design and the context DR should be greater in the future. These reasons include: the sample excluded some potentially price-sensitive types of households; recruitment was heavily incentivised so likely included households not disposed to dTOU (early adopters of dTOU would be more engaged and responsive); self-reports suggest that the guarantee of reimbursement if worse off may have reduced responsiveness in some households; better engagement and responsiveness are possible with better feedback and advice; the time-limited nature of the trial is likely to have reduced some forms of investment in the trial compared to an open-ended or longer-term commitment to dTOU; assessing the reduction in overall consumption was not possible and this is likely to have reduced the measured DR for high-rate periods; the future context for dTOU is likely to see increases in the value of DR and the technology and norms supporting dTOU engagement.

Recommendations for future dTOU trials and areas for further development

The following recommendations are made for future trials of dTOU tariffs. Some of the following points are discussed above.

1. **Provide a clear rationale and reasons for rate changes.** Clearly explaining the link between the rate changes on supply-following tariffs and renewable energy generation should increase engagement for the majority of trialists. This should also reduce frustration with unpredictability, complexity and the limited notification period. This will require a general increase in consumers' understanding and awareness of the energy system and market and the importance of resource management. Consumers should also feel (justifiably) confident about the fairness of both more cost-reflective pricing and also how the benefits from DR are being shared among stakeholders (consumer, supplier, DNO etc.), as suggested by the respondents and interviewees of this study and previous research [2],[5].
2. **Promote awareness and debate about the energy system.** Given very low levels of consumer awareness about almost all aspect of the energy system and the challenges it faces, promoting education and debate about these challenges, the need for change and more active consumers is highly recommended
3. **Link supply-following tariff to real-world conditions** of renewable generation (or a sample of past renewable generation data) so that the price signals are based on actual variability in renewables and demand. It would also be valuable in terms of trialing the back-office systems necessary to support this. It would be a challenge to add this layer is necessary to take learning towards a real-world, commercially feasible stage of development.

4. **Consider carefully the effect of price points on savings and feedback.** One of the clearest caveats concerns the limits to what should be inferred from the actual financial saving made by households on dTOU. This was largely a function of the competing aims of investigating responsiveness to dTOU and attitudes to it and the needs of recruitment. More detailed analyses of trial data are on-going and should produce some more definite insights but future trials should carefully consider the impact of tariff design and delivery on both the study of responsiveness and studying attitudes to dTOU tariffs. Better savings should lead to more positive, more motivating feedback to consumers.
5. **Participant Recruitment**
 - **Minimize exclusion criteria:** including some of households excluded from the LCL dTOU trial (pre-payment customers, dual fuel and some type of vulnerable customers etc.) is recommended to allow better assessment of the range of distributional impacts especially for price-responsive or early-adopting households.
 - **Minimise effect of incentives on sample and behaviour.** In the LCL dTOU trial participants effectively self-selected to be in the dTOU group and also (by declining) to be in the non-TOU group. The preferred approach to recruitment depends upon the research questions and aims of the trial: if the trial wishes to see the distributive effects for a broad range of different types of households then recruiting a broad sample may be the main challenge and incentives justifiable. Ideally, random allocation of participants to control and TOU groups would be used but as this is often unfeasible, large incentives can also mitigate self-selection. If, however, the main interest lies in the behaviour of early adopters in a context as near to real-world as possible, then incentives should be avoided in so much as they could influence recruitment, behaviour and drop-out rates. There would be some merit in studying early adopters given that dTOU will be opt-in for the foreseeable future. LCL used substantial incentives for recruitment to dTOU. While this helped recruit participants and also made a broader sample possible, minimizing incentives would be preferable due to the buffering effect of incentive payments on price signals and therefore behaviour. Recruitment in future trials should consider the possibility of dispensing with, or at least minimizing, incentives and guarantees. Dropping out of the trial would need to be possible, and uninfluenced by payments, in order to study churn rates, which was not possible on the LCL trial. As dTOU becomes less of a novelty, the need for incentives and guarantees should diminish.
 - **Recruit directly onto dTOU trial.** In the LCL trial households were first recruited for smart meter installation and then dTOU trialists were recruited from this pool of households. As the smart meter rollout progresses it will be unnecessary to recruit in two phases and this will be more cost-effective, reduce self-selection issues (at least for the control group).
6. **Obtain baseline consumption data to assess overall reduction.** The period for obtaining baseline data for households was severely reduced in the LCL dTOU trial: ensuring a substantial period for baseline data is available should become much easier as the number of smart meters installed grows. Recruitment could be targeted at households for which 12 months of smart meter data is already available.
7. **Make the trial open-ended.** While this may be difficult in practice, a trial which does not have a predetermined end-date would be preferable as some participants indicated that they may have made some investments of effort or money to better respond to rate changes if the trial had not been a temporary situation. For example, investment in the up-front cost for LED lighting, or when replacing an appliance purchasing a more expensive model with a timer function; in non-financial terms, trialist may confront household members who are not cooperating with the rate changes.
8. **Improve feedback.** Throughout the trial period participants should receive monthly feedback on their savings benchmarked against both previous consumption (to reflect savings from reduction) and relative to a standard flat-rate. As this was lacking in the LCL dTOU trial it would be interesting to assess the

impact this feedback has on motivation and engagement. Improvements to the IHD would also be ideal such as a traffic light indication of current tariff rate. If possible, disaggregated feedback on relative consumption of appliances would be ideal but as this is challenging, written advice on the relative costs of running different appliances would be a worthwhile alternative. Further improvement to feedback for dTOU mentioned by trialists would be to have feedback available online and via smart phones. Comparative feedback –where households can see how their efforts compare to similar households in their area – would be another valuable form of feedback for dTOU. Studying preferences for different forms of feedback would be a worthwhile avenue for future research.

9. **Include advice on load-shifting and reduction.** Given dTOU trialists written advice suggesting ways of achieving DR would also enhance the trial. Information on the relative consumption of appliances would also be of interest and value to many consumers.
10. **Household dynamics:** Future work could also aim to explore whether dTOU might play a role in the possible loosening of fixed roles within the household governing who uses appliances and the potential to increase responsiveness accordingly.

Glossary

Acronym/Term	Full Form	Definition
3G	Third generation	Common term used to describe the forthcoming smart meter technology.
ACORN	A Classification Of Residential Neighbourhoods (CACI Ltd)	Geo-demographic segmentation system similar to MOSAIC and commonly used for planning and marketing.
CLNR	Customer Led Network Revolution	An LCNF funded programme.
Cost-reflective pricing		Electricity pricing that reflects the cost of producing it.
DCC	Data and Communications Company	Organisation responsible for transfer of data between smart meter and other organisations.
DNO	Distribution Network Operator	
DR	Demand response	Changes in electricity usage by end-use customers from their normal consumption patterns in response to incentive payments or price changes.
DSR	Demand side response	For the purposes of this report DR and DSR are synonymous.
dTOU	dynamic Time-of-Use	Distinct from traditional time of use tariffs which typically have a fixed daily cost profile.
EDF Energy	Electricite de France Energy	The retail arm of EDF Energy.
IHD	In-Home Display	Stand-alone display placed in home, showing present electricity rate and other information.
L+G	Landis and Gyr	The suppliers of smart meters for the SM trial.
LCL	Low Carbon London	An LCNF funded programme.
LCNF	Low Carbon Network Fund	An Ofgem scheme intended to promote innovation in DNO activities.
LCZ	Low Carbon Zone	An area of London targeted for energy efficiency by the Mayor's office.
LPN	London power distribution network	The distribution network covering the majority of London's electricity supply.
ODS	Operational Data Store	The central repository for all measurement data in the LCL programme.
Continued...		

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Acronym/Term	Full Form	Definition
PMS	Participant Management System	A database containing information about trial participants.
SM	Smart Meter	Meter recording electricity consumption, usually in intervals of half an hour and sending this information back to the utility for monitoring or billing
Smart Grid		A Smart grid is an electricity network that can intelligently integrate the actions of all the users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies.
Smart Tariffs		dynamic/TOU/time-varying pricing which is only possible with smart meters
SMETS	Smart meter equipment technical specification	UK government specification providing a standardised and consistent definition of the functional requirements for smart metering equipment in UK distribution networks
TOU	Time of Use	Often used to refer to fixed time-of-use so TVP (see below) is preferred term
Static/Fixed TOU		TOU with fixed daily cost profile
TVP	Time Varying Pricing	Generic term for Time-varying/TOU/dynamic pricing

1 Introduction

- Aims and scope of document
- UK context: the balancing challenge and DSR
- UK electricity consumer attitudes
- Dynamic pricing trials and research gaps

1.1 Low Carbon London

The LCL programme is a technology demonstrator financed by the customer via the Low Carbon Network Fund (LCNF), administered by the Office of Gas and Electricity Markets (Ofgem). As part of this programme, a residential dTOU tariff was trialled with the aim of measuring consumer's willingness to engage with dynamic electricity pricing. This residential trial was conducted by a partnership of industry stakeholders organisations and academia. Key partners in the design and implementation of this trial included:

- Imperial College, London (ICL): Report author and programme academic partner.
- UK Power Networks: The London distribution network operator (DNO) and project coordinator
- EDF Energy: Retail energy supplier
- Siemens: Information and communication technology (ICT) framework
- CGI: Smart meter head end set-up and management

1.2 Aims and scope of document

This report describes the results of the Low Carbon London (LCL), residential, dynamic time-of-use (dTOU) tariff trial. Trial design and implementation are described.

This report is in many ways a complement to its companion LCL dTOU trial report, A3, *Residential consumer responsiveness to time-varying pricing* [8]. The latter reports on responsiveness to the price signals by analysis of consumption data from smart meters which reflect actual consumption. This report, A2, addresses the experiences of, and attitudes towards, dTOU of the households on the trial.

In some ways the separation of the two is an artificial one, as behaviour and attitudes (or the meter data and the households) are intertwined. 'Engagement' spans behaviour/practices, attitudes, understandings and what goes on within the household. Smart meter data tell us how much electricity is going into the home but does not (at least at present) say exactly how it is being used. This report aims to add some understanding to the 'black box' of the home by looking in more detail at how responsiveness is achieved, how it is experienced and its limits. In doing so it relies heavily on trialists' self-reports from interviews and surveys.

Lastly, one hope for the LCNF trials are that, "the results from the trials feed into both on-going trial design and, ultimately, into policy development." [7]. Recommendations based on trial findings will be made for future trials and research.

Caveats and limitations of scope

There is also no obvious or clearly demarcated limit to the remit of attitudes to time-varying pricing and there are a great many intersecting topics and perspectives. As well as covering consumers' attitudes to: being flexible, saving money, suppliers, the tariff design and trial experience, many other topics are closely related: attitudes to renewable energy, cost of living, attitudes to smart meters, attitudes to climate change,

perceived responsibility for climate change mitigation, media coverage, policy acceptance, ... Most of these areas will not figure in this report – partly by necessity and partly because they were not mentioned by participants in the survey and interviews. This report is focussed on attitudes to time-varying pricing and shifting, not smart meters per se, or energy conservation per se, or fixed time-of-use tariffs, for each of which there are large bodies of existing work.

Attitudes to time-varying pricing potentially involves attitudes to many related topics and debates about which the public are not yet well aware (fairness of various pricing schemes, smart meters, data privacy, trust in suppliers). This too makes the data collection and the conclusions from the trial bound by its present, though evolving, context.

A third caveat to the scope and findings of the report is a tension between an aim to explore UK consumer attitudes to time-varying pricing in a general sense, and the practical constraints of studying the trialists' attitudes to the specific dynamic time-of-use tariff used in the LCL dTOU trial and the way in which it was delivered. This emerges most starkly perhaps in relation to trial findings about financial savings which are affected by an extra tension and resulting compromise between the aims of the trial to study trialists' response to dTOU and to study their attitudes to it at the same time.

1.3 UK energy context: the balancing challenge and DSR

For a wider discussion of demand response and previous trials, see LCL Report A3 [8]

The balancing challenge

The UK is facing a hugely challenging commonly-cited 'trilemma' of how to attain secure, affordable and sustainable supplies of energy and how to efficiently manage an aging distribution network.

In order to increase lower carbon energy sources, the UK has a target of 15% of energy supply from renewable sources by 2020 [1]. This means that, according to the UK Renewable Energy Roadmap, more than 30% of UK electricity demand will be met by renewable generation by this date, largely through greatly increasing installed wind capacity. The increase in wind power capacity is both obligated and is actually increasing: 2.7 GW of new wind power capacity was brought online during 2013, a 35% increase of the total UK installed capacity. By mid-2013, the installed capacity of wind power in the United Kingdom was over 10GW and the UK is ranked as the world's eighth largest producer of wind power. Wind power is expected to continue growing in the UK for the foreseeable future, RenewableUK estimates that more than 2 GW of capacity will be deployed per year for the next five years. UK currently has approximately 6% of our energy needs met by renewables – still a long way from the official target of producing 15% of our energy from renewable sources by 2020.

However, matching the residential electricity demand characterised by static peaks to the variable and irregular supply of wind power is a major challenge. In addition there is a huge economic value to reducing and delaying costly investments to reinforce the aging UK distribution network and this may be achieved by managing demand within the limits of network constraints. The planned move towards more electrification of heat and transport will further complicate these balancing challenges.

Demand side response (DSR) and dynamic tariffs

A key way to achieve these goals of balancing demand with the limits of supply and the network will be price signals through innovative tariffs aimed at making consumers more active and involved in a smarter grid.

Whilst network constraints are to some extent predictable the unpredictable nature of renewables such as wind and solar will require time-of-use tariffs that are based on dynamic rather than static pricing if they are to support the integration of more of these energy sources into the grid.

The scheduled rollout of smart meters to all UK households by the end of 2020 potentially opens the door to smart tariffs and dynamic electricity pricing. Dynamic pricing is cost-reflective pricing and comes in several forms including:

- Fixed Time-of-use rates (TOU)
- Critical-peak pricing (CPP)
- Peak-time rebates (PTR)
- Variable-peak pricing (VPP)
- Real-time pricing (RTP)

Terminology can vary especially between USA and Europe and the above ‘flavours’ of dynamic pricing can be combined to yield hybrid tariffs (the LCL dTOU tariff, it will be seen is one such hybrid).

The UK regulator, Ofgem, supports DSR and dynamic tariffs and has retained scope for them in their recently mandated simplification of tariffs:

“Creating a more dynamic market, in which consumers participate more actively through DSR, is a fundamental element of our vision for smarter energy markets. This will become more important with an increasingly inflexible and intermittent generation mix and the need for distribution networks to cope with the additional load imposed by electric vehicles and heat pumps as part of a move to a low-carbon energy system.” [9]).

However, adoption of DSM by utilities has been slow. Reasons for the relatively slow uptake of DSM include, “a lack of metering, information and communication infrastructure, lack of understanding of the benefits of DSM, problems with the competitiveness of DSM when compared with traditional approaches, an increase in the complexity of system operation and inappropriate market incentives.”, [10].

Common myths remain about dynamic pricing, identified by Faruqui, [11] and [12], as follows, all of which are contrary to the evidence:

1. Customers have never encountered or heard of dynamic pricing
2. Customers don’t respond to dynamic pricing
3. Electricity is a necessity and consumers won’t respond
4. Customer response does not persist over time
5. Enabling technologies do not help much
6. Current electricity prices are too low or prices are too high
7. Dynamic pricing will harm low income consumers
8. Customers don't want dynamic pricing

Benefits to consumers of dynamic pricing

Flat-rate pricing does not signal to consumers when electricity is expensive to consume and so results in higher prices for everyone and some households effectively subsidising other households. In contrast, DSR can lower bills for those who shift load. DSR can also improve the overall operation of the electricity system

for all consumers, helping to reduce bills for all, as well as strengthening security of supply (by providing spare capacity) and promoting sustainability through 'wind-following'. There is presently very low awareness of these issues around cost-reflective pricing and DSR among UK consumers. There is instead an 'assumption of fairness in today's tariffs'[13].

Concerning the distributional impacts of dynamic pricing on households and the assumption that it will hurt low-income households, Owen and Ward [14] suggest that many low income and vulnerable households could benefit from TOU electricity tariffs but those with on-peak electric heating may be the main group who could be disadvantaged. Something like 2% of households have electric heating without storage but these numbers could rise if use of heat-pumps rises. This conclusion however applies to fixed TOU rather than dTOU for supply-following. Findings from the recent Customer-Led Network Revolution trials of static TOU indicate that wealthier demographics appear to be those benefitting most from the cross-subsidies under the current flat-rate tariffs [15].

1.4 UK electricity consumer attitudes

One reason for the slow exploration of dynamic pricing despite the potential benefits may be the lack of evidence about consumers attitudes and acceptance which may be required for decision-making. Replacing supposition about what consumers want with evidence requires UK consumers to have first-hand experience of dynamic TOU tariffs but a brief overview of the context of UK consumers attitudes to the energy market generally provides a useful background.

Dissatisfied and disengaged consumers.

Concern about energy costs are a recurring and prominent concern for UK households even though energy costs in many other European states are higher than the UK (and as a proportion of income also). This is in large part due to the fact that UK energy retail prices have risen 138% since 2003 (NEA) and the high profile coverage of this in the media. The lower-than-average retail cost of energy in the UK is made up of higher-than-average generation costs but lower taxes. Due to this, scope for price point movement is higher in the UK than most other EU countries.

A 2012 study, [4], highlighted cynical attitudes towards energy companies and complex tariff structures. The history of large increases in energy prices despite large and increased profits by utilities, tariff complexity, miss-selling scandals plus a cost of living crisis have all undoubtedly contributed to this. However only a small minority of consumers compare prices and switch suppliers –largely due to the perceived difficulty of comparing tariffs or the belief other Big Six competitors price changes.

The UK regulator, Ofgem, accept that consumers are passive, disengaged, unhappy and distrustful of the 'Big Six' energy suppliers. Ofgem's Retail Market Review and Smarter Markets Programme aim to ensure 'simpler, clearer, fairer' billing and tariffs, greater competition in energy markets and better protection for consumers. DSR is a priority area in these changes as it supports the aims of:

- creating value for money
- promoting security of supply
- promoting sustainability
- improving consumer trust and energy literacy is also part of this programme [16].

The issue of tariff complexity is highly relevant to TOU tariffs, especially dynamic TOU, under which calculating expected expenditure, and comparison with other tariffs would be more complex. Ofgem's

market reforms have retained scope for TOU tariffs but it remains to be seen if suppliers will offer them once the smart meter rollout is underway.

Attitudes to smart meters

A 2013 study by O2 into UK public attitudes to smart meters [17] reported low consumer awareness and understanding of smart meters and highlighted data security/privacy (59 percent), accuracy of billing (32 percent) and the installation process (28 percent) as the most important concerns. Visibility and control of energy use and an end to estimated bills were seen as key benefits but scepticism over cost savings existed.

In contrast to media coverage and, to some degree with the O2 study, a 2013 Ipsos MORI study[18], found that the public are not seriously concerned about privacy, though there is some suspicion that benefits of smart meters will go to suppliers not customers who will end up paying for them. According to this study, the main reasons why some respondents were interested in having a smart meter, “related to budgeting (51%), avoiding waste (41%), and greater accuracy in billing (24%). A ‘general lack of interest’ (41%) was the main reason given by those who said they were less interested in having a smart meter installed, followed by the inconvenience of the installation (20%), a lack of knowledge (10%) and the cost of smart meters – either to themselves, the taxpayers, the Government or the energy companies (9%). Higher levels of perceived knowledge of smart meters appeared to be related to increased support and interest.” [18].

Certainly, there is very low awareness of the potential of smart meters to make possible new kinds of smart tariffs.

Attitudes to smart tariffs

UK households’ first-hand experience with time-varying pricing is limited to *fixed* time-of-use tariffs (Economy7 or Economy10 or similar tariffs) which give cheaper night-time rates predominantly (but not exclusively) for households with overnight storage heaters. UK consumer have had no experience with dynamic TOU, only static TOU but a 2012 study shows that there are issues of awareness: with households being on TOU inappropriately or not getting the best out of it.

- The study identifies 13% of domestic electricity bill payers as users of TOU tariffs, primarily Economy7 (66%) and Economy10 (10%)
- Only 50% of TOU tariff users deliberately run appliances, other than water and space heating systems, at off peak periods to save money
- Only 50% of TOU tariff users deliberately run appliances, other than water and space heating systems, at off peak periods to save money.
- Of all TOU tariff users, 38% have no storage heating and do not use any appliances at off peak rates, meaning they get no real benefit from the tariff they are on - indeed they are likely to be paying more for their electricity annually as a result.
- Just over half of TOU tariff users believe additional information or advice would help them make better use of their tariff and heating system. Information on the times it is cheaper to use electricity is likely to be most helpful[19].

The potential of smart meters to support new types of smart tariffs is not yet being effectively communicated and there is undoubtedly very low awareness of socialised costs built into current flat-rate electricity tariffs.

Energy literacy: Indeed awareness is also very low regarding the breakdown of the household utility bill into the components of their total bill and the associated stakeholders in the value chain (and the challenges they face). For example, although a portion of a household's electricity bill goes to the DNO they have no direct relationship with, or awareness of, this company except perhaps if there is a fault. Also currently lacking is a knowledge of how much individual appliances (freezer, TV, electric oven etc.) contribute to the household bill although this would potentially be useful information for households on time-varying pricing. This context of a very low level of awareness of almost all aspects of energy is a fundamentally important backdrop for looking at consumers' attitudes to time-varying pricing.

Public acceptance of energy system changes

A UKERC Report on "Transforming the UK energy system – public values, attitudes and acceptability"[5], highlighted key factors that influence public assessment of proposed changes. Findings drew on deliberative workshops and a nationally representative survey of 2,441 members of the public and major findings include:

- People in Britain are fully supportive of the idea of energy system change.
- Neither energy companies nor Government were trusted.
- In the national survey 74% of participants were very or fairly concerned about climate change, while 82% were worried about the UK becoming too dependent upon energy from other countries.
- Support for solar (85%) and wind energy (75%) remained very strong
- 81% of respondents want to reduce their energy use.
- 79% of respondents believe the UK should reduce its use of fossil fuels.
- 83% of respondents are fairly or very concerned that in the next 10-20 years electricity and gas will become unaffordable for them.
- 1/3 of the 73% of respondents that agreed Britain needs to reduce the amount of energy it uses thought that a lot of energy is currently being 'wasted', 'used unnecessarily' and 'taken for granted'.
- people are more likely to accept changes that show signs of commitment to their underlying values, such as energy system components that are clean, efficient, fair and safe.
- The public is also keen for policy makers to clarify how current changes to the energy system fit with longer-term plans, and to develop an intelligible and coherent strategy for this".

1.5 Dynamic pricing trials and research gaps

(For a more systematic review of trials of dynamic pricing of electricity see LCL Report A3 [8])

A number of meta-analyses ([20], [21], [3]) collating findings from many dynamic pricing trials indicate that economic incentives are effective in changing consumer behaviour. Results have been highly varied across trials and the reduction in total energy consumption is typically small compared to the effect on peak demand.

The Energy Demand Research Project (EDRP) results show an approximate 4% reduction in weekday peak consumption for consumers with in home display – though significance was low due to the small number of participants. The much larger Ireland Electricity Smart Metering Trials (IESMT) showed a 7-12% reduction in peak demand. Results from North American trials show similarly large variations.

In general this was positive with over 80% of trialists on nearly all trials responding positively [22]. This, however, is likely to be strongly related to the fact that nearly all trials were designed to be revenue neutral if the average consumer did not change their profile. In this situation, people who respond appropriately to price signals, even minutely, are guaranteed to make a net saving from their previous tariff. Suffice to say, most consumers across these trials saved money. The IESMT found that households with children under the age of 15 were more responsive to their TOU tariff by 10.7% compared to 6.5%. A recent UK trial of static time-of-use energy tariffs, as part of The Customer-Led Network Revolution project, produced some very positive results. Peak-time and overall electricity use was reduced compared to control groups (by 10 and 3 per cent respectively) and the vast majority of participants were keen to use multi-rate tariffs in the future.

Most time-of-use pricing trials have, however, investigated *static* TOU to reduce fixed peaks in demand; the lack of predictable patterns in a dynamic tariff for wind-following is a potentially important difference for consumers. Such dynamic TOU tariffs have yet to be offered or trialled in the UK and debate and controversy over consumers' appetite for the perceived complexities, risks and fairness remain. The UK context for electricity demand and dynamic pricing also differs to that of less temperate North America where most dynamic pricing trials have been conducted. A trial of dynamic not fixed TOU, carried out in the UK is required. Such a trial, of appropriate size, using an experimental approach and including qualitative work could begin to understand these remaining questions about UK consumers' response to unpredictable price signals, what goes on inside the home, and potential barriers to increased flexibility.

Some key research questions for the LCL dynamic time-of-use (dTOU) trial include:

- How would UK households respond to price signals at unpredictable times?
- How does the unpredictability of dynamic TOU affect engagement and the consumer experience?
- Would UK households be motivated by the idea of a wind-following tariff?
- What are the challenges for such tariffs and how can engagement be maximised?
- What attitudes, behaviours and household dynamics are associated with flexibility?
- Which appliances/behaviours do UK households find most and least flexible for load-shifting?
- What times of day/week are best/worst for load-shifting?
- How is flexibility achieved within the household?
- What are UK households' preferences for tariff design, notifications, feedback etc.?
- What are UK consumer expectations about savings?
- Are there any unexpected benefits or other effects of the dTOU tariff?

2 Trial design and delivery

This section will cover two areas:

- Recruitment and sample
- Trialist experience

2.1 Recruitment and sample

- Smart meter installations
- dTOU group recruitment
- Final sample obtained

Recruitment of the dTOU group was done from the population available to the project: EDF Energy customers in the London Power Networks (LPN) area. The LPN area is largely but not fully geographically contiguous to the London area: there are a few Greater London postcodes which fall outside of LPN area and vice-versa. Recruitment for the LCL dTOU trial was effectively in two stages: recruitment and installation of smart meters into households (the orange circle in Figure 2.1 below). Recruitment of households onto the dTOU trial (the white circle) was then carried out from this pool of over 5,500 households with smart meters.

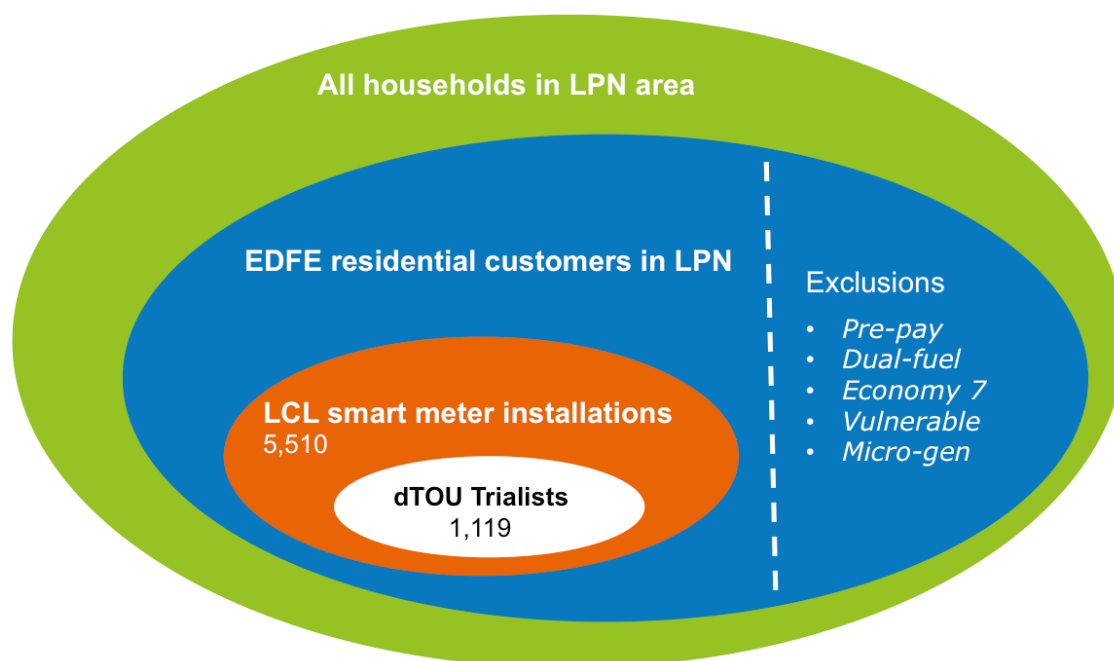


Figure 2.1 Summary of smart meter and dTOU samples

2.1.1 Smart meter installations recruitment

For a more detailed account of smart meter recruitment and installation see LCL Report C5 [23]

The smart meter installed was Landis and Gyr (L+G) E470 (see Figure 2.2).



Figure 2.2: the Landis and Gyr E470 with in-home display.

Recruitment methods

Recruitment was opt-in recruitment and households were able to leave the trial at any time. The contact methods EDF Energy used for recruiting customers for smart meter installation were: local events held in community centres; a mail-shot to all customers; phone calls made by a call centre.

The main message used for recruitment was, “An end to estimated billing”.

Target sample size and area

- Maximum of 6500 smart meter installations
- Geographic area for meter installations: EDF Energy residential customers within the London distribution network administration area (LPN) only (principally because of the availability of UK Power Networks network data within this area)

The number of smart meters deployed was determined by a range of factors, including: regulatory constraints; EDF Energy’s wider smart metering activities/plans; costs; and a desire for statistically valid results from the planned residential dynamic time-of-use trials. The original project bid had proposed smart meter numbers of 5,000 and this was the preliminary target for recruitment.

It was calculated that the programme required 1,521 participants for the dTOU trial in order to generate sufficient data for robust statistical analyses, and EDF Energy had conducted a survey which suggested dTOU take-up would be in the region of 20%.

The LPN area is largely contiguous with Greater London with some differences –each include some postcode areas that the other does not have (see Figure 2.3 and Figure 2.4 below).

A map of London divided into various boroughs, color-coded into five regions. The regions are: Blue (North London), Green (West London), Red (Central London), Yellow (South London), and Orange (East London). The map shows the following boroughs and their corresponding regions:

- Blue (North London):** E4, E17, E18, E19, E20, E21, E22, E23, E24, E25, E26, E27, E28, E29, E30, E31, E32, E33, E34, E35, E36, E37, E38, E39, E40, E41, E42, E43, E44, E45, E46, E47, E48, E49, E50, E51, E52, E53, E54, E55, E56, E57, E58, E59, E60, E61, E62, E63, E64, E65, E66, E67, E68, E69, E70, E71, E72, E73, E74, E75, E76, E77, E78, E79, E80, E81, E82, E83, E84, E85, E86, E87, E88, E89, E90, E91, E92, E93, E94, E95, E96, E97, E98, E99, E100.
- Green (West London):** W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W16, W17, W18, W19, W20, W21, W22, W23, W24, W25, W26, W27, W28, W29, W30, W31, W32, W33, W34, W35, W36, W37, W38, W39, W40, W41, W42, W43, W44, W45, W46, W47, W48, W49, W50, W51, W52, W53, W54, W55, W56, W57, W58, W59, W60, W61, W62, W63, W64, W65, W66, W67, W68, W69, W70, W71, W72, W73, W74, W75, W76, W77, W78, W79, W80, W81, W82, W83, W84, W85, W86, W87, W88, W89, W90, W91, W92, W93, W94, W95, W96, W97, W98, W99, W100.
- Red (Central London):** EC1, EC2, EC3, EC4, EC5, EC6, EC7, EC8, EC9, EC10, EC11, EC12, EC13, EC14, EC15, EC16, EC17, EC18, EC19, EC20, EC21, EC22, EC23, EC24, EC25, EC26, EC27, EC28, EC29, EC30, EC31, EC32, EC33, EC34, EC35, EC36, EC37, EC38, EC39, EC40, EC41, EC42, EC43, EC44, EC45, EC46, EC47, EC48, EC49, EC50, EC51, EC52, EC53, EC54, EC55, EC56, EC57, EC58, EC59, EC60, EC61, EC62, EC63, EC64, EC65, EC66, EC67, EC68, EC69, EC70, EC71, EC72, EC73, EC74, EC75, EC76, EC77, EC78, EC79, EC80, EC81, EC82, EC83, EC84, EC85, EC86, EC87, EC88, EC89, EC90, EC91, EC92, EC93, EC94, EC95, EC96, EC97, EC98, EC99, EC100.
- Yellow (South London):** S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, S31, S32, S33, S34, S35, S36, S37, S38, S39, S40, S41, S42, S43, S44, S45, S46, S47, S48, S49, S50, S51, S52, S53, S54, S55, S56, S57, S58, S59, S60, S61, S62, S63, S64, S65, S66, S67, S68, S69, S70, S71, S72, S73, S74, S75, S76, S77, S78, S79, S80, S81, S82, S83, S84, S85, S86, S87, S88, S89, S90, S91, S92, S93, S94, S95, S96, S97, S98, S99, S100.
- Orange (East London):** E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E21, E22, E23, E24, E25, E26, E27, E28, E29, E30, E31, E32, E33, E34, E35, E36, E37, E38, E39, E40, E41, E42, E43, E44, E45, E46, E47, E48, E49, E50, E51, E52, E53, E54, E55, E56, E57, E58, E59, E60, E61, E62, E63, E64, E65, E66, E67, E68, E69, E70, E71, E72, E73, E74, E75, E76, E77, E78, E79, E80, E81, E82, E83, E84, E85, E86, E87, E88, E89, E90, E91, E92, E93, E94, E95, E96, E97, E98, E99, E100.

Figure 2.3: LPN postcode district map
(Source: UK Power Networks)

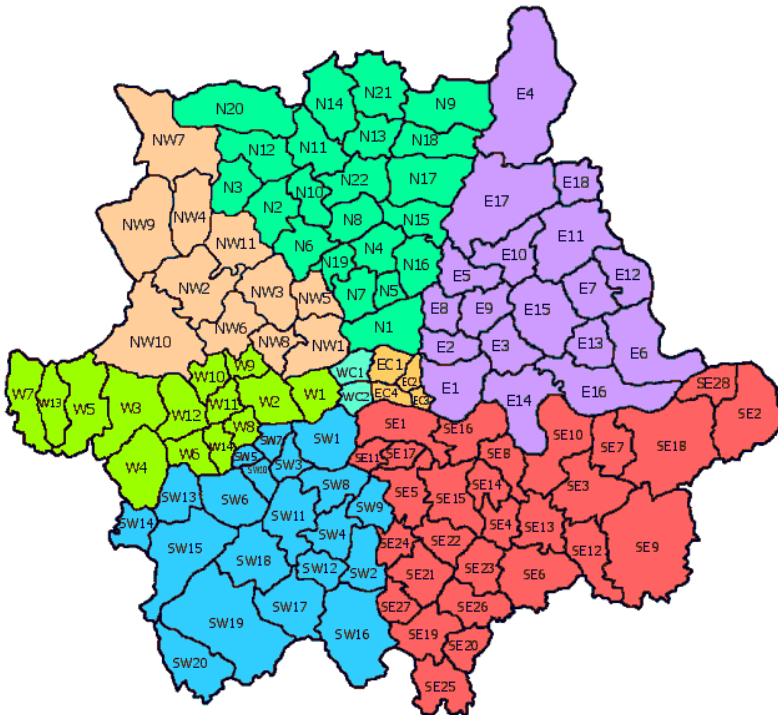


Figure 2.4: Greater London postcode district map

Self-selection but stratified sampling

The goal was to get a sample that was representative of households in the LPN area recruited only from EDF Energy customers. The households recruited for smart meter installation would be the pool from which households would subsequently be recruited to participate in a residential dynamic time-of-use trial. A large

and varied sample at the stage of the smart meter installations was a necessary prerequisite for recruiting a representative sample for the dTOU trial. A large and varied sample of households was also necessary to provide a useful control group (or comparison group) for between-groups analyses with the dTOU trial group. Recruitment of EDF Energy customers for smart meter installation had to be done on a voluntary, opt-in basis and this meant there was the potential for biases in the sample arising from take-up rates being higher or lower for different types of households.

A stratified sampling approach was employed in order to achieve the desired sample to overcome any differences between EDF Energy households vs all LPN households, and to attempt to partly mitigate some biases arising from self-selection (recruits versus EDF Energy households in LPN). Examining ACORN data revealed that among the EDF Energy customers in LPN there were relatively more Educated Urbanites and fewer Secure Families and Asian Communities compared to all LPN households. Targets were set for each of the 17 ACORN groups (from A– *Wealthy Executives*, to Q– *Inner City Adversity*) and recruitment aimed to hit these individual targets whatever their respective take-up rates were.¹ One other stipulation for the sampling criteria was that the recruitment be spread out over as wide an area of LPN as possible.

2.1.2 Exclusion criteria

Besides the need for a representative sample in demographic terms, a range of exclusion criteria influenced the smart meter sample makeup. Two of the most significant exclusions, in size and potential impact on findings, were households with pre-payment meters and those with dual fuel (buying both electricity and gas from EDF Energy). Total number of EDF Energy households in LPN was 911,000. The most notable exclusion criteria are listed below:

- Pre-pay households (196,599 households excluded in LPN)
- Dual-fuel households (49,085 households excluded in LPN)
- Economy 7
- Vulnerable households
- Micro-gen households

Further exclusions were made when installations were aborted due to poor communications performance with the smart meter (from IHD and or the mobile network).

Pre-payment customers: These households were excluded because no smart meter with a pre-payment facility compatible with existing infra-structure was available at the time of recruitment.

Dual Fuel (DF): The rationale for not including DF customers was that EDF Energy did not want customers to have a customer experience with gas that was different to their experience with electricity. Installing smart gas meters, and a more complex refund process, was not feasible within the timescales of the project. In order to understand the significance of this exclusion we ideally need to understand how DF customers differ from other LPN customers and how prevalent they are. Approximately 5.4% of the EDF Energy customers in LPN were dual fuel. We do not have sufficient data to evaluate how Dual Fuel customers tend to differ, if at all, from non-DF customers but they may be more price consciousness/price-sensitive.

¹ Initially, it was hoped to have a stratified sampling approach to recruitment which also controlled for electricity consumption (which would be related to household size). Like ACORN groups, consumption levels would be pre-existing data available, in principle, to use to help plan and direct recruitment. It was decided, however, that this would make the recruitment process too complicated in practice and so it was hoped that a good, near-random spread of electricity consumption and household size would be achieved while stratifying by ACORN group only.

Micro-generation: Whilst micro-generation is becoming widespread in some areas, particularly in response to incentives for micro-generation, to include these customers would have required a separate experimental group. This is because, clearly, micro-generation affects net demand profiles, but also micro-generation is known to affect energy use behaviour.

In some instances customers were recruited that were supposed to be excluded and they were excluded from analysis at a data-cleaning stage.

2.1.3 Recruitment for dTOU trial

Recruitment process

- The initial customer engagement/awareness period for the TOU Tariff involved email and direct mail
- Customers were able to register their interest for the TOU trial using an Online Web Form on edfenergy.com
- recruitment was carried out by phone from the EDF Energy call-centre
- Recruitment was opt-in and trialists were able to leave at any time
- Recruitment was incentivized, for sign-up to stay for the full trial period
- recruitment within LPN area

dTOU Customer recruitment materials: 'Economy Alert'

- The EDF Energy dTOU tariff was named 'Economy Alert' (see Figure 2.5
- The main recruitment message during recruitment used was *"Control how much you save"*

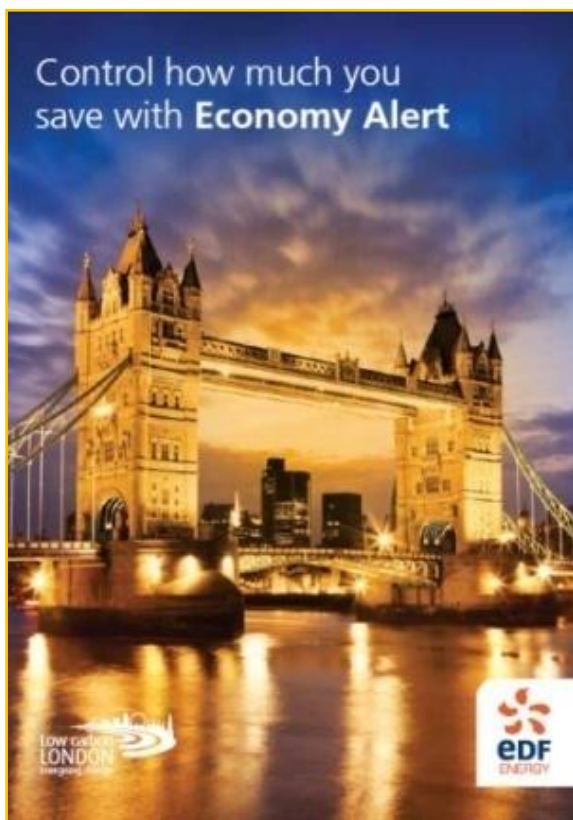


Figure 2.5: Economy Alert brochure

The following incentives were used for Economy Alert

- £100 for signing up to Econ Alert
- + £50 if stay on Econ Alert to end of trial
- Economy Alert also had lower Normal rate lower than EDF Energy's Standard Variable flat rate tariff so this was another incentive which made recruiting trialists easier (see tariff design section)
- Trialists were also given a guarantee that they would be reimbursed at the end of trial if they were financially worse off on Economy Alert than they would have been on their previous tariff based on actual consumption
- Trialists were also given assurances about how many hours would be charged at High-rate

Selection criteria

In addition to the criteria for smart meter installations in order to be offered the dTOU tariff, customers had to meet a number of conditions:

- Have installed smart meter as part of LCL
- Have had their smart meter installed more than 1 month before the dTOU trial start
- Have an IHD installed and working.
- Not have debt or any special conditions associated with their account.
- Not have plans to move home within the first 6 months of the trial.
- They must also have completed the Household & Appliance Survey (see later section on surveys under Data Collection).

2.1.4 Final sample

Trial period	• Jan–Dec 2013
Recruitment	• From 5,533 smart meter households • Mailshot + phone call • Exclusions (e.g., prepay, dual fuel, Economy 7) Recruitment Messages: • Smart meter: "An end to estimated billing" • dTOU Tariff: "Control how much you save" • Incentivised (lower Normal rate + cash + guarantee) • No more than 5% of hours at High rate
dTOU Sample	• 1,119 households • Representative of LPN area demographics (ACORN) • 6.7% attrition

Table 2.1: dTOU recruitment summary

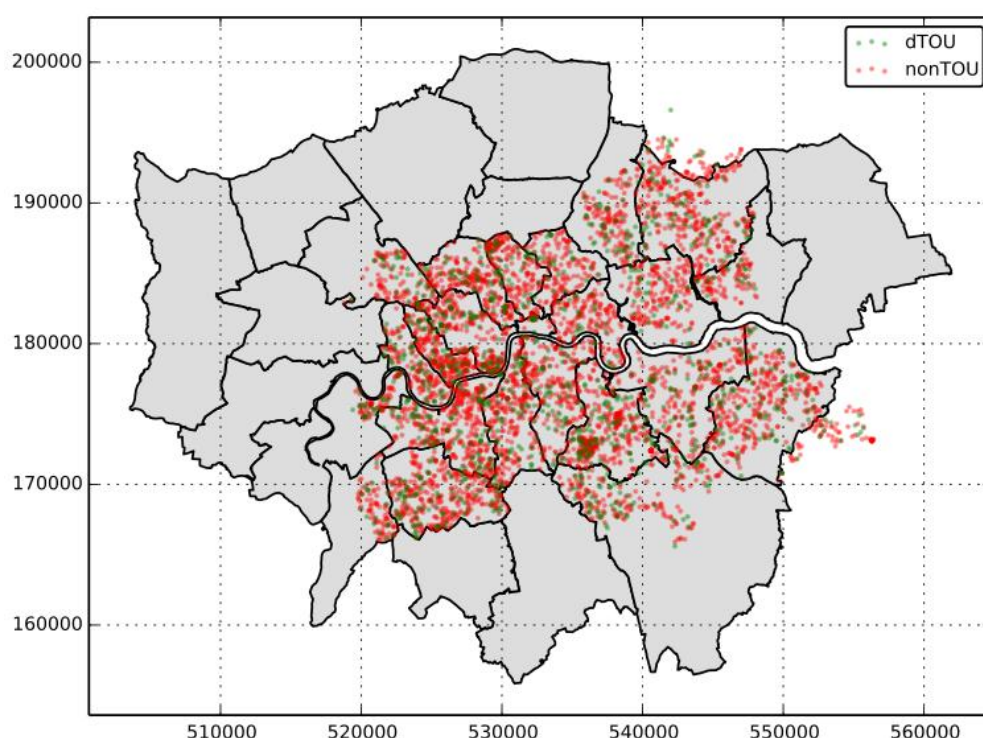


Figure 2.6: Map of LCL smart meter installation (non-TOU & dTOU) and recruited dTOU trialists (dTOU)

Figure 2.6, above, shows the geographical spread of the smart meter installations (both dTOU trialists and the remaining households forming the non-TOU group).

Attrition rate

In the UK electricity market, which enables competition between suppliers, customers can change supplier. In the case of homes within the LCL trial, if a householder chose to switch supplier their smart meter data would remain in situ but the data from it would no longer be visible to EDF Energy. Similarly if someone moves house the meter data is no longer valid because the right for the project to use the data is connected to the householder's agreement opt-in. Some loss of trial participants was expected and was factored into the calculation of the required number of installed meters.

The rate of attrition for the LCL smart meter group was a fairly steady rate of roughly 8% per annum. The final sample size for smart meter trial participants by the close of 2013 is shown in Table 2.1, below.

Attrition for the dTOU group was lower, though this may be explained by the incentive they were given to stay on the trial until the end. Ultimately, the offering of incentives to join and stay on the dTOU trial until the end was valuable in order to get a full year of data but did mean that the trial could not study take-up rates or those for drop-out/churn.

	nonTOU	dTOU	Total
Beginning of trial	4,414	1,119	5,533
End of trial	4,068	1,044	5,111
Attrition rate	7.8%	6.7%	7.6%

Table 2.2: Trial group population numbers and attrition rates

Representativeness of sample

ACORN: The final sample obtained for the dTOU trial matched the make-up of LPN closely on the 17 ACORN Groups used for stratified sampling except for Groups B (Affluent Greys), N (Struggling Families) and Q (Inner City Adversity) – both the ACORN Category Hard Pressed- which were approximately 30-40% under represented compared to LPN levels. In the case of Group B this is such a small group in LPN that it would not have much impact. Group L (Post-Industrial Families) were over-represented by approximately one third but all other groups did not deviate from their prevalence among LPN households.

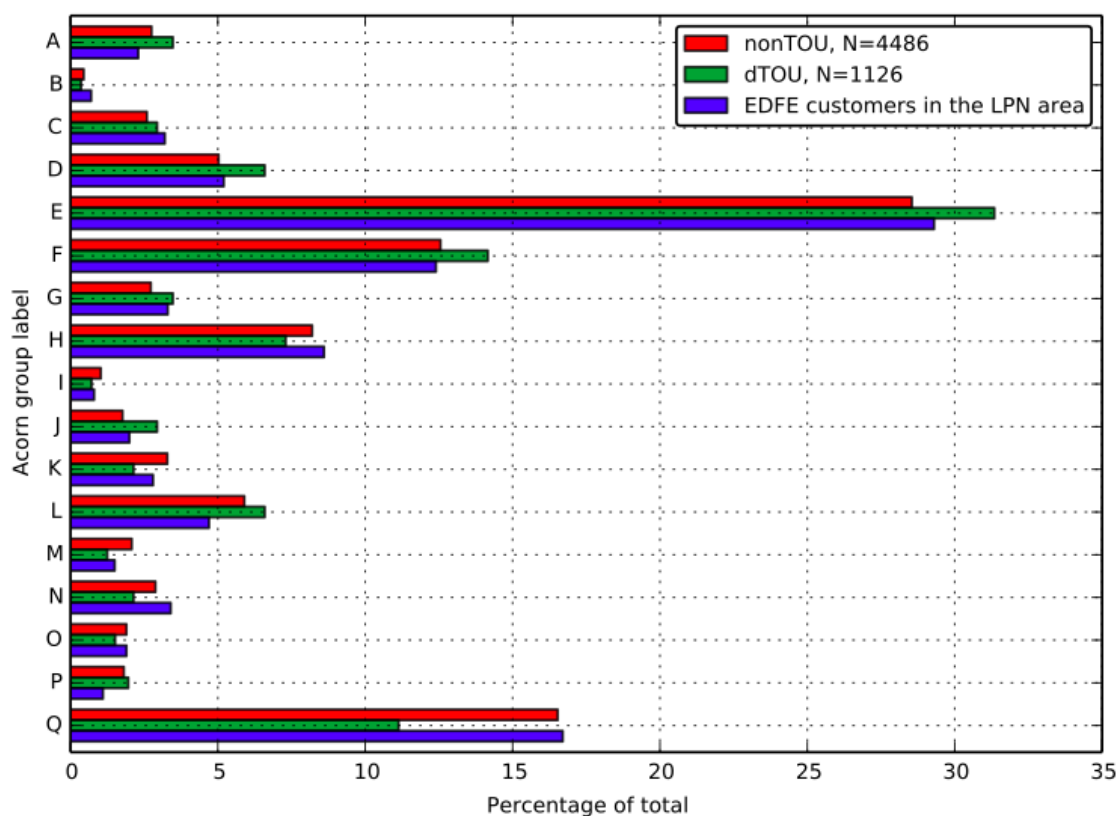


Figure 2.7: Proportions of Acorn groups for EDF Energy customers in the LPN area, the dTOU group and the non-TOU group.

Self selection: Although the sample was stratified using ACORN groups this did not prevent the self-selected sample being biased or skewed according to other criteria associated with accepting or refusing to participate in the trial. For example, households under-represented in the final sample may include: those less interested in technology; those who are difficult to reach by the recruitment methods used (though efforts were made to telephone in early evening as well as daytime); and those who felt too busy to go

through the installation process (installation did require an engineer to visit the home). The sample recruited is, to some degree, biased towards ‘early adopters’ of smart meters.

2.2 Tariff design and trialist experience

(For more details on the rationale behind the design of the events and schedule see LCL Report A3 [8])

Rates (pence/kWh)	• Low 3.99p • Normal 11.76p • High 67.2p
Notification	• Day-ahead • 8.30am
Delivery	• IHD • Mobile phone SMS

Table 2.3: Key characteristics of Economy Alert tariff design

- 3 price bands: The smart meters had 3 price registers, thus allowing a maximum of 3 tariff price points. The Normal rate was lower than EDR Energy’s Standard Variable flat rate tariff so this was another incentive which made recruiting trialists easier. The price model (price points) were developed by EDF Energy based on the events schedule/calendar. Price Points were developed for the tariff on the basis of being commercially viable product for EDF Energy (but see later discussion of savings).
- Revenue neutral tariff bands: Tariff band prices were set so as to result in no annual change in bill for Elexon1 Profile Class 1 consumers. This was in accordance with the rules for trials as laid out by the Office of Gas and Electricity Markets (Ofgem).
- Up to 3 event days per week in order to limit inconvenience to consumers.
- Varying duration
- Events simulated supply-following (random sweeping) plus network constraint events (see below)
- Up to 1 double (up-down or down-up) tariff band change per week: There was some concern that consumers would be confused or irritated by an overly complex tariff structure. Customer experts at the partner EDF Energy (EDF Energy) considered this the maximum acceptable complexity for the tariff. The detail which could be communicated via SMS was a key consideration in this decision.
- All trial participants received the same Price Event Notifications at the same time following the events calendar.
- Rate-change notifications made a minimum of 24 hours ahead of delivery. Alerts were sent at 8am the day before the rate change in order to allow the possibility of bringing activities forward in time before the rate change.
- Rate-change notifications via the IHD (see Figure 2.9) and the option of also having alerts sent to mobile as text message (SMS). IHD functionality constraints meant the messages had to be maximum of 80 characters
- 12-months trial duration

- Monthly feedback report to household

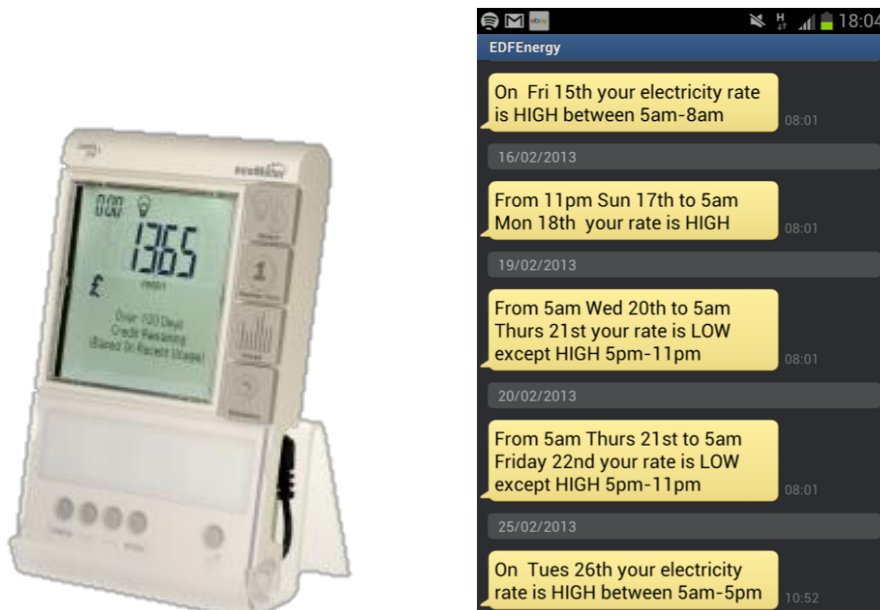


Figure 2.8: In-home display (IHD) and example rate change notifications on mobile phone



Figure 2.9: In-home display (IHD) showing rate change notification and low current load (green light)

2.2.1 Rate change events and schedule

(For more details on the rationale behind the design of the events and schedule see [8])

Trialists were told in the T&Cs that, "We will not apply more than 5 Special Rate periods in a week (Sunday 00.00, Saturday 23.59)" ([24], p.11). They were also told by phone that the High rate would not make up more than 5% of the total hours

Two types of rate change events: Supply-following events and Network Constraint management events

Supply-following events: As one of the key drivers for the investigation of dynamic pricing is the integration of greater renewable generation capacity, supply-following price signals predominated in the tariff schedule. The design of supply following events was informed by data and literature on the variability in wind power generation. From this it was decided that supply following (SF) event durations of 3, 6 and 12 hours would be used for both high and low events, with an additional 24 hour duration event for low price only (it was considered unreasonable to impose a 24 hour high price on consumers).

Constraint management events: these events were designed to closely resemble rate changes in critical peak pricing tariffs.

Each of the supply-following events were repeated 3 times, giving a total of 45 high price events and 48 low price events. Given design constraints this left scope for a further 21 event days for constraint management events.

These events were distributed in a randomised block design

From Figure 2.10, below one can get an idea of the relative frequency of the Low (green), Medium (white) and High (red) tariff rate over the 12 month trial. Mostly Medium tariff; more Low than High.



Figure 2.10: Rate-change event schedule in local time

2.2.2 Feedback

Dynamic tariffs seek to influence consumption by communicating to the consumer price signals and also feeding back information about consumption and savings. It is worth noting the potential of well-designed feedback to play at least a supporting role in interventions to change consumption practices although designing feedback for dTOU is very much in its infancy.

Empirical studies have found that smart meters combined with frequent billing provide better demand response than meters alone. “The most significant single message is that improved feedback is necessary for good understanding of energy use and effective action to reduce it, but not always sufficient.”[24]. Three EDRP EDF Energy trials included monthly paper billing or feedback and these point to the impact of monthly expenditure feedback [26]. The EDRP trials found monthly costs feedback to be an important type of feedback for customer consumption:

"Paper [feedback] customers with additional bill data and energy efficiency advice by post in addition to a smart meter) show greater reductions in consumption than Control [...] customers with just a smart meter)" (EDRP Final Report, p.36 [26])

Not only is regular feedback valuable for changing practices/behaviours but it is popular with consumers.

"a Future Foundation 2006 survey for CGI showed that 70% of GB consumers want better or more frequent information – Future Foundation (2006) Energy Efficiency – Public Attitude, Private Action"

(DECC 2012; emphasis added [27])

Although 97% of the LCL trialists had chosen quarterly billing or annual billing (quarterly bills averaged over the year) this preference reflects a non-smart meter context. Accordingly, monthly feedback was considered essential to reinforce the price signals on Economy Alert and give trialists information on how they were doing month-to-month in responding to the rate alerts. Details of the feedback trialists received is given below.

- IHD: Real time & historic
- monthly feedback letter: Historic, graphical
 - Month-on-month
 - kWh & expenditure
 - Breakdown by L/M/H rate
- Benchmarked savings feedback **given post-trial only**

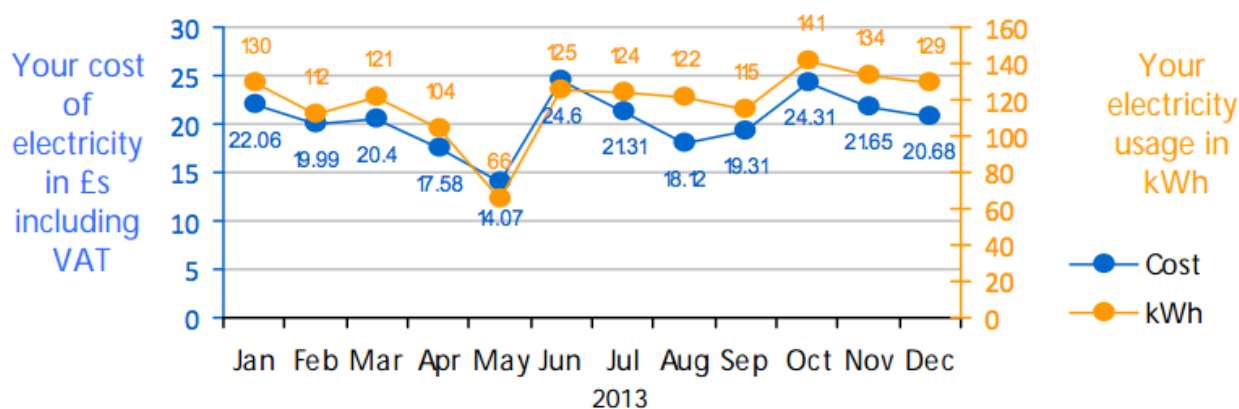
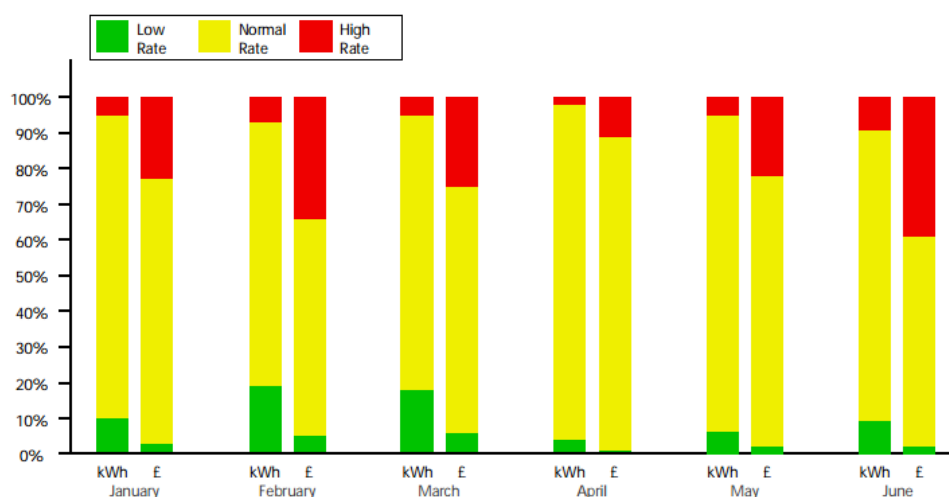


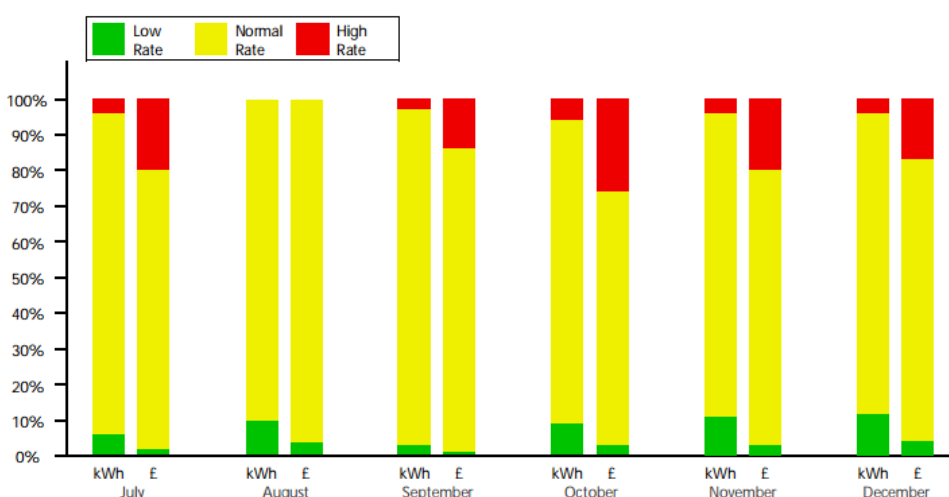
Figure 2.11: Monthly feedback for dTOU: total consumption and expenditure month-on-month

The main aim of the second section of the monthly feedback letter (see Figure 2.11 and Figure 2.12) was to underscore the impact of the price differentials on the expenditure. I.e., to show that just a few kWhs of High-rate electricity could have a relatively big impact on in cost terms. The percentage of how many hours were offered at each of the three rates varied from month to month and so this was also displayed on the feedback the bar charts below.



The times that the three unit rates apply on the Economy Alert tariff vary from month to month. Below are the percentages of hours, which were **available** to you at each of the three unit rates in a given month:

	January	February	March	April	May	June
Low rate	11	13	16	5	9	7
Normal rate	85	80	78	92	85	85
High rate	4	7	6	3	6	8



The times that the three unit rates apply on the Economy Alert tariff vary from month to month. Below are the percentages of hours, which were **available** to you at each of the three unit rates in a given month:

	July	August	September	October	November	December
Low rate	6	4	3	8	11	20
Normal rate	92	95	94	88	85	73
High rate	2	1	3	4	4	7

Figure 2.12: Monthly feedback for dTOU: percentage breakdown of consumption and expenditure by High, Normal and Low rates

Trialists' experience of how clear and useful they found the IHD and letters was assessed via survey towards the end of the trial. This is discussed in the section on Findings under "What limited and helped responsiveness?".

The feedback about expenditure did not include a calculation of savings made relative to what the household would have spent on the standard flat-rate tariff. Trialists received this calculation for the whole 12-month trial period after the trial ended but not month-by-month during the trial.

3 Data collection and analytic procedure

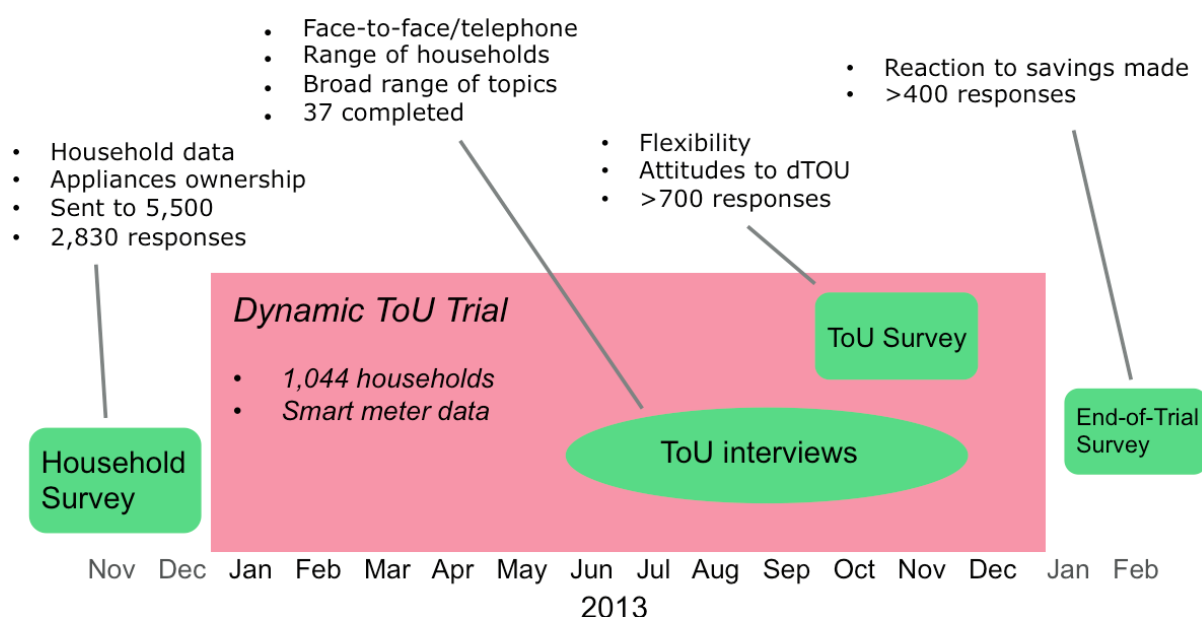


Figure 3.1: Data collection activities

3.1 Smart meter data

The recruitment of households and installation of the smart meters under LCL was the main data collection activity to obtain smart meter data for the LCL dTOU trial (see Figure 3.1). A great deal of other work in developing and managing databases and customer comms was also involved of course. The recruitment process for smart meter installation and dTOU trial participants has been covered in Section 2 of this report. Smart meter data collection, including smart meter installation and data quality issues, are detailed in LCL reports C5 [23] and A3 [8].

3.2 Surveys

Three surveys were carried out with trialists.

Household and Appliance Survey

More detailed background data on households was collected via a survey in late 2012. It was administered to all households where a smart meter had been installed as part of the Low Carbon London residential trial. Consent was also requested for the researchers to contact households for interviewing. A paper copy of the survey (with return-paid envelope) was sent to all households with an installed smart meter and the option of completing it online was also available. These households who returned the survey represent a more valuable core set of data for analyses.

Format: paper and online

Content: 32 questions covering topics including household make-up, occupancy and work habits, details of the building, lighting, heating and appliance ownership, use of IHD, attitudes to low carbon energy, and a request for consent to be contacted for interviewing.

Incentive: £20 cash (collected from Post Office).

Response rate: 51%; 2,612 responses were received by post and 218 responses via an online version giving a total of 2,830.

The second and third surveys were carried out only with dTOU trialists

dTOU Survey (Nov-Dec 2013)

Format: paper copy sent in post with return-paid envelope.

Content: 13 multi-part questions covered trialists' experience with Economy Alert; what they had done to respond to the rate changes; what appliances were most/least flexible; what limited and what helped flexibility; attitudes to savings, renewable energy and alternative variations of dTOU. Content was informed by analysis of interviews with trialists.

Incentive: £20 cash (collected from Post Office).

Response rate: 68%; 708 replies (sent to 1,119)

Post-Trial Survey (April 2014)

Format: paper copy sent in post with return-paid envelope.

Content: 17 questions covering trialists' attitudes to flexibility and the tariff after being informed of actual savings. Content was informed by analysis of interviews with trialists and free-responses to the earlier dTOU Survey.

Incentive: Prize draw.

Response rate: 40%; 418 replies (sent to 1,119)

This data was stored in a dedicated project database separate to consumption data. Some additional data was obtained from the existing customer data held by EDF Energy and during recruitment calls and post-install calls.

- Pre-existing customer data from EDF Energy SAP System
- Recruitment call for LCL Smart Meter installations (Excel doc attached)
- data from post-install Telephone interview (Word doc attached)
- TOU Recruitment call
- on-going data collection which needs space/updatable fields for, for example: technical support calls; complaints calls log; participation withdrawal and reason

3.3 Interviews

The key features of the interviews with dTOU trialists are summarised as follows:

- carried out between June 2013 and early December 2013
- face-to-face and by telephone
- semi-structured
- duration varied between 40–80 minutes
- 37 with dTOU trialists
- range of households: number of occupants, ACORN Groups, responsiveness,
- not incentivised
- topics covered
- informed the development of the surveys carried out with the dTOU group (dTOU Survey and Post-Trial Survey)

Not aimed at representativeness but at insight and understanding - *how* and *why* not *how many* [28]. Data collected are summarised in Table 3.1.

Data type	N	Response rate	Incentive
Smart meter consumption data	5,111 1,044 dTOU 4,068 non-TOU	100% (minus drop outs)	None
Interviews	37	-	None
Surveys			
Household & Appliance Survey	2,830	51%	Yes (£20 cash)
dTOU Survey	722	68%	Yes (£20 cash)
Post-trial Survey	421	40%	Yes (prize draw)

Table 3.1: Summary of data

3.4 Analytic procedures

All interviews were recorded and transcribed and qualitative analysis carried out with the help of Nvivo analytic software. Insights from analysis of the interviews fed into the survey design.

All participant data from surveys, recruitment calls and other customer data was stored in a dedicated secure database. Survey data was analysed with the help of Excel and IBM SPSS (Statistical Package for the Social Sciences).

4 Findings and discussion

Engagement with dTOU tariffs encompasses consumers' electricity-related behaviours/practices and their attitudes and understandings of it and these are difficult to separate. Although this report is focussed on the attitudes of trialists a necessary context the main findings or details of DR findings see IC-LCL Report A3 [8] The following outlines some of the main findings from LCL Report A3.

Note about units for reporting DR: DR values are, presented in units of kW/household as opposed to percentage reductions (except for some network constraint price events). Load varies considerably by hour, day and season so a large percentage of a small load could still be a small amount of load so percentages always need to be related to the size of the load during that half-hour time period. From a network operation perspective, absolute (kW) reductions in demand are what matter and from the point of view of consumers' energy practices, and behaviour change, kW are more easily related to types of actions. Further, the use of a per-household average makes extrapolation to any number of households easy to perform.

4.1 Summary of actual DR/flexibility/responsiveness

(for more detail see IC-LCL Report A3 [8])

- The mean DR values over the trial, including all events and times of day were:
High price –0.04 kW/household for the whole dTOU group; –0.12 kW/household for the best 25% of households.
Low price: 0.03 kW/household for the dTOU group; 0.11 kW/household for the best 25% of households
- Overall, the range of DR performance was large; the best 25% households produced three times the DR of the mean, for some types of price events four times the mean.
- For low rate events more than high rate events better responders far outstripped the full group mean in their demand increase.
- The events mimicking constraint management scenarios (with high and low pricing being combined into the same event) resulted in peak reductions ranging from 4% to 10%. The average demand reduction was 10%, while the best quarter of responders achieved about 40% reduction in demand (almost 4 times the average)
- DR was more pronounced during the winter and spring months than the summer and autumn months
- There was little trend in the DR resource when grouped by day of week, though Sundays did appear to have a greater response to low price events
- The DR resource was greatest during the normal waking hours of the day; approximately 7am to midnight
- During the waking hours of the winter months, demand response for the best 25% of responders was nearly 0.4 kWh/household
- Better responsiveness to High rate events was associated with better response to Low rate events but this correlation was of medium strength only (Pearson r-value –0.356; significant at 0.01 level, two-tailed; n=922).

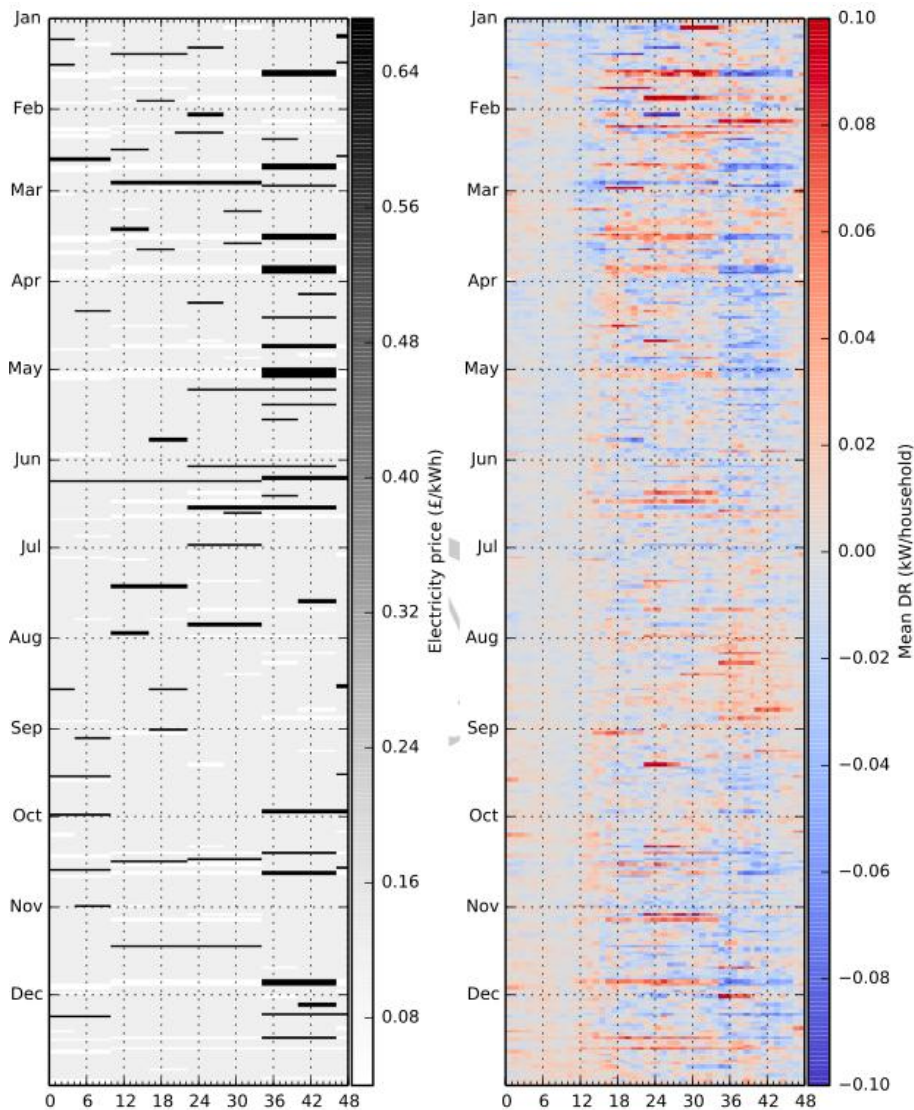


Figure 4.1: Heat map of price (left) and DR (right) by time of day for the trial year (red indicates increased load, blue decreased load)

At first glance the DR figure on the right (Figure 4.1) appears to indicate a honeymoon/novelty effect for the first two or three months of the trial. However this could be due to the greater concentration of price events in this part of the trial schedule. Further analyses will look at persistence and variations between different periods through the trial, including understanding variation in DR by season, frequency of price events and other variables.

From a seasonal perspective, it appears that DR is lower during the summer months; perhaps because people are outside more or because they have less loads to shift.

DR by time of day

There are differing amounts of demand response at different times of day and days of the week. This variation is attributable to factors including occupancy, household practices and the usual load at that time of day. For example, in Figure 4.2, below, the times of lowest DR are when occupants are asleep and –for responding to the High rate– when load is low (and therefore the scope for reducing load is limited).

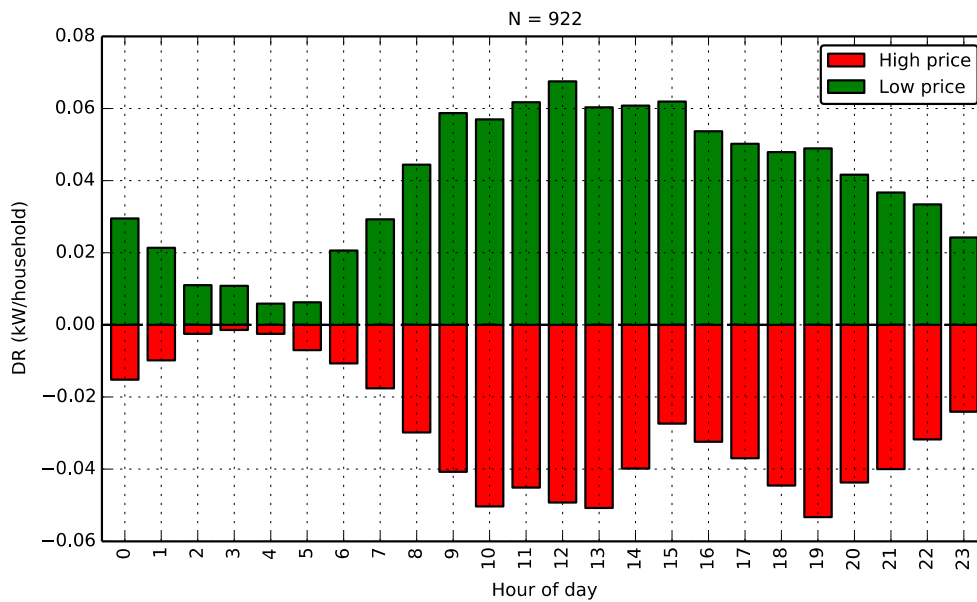


Figure 4.2: DR by hour of day (all dTOU group)

The DR during the non-waking hours, especially 2am–5am, is, unsurprisingly, very much smaller than during waking hours. This is another indication of limited use of timer devices on wet appliances. Similarly, a final observation from the preceding ‘heat map’ figure is that the absence of much ‘red-shift’ in the late night/early-hours corresponds to the survey self reports (see later) suggesting little use of timers to use Low-rate during the night.

Day of week

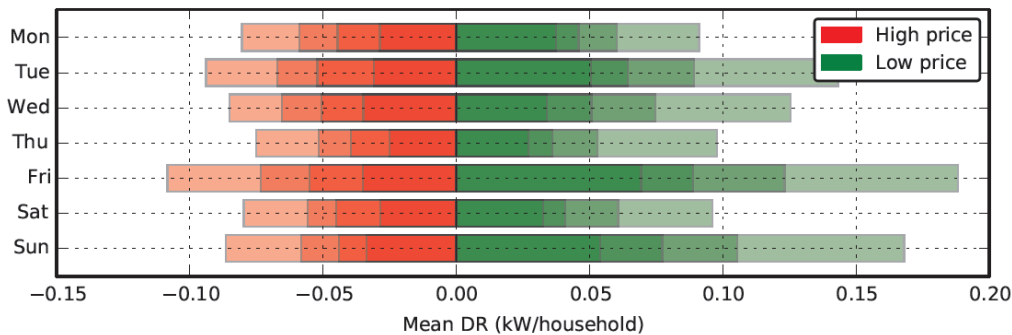


Figure 4.3: DR by day of week (all dTOU group)

Friday and Sunday have the greatest potential for increased load to respond to Low rate (Figure 4.3). It is surprising perhaps that such a variation is seen in weekdays and that Saturday has a relatively low potential regarding the low rate.

Averaging over weekdays, the above pattern in actual DR is similar to the survey responses (Figure 4.4 and Figure 4.5), which also reported greater responsiveness on weekends and for Low-rate periods, as shown in the two figures below. Once again, the self-reported data broadly corresponds to the measured DR showing little DR overnight.

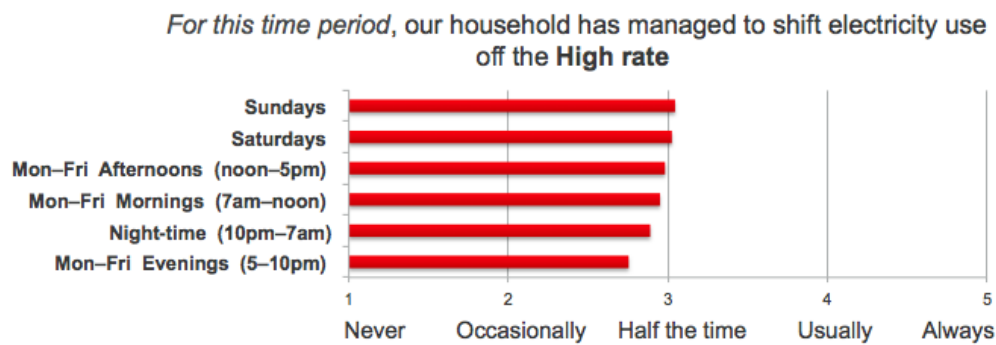


Figure 4.4: Household's reported shifting of electricity use off the High rate



Figure 4.5: Household's reported shifting of electricity usage onto the Low rate

These results show the mean of responses (ranked high to low) for all responding households and so the variety across households is not shown. The surprisingly small differences between averaged preferences for days of week is probably due to the effect of this aggregation of responses across households which masks stronger patterns and preferences for certain days. More detailed analyses are needed to understand better the variety across households. For example, for households where all occupants work fulltime the differences between flexibility on weekdays and weekends may be much greater than the aggregate results above show.

Having briefly summarised the actual responsiveness found, two of the most fundamental, obvious and pressing questions to consider about the dTOU tariff from the consumer/customer point of view are the following:

- Did households make financial savings?
- Would households want to remain on dTOU?

Turning now to the survey findings, these two issues will be considered first.

4.2 Savings: actual, expected and desired

The topic of savings made on a dTOU tariff is an extremely complex one dependent upon many inter-related issues, including:

- price points for the different rates
- tariff schedule of rate change events
- households' actual flexibility or DR

- consumers expected and desired level of saving
- the communication and feedback of information about the impact of rates and of savings

Beyond the context of this trial the topic of savings also involves the value of DR in the energy system/market and the question of consumers price sensitivity for different price points.

It is important to emphasise that the observed savings made by households on this trial are highly contingent upon the specifics of the tariff price points and schedule chosen. Consequently, care should be taken not to draw conclusions about possible or likely savings of dTOU tariffs in general from looking at the actual savings made on the LCL trial. Further analysis of trial data (on-going) will furnish much more useful and accurate insights into savings.

Bearing this important caveat in mind, Figure 4.6 below shows the frequency distribution of percentage savings made by each household in the dTOU group. Over 75% of households paid less on the dTOU tariff than they would have on the standard tariff.

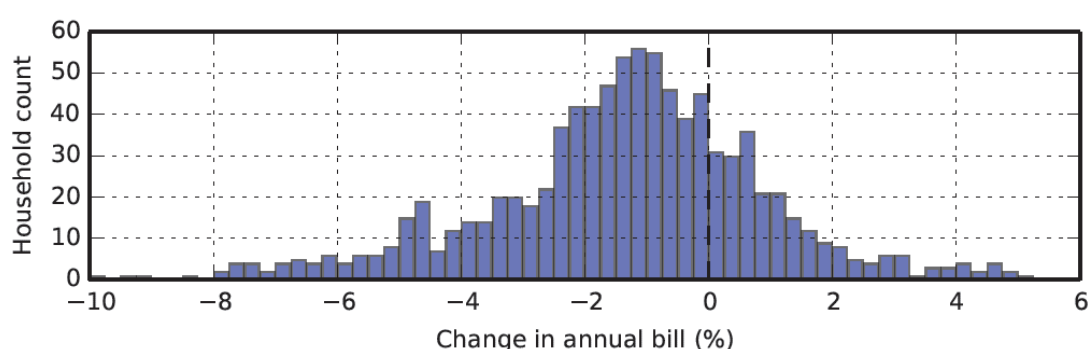


Figure 4.6: Savings made per household in the dTOU group

Looking at the average savings for the dTOU group, the Table 4.1 below shows savings ranged widely from a £40 loss to £147 saving over the year. The average savings were very modest: £21 or 4.3% mean and £16 median but as mentioned, these savings are far from being a simple proxy for DR and are highly contingent upon the specifics of the Economy Alert tariff design. As will be discussed later, more work is needed to characterise the best-responding households and the financially best-off and worst-off households.

Actual savings (n = 922)	min – max	mean	median	% saving (mean)
Compared to Standard variable flat tariff	£40.21 loss – £147.70 saving	£21	£16	4.31 %

Group	n	£ Max	£ Min	£ Mean	£ Median	% Max	% Min	% Mean	% Median
TOU	922	-147.7	40.21	-£21*	-16.28	-26.4	4.72	-4.31	-3.94
non TOU	3437	-183.79	36.53	-13.13	-10.29	-11.46	6.45	-2.39	-2.5

Table 4.1: Actual savings made over 12-month trial period (minus indicates saving relative to standard variable single-rate tariff; losses in red)

One effect of the tariff structure worth noting is that the Normal rate was lower on the dTOU than the standard tariff rate. This gave no incentive for shifting load but meant that high consumers benefitted financially. In fact, the household who would have benefitted most from being on dTOU was actually a household in the non-TOU group with a very high total consumption – see Table 4.1); this household would have saved £183 compared to the biggest saver in the dTOU who saved £147. The largest losses are similar for the two groups too, but this is not the case for *percentage* savings which reflect overall consumption levels, where the best saver was from the dTOU group (26% versus 11% for the non-TOU group). The favourable Normal rate helped hit recruitment targets but ideally all dTOU price points signals should be consistently cost-reflective and work to encourage the desired load shifting rather than favour high consuming households.

Attitudes to savings

The dTOU Survey asked the following two questions. Note that the question did not offer multiple-choice options which could influence the respondent but was free-response.

*Q. If you had to guess, how much would you **estimate** you will have saved over the 12 months of being on Economy Alert when compared to your previous flat rate tariff or similar? (Please write in a figure below)*

£ / year

And,

*Q. How much would you **want to save** on your bill (compared to being on a standard flat rate tariff) for you **to be happy staying on a tariff like Economy Alert?** (Please write figures below)*

£ / year

AND/OR

..... % saving on annual bill

As can be seen in Table 4.2 below, there was a very wide range in the responses given about estimated savings and desired/required (both £ and %) savings. The very high number of ‘No Reply’ responses also suggests uncertainty and or unwillingness

Self-reports (n=708)	min – max	mean	Mode	Median	No Reply
Estimated savings made	£50 loss – £600 saving	£53	£50	£50	219
Savings wanted to be happy to stay on dTOU (£)	£0 to 500	£106	£100	£100	340
Savings wanted to be happy to stay on dTOU (%)	0 to 100%	18%	10%	15%	384

Table 4.2: Expected and desired savings over 12-month period (savings relative to standard variable single-rate tariff)

Also apparent is that the mean estimated savings were half of the mean savings stated as required for trialists to be happy to stay on the dTOU tariff. There was also a mismatch or shortfall between the desired

savings and the *actual* savings The table below shows the actual savings for the dTOU group compared to what they would have paid for their electricity on EDF Energy’s standard single-rate tariff. The mean (£21) and mode (£16) are very modest sums and far less than the £50 expected and £100 required savings reported by survey respondents.

The mismatch between expected and desired savings does not appear to have influenced trialists attitudes to wanting to remain on the dTOU tariff however, and this is true even after they were informed, at the end of the trial, about their actual savings which again were less than they had expected for 42% of households (either “a bit less” or “much less” than they had expected). (See Figure 4.7).

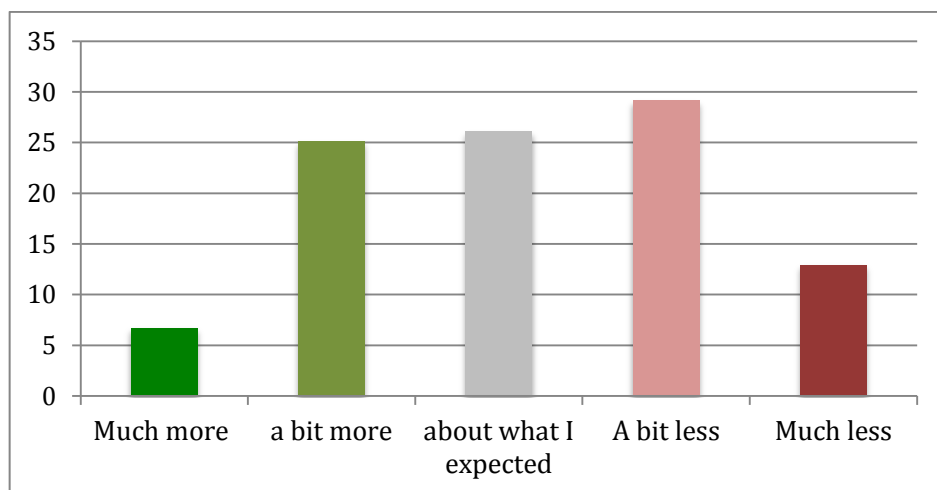


Figure 4.7: Did your household save MORE or LESS money on Economy Alert than you had been expecting up until receiving this information? (%), n=418

Savings and dTOU tariff design

As mentioned, it should be stressed that the savings made on this trial are not simply a reflection of DR but were greatly affected by the particular price points chosen for this trial (67p, 11p, 4p/kWh) and the frequency, type and timing of rate changes on the schedule. The LCL dTOU trial had a very high price point for the High rate. This was likely effective in encouraging DR and allowing the trial to study flexibility. It did however have a large impact on households’ financial savings thereby compromising in some ways the study of reactions and attitudes to the tariff.

Further analyses of trial data will continue to understand more fully the possible and likely financial savings and their distribution across households but given the 67p/kWh price point used this on-going work is likely to produce more encouraging figures concerning the potential for savings on dTOU more generally.

The design of future commercial dTOU tariffs will be an even more complex affair which will involve many variables which will change in the future such as the value of DR to various stakeholders [16], the technology available to support DR, and various aspects of consumer engagement such as public understanding of the need for DR and norms about flexible consumption.

As dTOU tariff design evolves, is tested in the market and is refined and different versions developed aimed at different market segments, the savings possible and their prediction is likely to improve. This changing context of growing awareness and familiarity will in turn affect attitudes and acceptance of dTOU. One issue that tariff design will need to confront is how to manage and share the financial benefits and risks associated with the unpredictable schedule of dTOU tariffs linked to weather-based intermittent renewables, at least for long periods of calm, cloudy and cold conditions which would increase generation costs. For this kind of

tariff, this management and sharing of benefits and risks among stakeholders may be added to smart tariff design principles/issues previously identified (e.g., UKERC, 2010 which lists Price Elasticity; Cost Reflectivity; Fairness; Distributional Impacts; Unintended Outcomes; Consumer understanding/acceptance). Another issue which may increasingly need to be incorporated into smart tariff design principles is the level of support for price-responsiveness from technology (for example, fixed TOU Economy 7 tariffs would not have been feasible without overnight storage heaters). As such, enabling/empowering technology is very unlikely to be taken-up uniformly and so is linked to distributional impacts (wealthier households will be able to invest in smart appliances for example which save money on running costs).

4.3 Would like to remain on dTOU?

Trialists and would-be adopters of these tariffs are certainly interested in the financial savings to be made on dTOU. It would be a common assumption that the decision about whether to remain on such a tariff would be primarily determined by how actual savings stack up against desired savings.

Towards the end of the trial households in the dTOU group were asked if they agree with the statement, “*If it was possible, we would want to stay on the Economy Alert tariff after the end of the trial?*”. One of the most encouraging findings from the survey data was that 77% of trialists who responded (708/1,044) indicated that they would want to stay on the dTOU (see Figure 4.8 below).

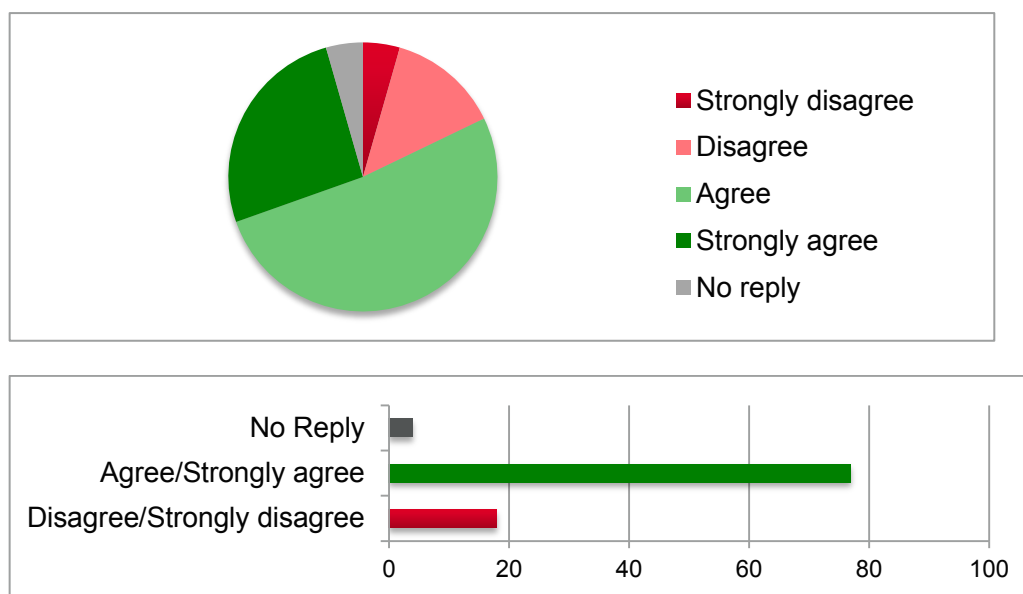


Figure 4.8: *If it was possible, we would want to stay on the Economy Alert tariff after the end of the trial?* (%) n=708

Trialists did not receive on-going monthly feedback on financial savings made on Economy Alert benchmarked against either previous bills or what they would have been charged under the standard flat-rate tariff. They received a letter after the end of the trial informing them of the total actual savings made over the whole 12-month trial period. Trialists were asked if they would have liked to remain on dTOU (if it was possible beyond the end of the trial) twice: both before this savings letter was sent out and after.

Given that trialists did not receive feedback about actual savings benchmarked against a flat-rate tariff, the same question was asked after they had received this information at the end of the trial. This question, in the Post-Trial Survey, was prefaced with, “*Bearing in mind the financial savings (or loss) that your household*

made on Economy Alert, please indicate whether you agree or disagree with the following statement". As the Figure 4.9 shows, 70% of responding households still wanted to stay, with only 13% indicating that they did not wish to remain on dTOU). This is perhaps surprising and certainly encouraging given level of savings made by most were modest.

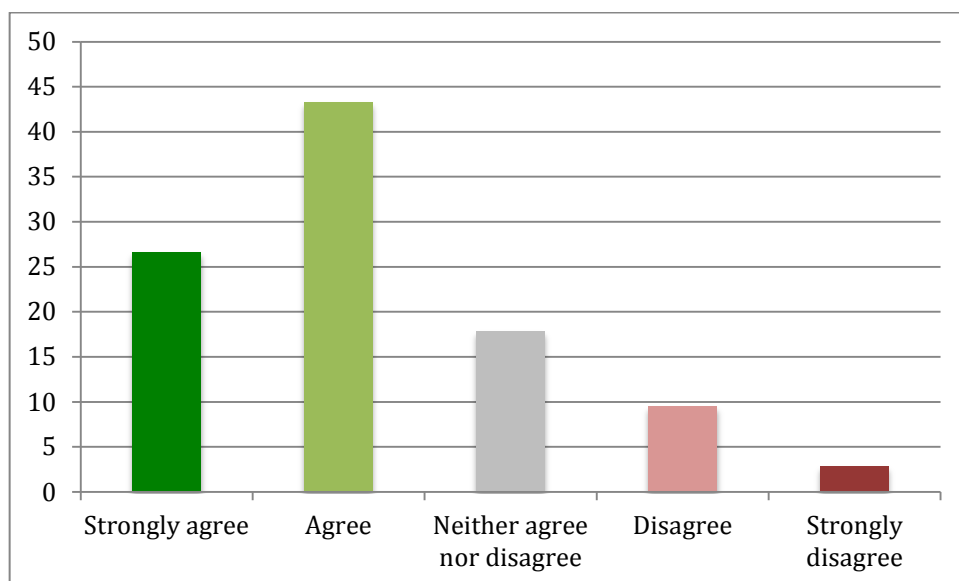


Figure 4.9: Our household would prefer to remain on a tariff like Economy Alert if possible (%) [n=421, Post-trial Survey]

Going beyond their own circumstances, trialists also showed a surprising degree of advocating dTOU for other households. When asked "If it encourages more efficient use of electricity and resources, multi-rate tariffs like Economy Alert should be offered to everyone", 91% of responding households (n=708) indicated that they either agreed or strongly agreed with the statement (Figure 4.10). Admittedly, the question includes the clause, "If it encourages more efficient use of electricity and resources...", and the responses are dependent on this link being established but consumers' attitudes to dTOU will inevitably evolve as awareness of the arguments for DR are put forward and publically debated. Including this clause is an attempt to anticipate the greater understanding of smart tariffs and DR in the near future.

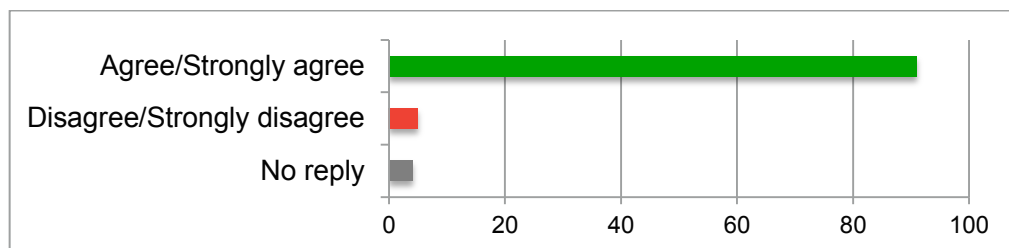


Figure 4.10: If it encourages more efficient use of electricity and resources, multi-rate tariffs like Economy Alert should be offered to everyone (n=708)

Even more impressively, 81% of responding households either agreed or strongly agreed with the statement, "If it is a fairer way of charging people for the real cost of electricity at different times, multi-rate tariffs like Economy Alert should be the standard tariff for everyone" (see Figure 4.11).

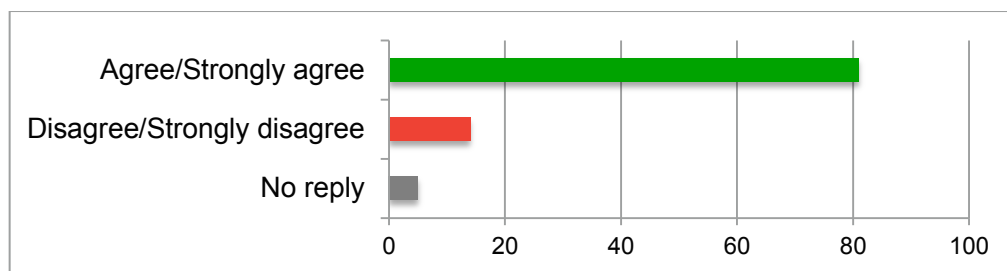


Figure 4.11: If it is a fairer way of charging people for the real cost of electricity at different times, multi-rate tariffs like Economy Alert should be the standard tariff for everyone (n=708)

As for the preceding survey item, the question establishes a link between dTOU and arguments for smart tariffs based on more cost-reflective pricing being accepted as fairer than the cross-subsidies of current flat-rate tariffs (“If it is a fairer way of charging people for the real cost of electricity at different times,”). Even if the reported support for dTOU tariffs is contingent upon them being regarded as fairer and more efficient, this finding at least indicates that increasing awareness about these arguments for dTOU is a valuable step towards acceptance of dTOU.

The two issues of savings and willingness to remain on a dTOU tariff (and thereby take-up and churn more generally) are linked but it has been shown above that even very modest financial savings do not necessarily deter consumers. The topic of trialists’ enthusiasm for and satisfaction with dTOU will be discussed further in later sections where it will be shown, consistent with the findings above, that trialists report experiencing other non-financial benefits to dTOU.

4.4 How: which appliances and actions?

In the absence of disaggregated monitoring of consumption which can identify different appliances, data about what energy practices householders are shifting must come from self-reports. The dTOU Survey asked trialists about which appliances/behaviours they were more or least able to shift in response to the High and Low rates.

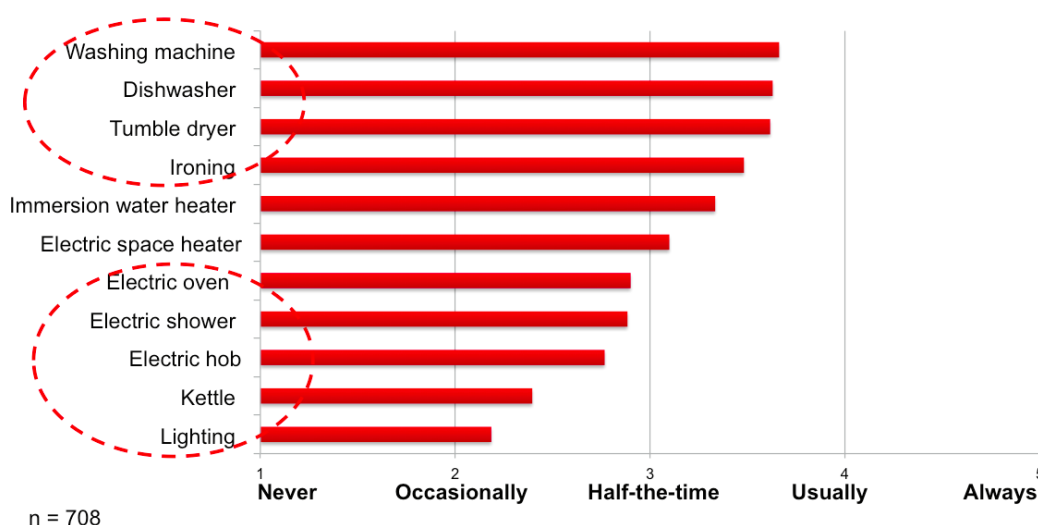


Figure 4.12: For this appliance, our household managed to avoid the High rate (ranked averages, n=708)

Wet appliances (washing machine, dishwasher, tumble-dryer), plus ironing, were reported to be the easiest to shift. Lighting, cooking and showering were reported to be the hardest to shift, however some shifting of even these was reported. Comparing Figure 4.12 with Figure 4.13, it can be seen that the pattern of appliance-flexibility is similar for low and high rate events.

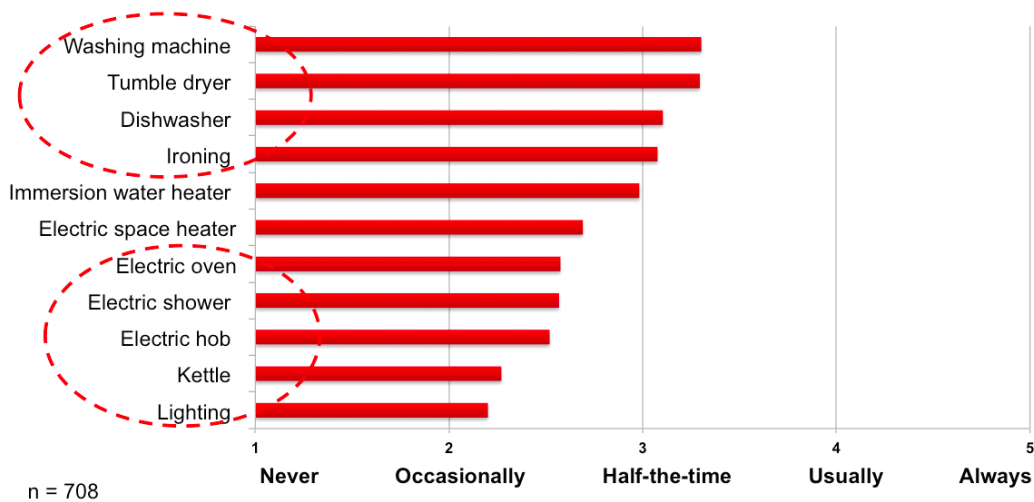


Figure 4.13: For this appliance, our household managed to move some consumption onto the Low rate (ranked averages) n=708

Interestingly, the supposedly hard-to-shift cooking practices are reported to be flexible (more than 'Occasionally') onto Low-rate for 35–40% of trialists who owned electric oven or hob (see Figure 4.14).

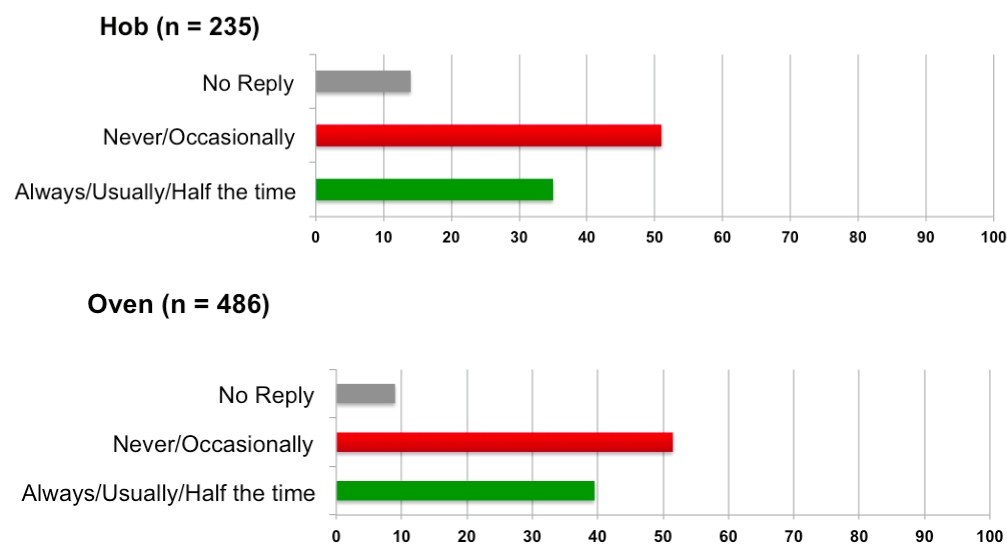


Figure 4.14: Reported flexibility of cooking practices (n=708)

These findings about the relative flexibility of appliance/practices is consistent with earlier work. Palmer et al 2012 (see Table 4.3) identified a priori the following groups of appliances and these are broadly in agreement with the self-reports given by LCL respondents[30].

Switchable	Partially switchable	Non-switchable
Washing machine	Ovens	Lights
Tumble Drier	Space heating	TV
Dishwasher	Cold appliances	Audio equipment
Water heating		Computers
		Hobs
		Microwave

Table 4.3: Switchable, Partially switchable and Non-switchable appliances

(Source: Palmer, J., Terry, N., and Kane, T. (2012) Further Analysis of the Household Electricity Survey Early Findings: Demand side management, Nov 2012)

Having fixed routines for when certain activities are done was considered as a possible barrier to flexibility. These pre-existing routines might be broken in the new context of dTOU tariff but it is potentially useful to know which practices are done at regular set times and which less so. The survey asked, “Does your household tend to have a fixed routine for WHEN this appliance is used (same days of the week or times of the day)?”. Responses (Figure 4.15) indicated that, according to the mean responses, behaviours are generally not performed at set times but that showering, lighting, cooking and water heating are the most fixed in when they are done, and the least fixed are the kettle, dishwasher, and ironing. Once again, the variation across households is masked by the averaged results shown below and this variety may prove interesting in further analysis.

Looking across the previous charts, the most inflexible appliances tend to be those that have fixed routines (shower, lighting, oven, hob) but the kettle is an exception to this – it has no fixed routine but is not considered flexible.

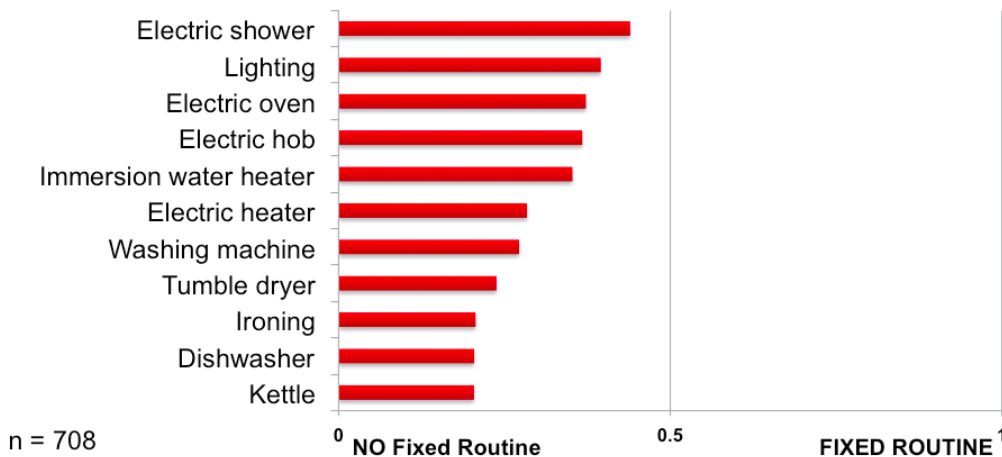


Figure 4.15: Does your household tend to have a fixed routine for WHEN this appliance is used (same days of the week or times of the day)? (Y/N, ranked averages, n=708)

4.5 What limited and what helped responsiveness?

- **Feedback**
- **Timers**
- **other actions that helped households respond**

4.5.1 Feedback: IHD and monthly feedback letter

As can be seen from Figure 4.16 and Figure 4.17, the vast majority of respondents reported that the IHD was clear and useful for responding to the price signals on Economy Alert. A large majority also found the monthly feedback letter to be *clear*, with a somewhat smaller majority (55% vs. 40%, 5% No Replies) reporting the letters to be *useful* for responding to High/Low rates. The IHD displays the rate change notifications and real-time feedback and well as historic feedback so it was to be expected that the IHD would be found to be more useful for responding to price signals.

Given that the design of feedback for dTOU trials is a new field and the monthly feedback letters aimed to convey quite a lot of information in a dense format these results showing that the letter was found to be clear and relatively useful, were reassuring. But the interviews and surveys also highlight the variation in preferences between different households.

The most prominent suggestion for improvements to the IHD for dTOU were for it to have a traffic light display for current rate as well as or instead of for current load. The satisfaction of the trialists with the IHD unit for supporting responsiveness will be taken up again later.

Households on the dTOU trial did not receive feedback about financial savings benchmarked against a flat-rate tariff. This is considered essential for future trials (as it would undoubtedly be for a real-world commercial dTOU tariff).

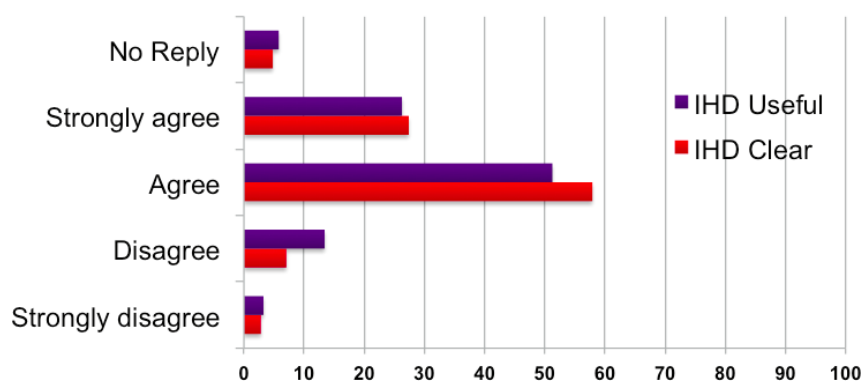


Figure 4.16: Responses to survey items (i) and (ii):

(i) I/We found the information via the in-home-display unit clear

(ii) I/We found the information via the in-home-display unit useful for responding to High/Low rates (n=708)

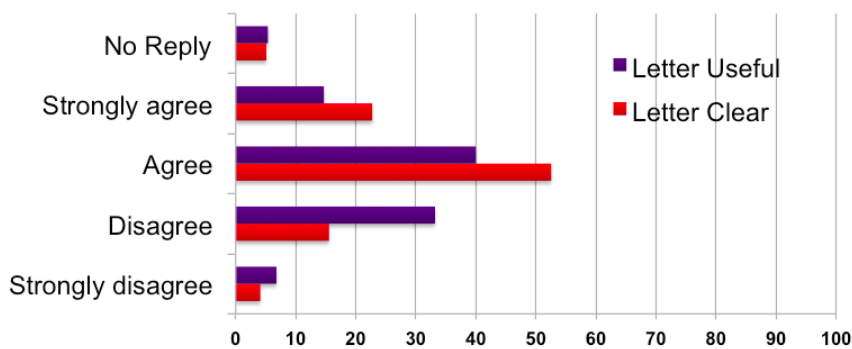


Figure 4.17: Responses to survey items (i) and (ii):

(i) I/We found the information via the monthly feedback letter clear

(ii) I/We found the information via the monthly feedback letter useful for responding to High/Low rates (n=708)

Another survey item was able to compare the usefulness of the IHD with other things that supported responsiveness. The IHD was, on average, the most useful of all but the fact that respondents also found useful “Writing the alerts down on a calendar or notepad” indicates room for improvement in the IHD (Figure 4.18). Another suggestion made by trialists was for the IHD to clearly display the current tariff rate instead of, or as well as the traffic light system for current load. The IHD model used was limited in the length of the text messages used for rate notifications and could only store one message. Partly for this reason, many trialists appreciated having the notification messages sent to their mobile phones also – after the IHD this was the second highest scoring response.

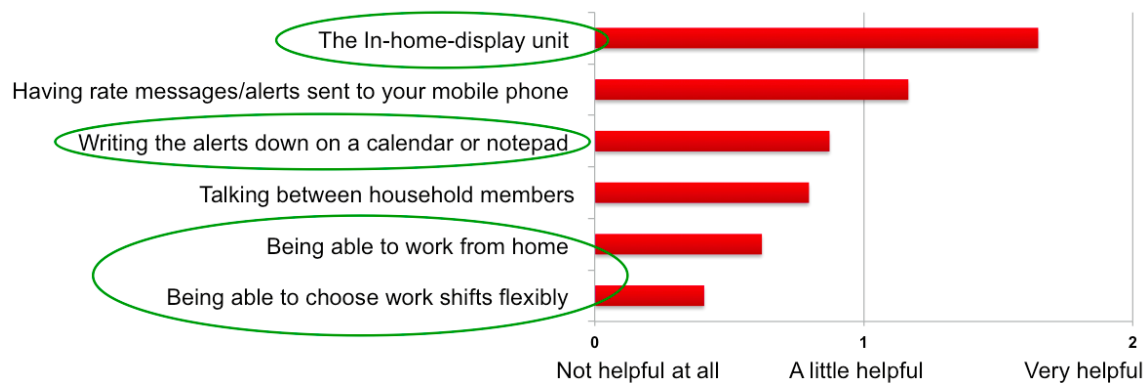


Figure 4.18: (Q7) Which of the following has your household found useful to help you respond to the High/Low electricity rates? (n=708)

The results also indicate that being able to work flexible hours or work from home helped few households, though some households who could work flexibly or from home found this to be very helpful.

4.5.2 Use of timer devices/functions

The following question was asked for a number of major appliances.

Q4: For each appliance/row, please tick one box to indicate how you have used timer switches to turn appliances on/off to respond to the High or Low rates.

For all appliances asked about, most people who owned that appliance reported that they did not have a timer on that appliance (n=708). Clearly the lack of timers on appliances is a barrier to DR to some degree.

Figure 4.19 and Figure 4.20 show the responses from those households who both owned the appliance in question and had a timer function on it. They show how often households use timers available to them.

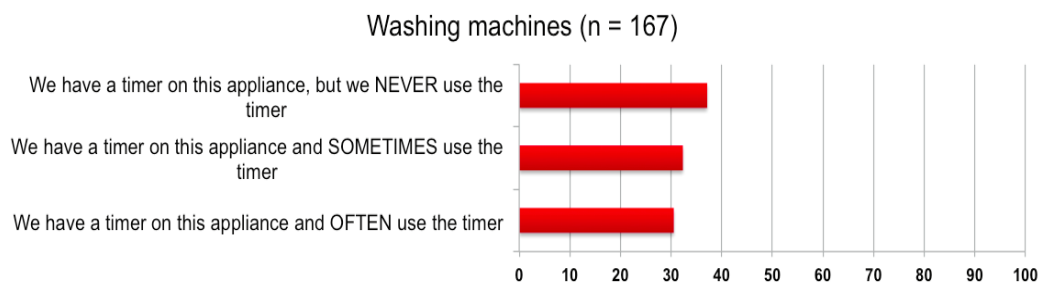


Figure 4.19: Reported use of timers on washing machines

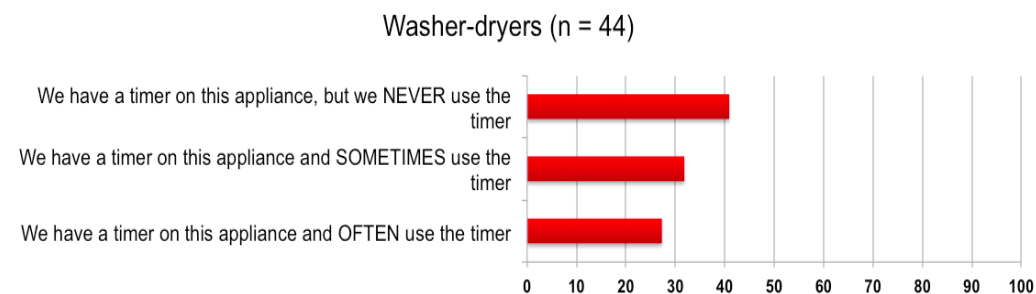


Figure 4.20: Reported use of timers on washer-dryers

Although the number of households with washing machines with timers is much greater than those owning washer-dryers, patterns of reported usage of timers on these appliances is very similar: approximately 60% report using the timer 'sometimes' or 'often'. Washer-dryers might be assumed to lend themselves to easier timer usage as there is no need to move washing between machines or worry about wet laundry waiting too long in the washing machine and getting crumpled or musty.

Among households who own appliances with timers, tumble-dryers were reportedly used more often than those on washing machines or washer-dryers. Dishwashers were the appliance with the least frequent use of timers (see Figure 4.21 and Figure 4.22).

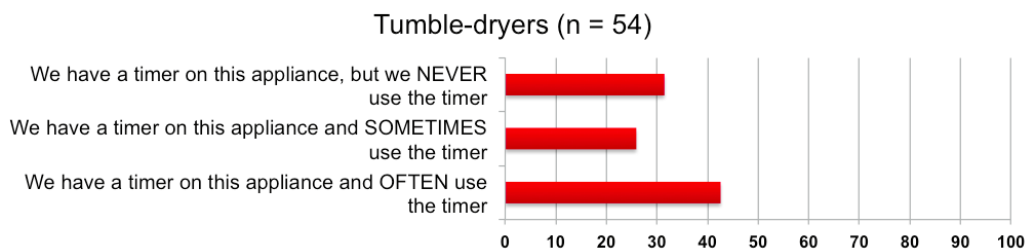


Figure 4.21: Reported use of timers on tumble-dryers

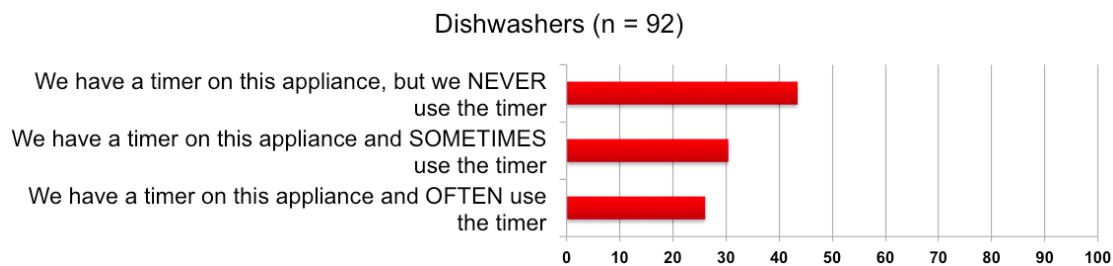


Figure 4.22: Reported use of timers on dishwashers

Overall reported use of timers was limited and this corresponds to the lack of DR observed during the night-time hours, as noted earlier with reference to Figure 4.2 in 4.1. This represents an area to potentially increase DR through greater use of timers.

Comments from respondents indicate that reasons for timers not having been used more widely and frequently on the trial include:

- lack of timer function on appliances (washing machine, tumble-dryer, dishwasher) currently owned
- lack of awareness about timers (no advice about using them was given to trialists)
- timers considered too difficult or inconvenient to use (this was reported by trialists in relation especially to heating controls)
- choice not to use timers for laundry due to concern about laundry sitting in the machine and getting crumpled or musty
- in some cases, concern about leaving an appliance running while they are asleep or out for fear that it might cause a fire or flood
- and choice not to use timers due to concern about the noise (for own sake or neighbours) from running wet appliances at night. This issue of noise was explored in more detail and is discussed below.

4.5.3 Appliance noise limiting night-time usage

As Figure 4.23 indicates, depending on the appliance, between one third and almost one half of households who own these appliances are restricted by noise issues. If quieter appliances and or better acoustic insulation in buildings were introduced, and more appliances had timer functions, then a sizeable increase in shifting onto night-time Low-rate periods could be feasible (and in some cases, a corresponding shifting of load off evening peak-time hours).

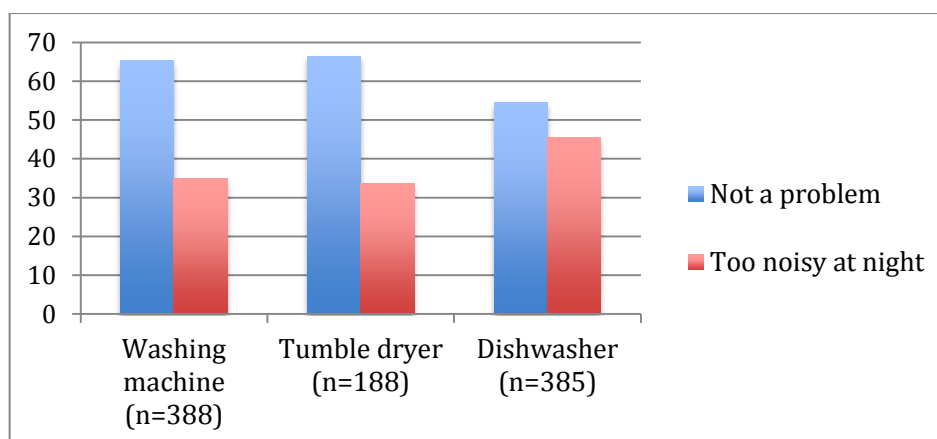


Figure 4.23: Would concern about excessive noise (for your neighbours or your own household's sake) stop your household from using any of the following appliances during the night? (%)

4.5.4 Other things that helped responsiveness

Looking in a little more detail at the changes households made to their energy practices, trialists were asked what other actions they had taken to take advantage of the rate changes. The results (averaged for all respondents) are shown in Figure 4.24.

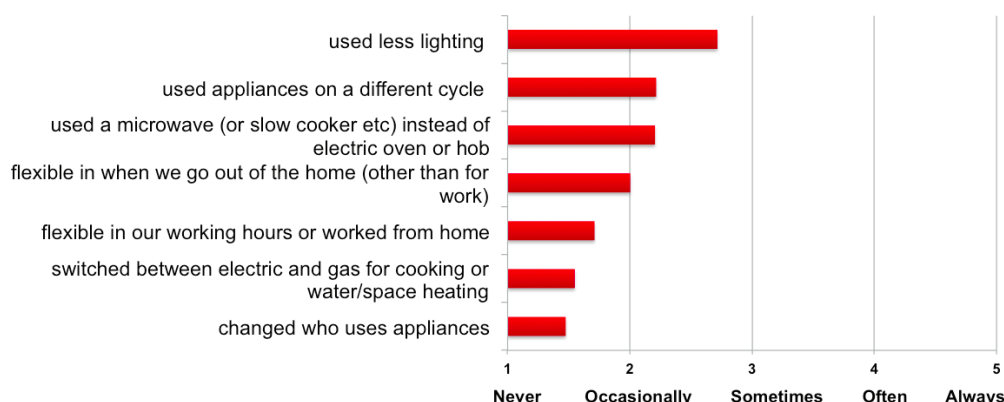


Figure 4.24: Thinking about what you and other members of your household have done to take advantage of the Economy Alert rate changes, please indicate how often you have used each of the actions below (ranked averages), n = 708

Interestingly, the activity reportedly done most frequently to take advantage of the rate changes was using less lighting: not a shifting behaviour but a curtailment/ reduction behaviour. This indicates that one effect of the dTOU tariff (and the High price specifically) is that it creates greater awareness of energy efficiency and waste. This finding is also seen in the reports of an overall reduction in electricity consumption since going on the trial. In contrast, the activity reported to be undertaken the least often from the list of seven, was changing who uses the appliance. Potentially, being flexible about who operates the appliance could help a household be more flexible, say when the person who usually does the washing, for example, is out of the house. This suggests that routines and roles for *who* uses appliances are either resistant to change or this would not help increase flexibility.

Looking at the frequency data for changing who uses appliances (Figure 4.25), we can see that although most households report never doing this, 21% do report changing who uses appliances to take advantage of dTOU either 'always', 'often' or 'sometimes'.

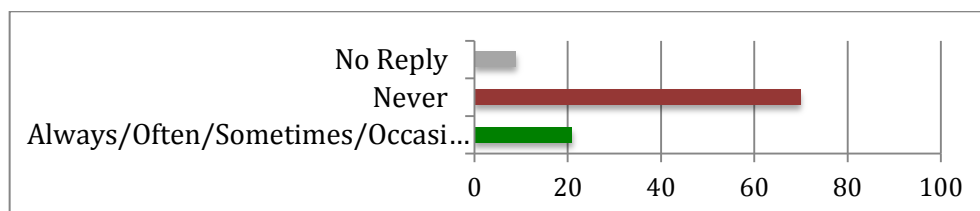


Figure 4.25: We have changed who uses appliances (e.g., washing machine/dishwasher/ironing), n=708

Another question explored this topic from a slightly different angle, asking not has the household changed roles for appliances but whether having fixed roles has limited their response to price signals (Figure 4.26). Most households reported that their flexibility was not limited by fixed roles for who uses appliances, suggesting that either they live alone, or have no such fixed roles, or that altering their fixed roles would have made no difference. However, approximately 20% agreed that roles were a limiting factor and the fact that they were not able or willing to adapt these roles is potentially very interesting, both sociologically and from the point of view of increasing DR in the future.

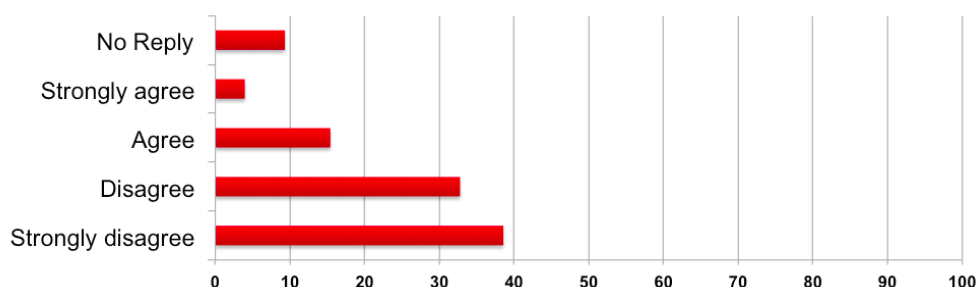


Figure 4.26: Our response to Economy Alert High and Low rates has been limited by ... Having fixed routines for who uses appliances (washing machine/dishwasher/ironing etc.) that we did not want to change (n=708)

4.5.5 Other things that limited responsiveness

Trialists were asked about a range of factors which may have limited their ability to respond flexibly to dTOU price signals. (The results in Figure 4.27 are average scores for the whole dTOU group and so variation across households is not visible.) Occupancy patterns ("no-one being at home") was the most highly-rated of all limiting factors. Working patterns was also rated as another major limitation; combined with the earlier finding that very few households were able to be flexible in working hours this indicates the potential for greater DR if employees were able to secure more flexible working practices or options for teleworking.

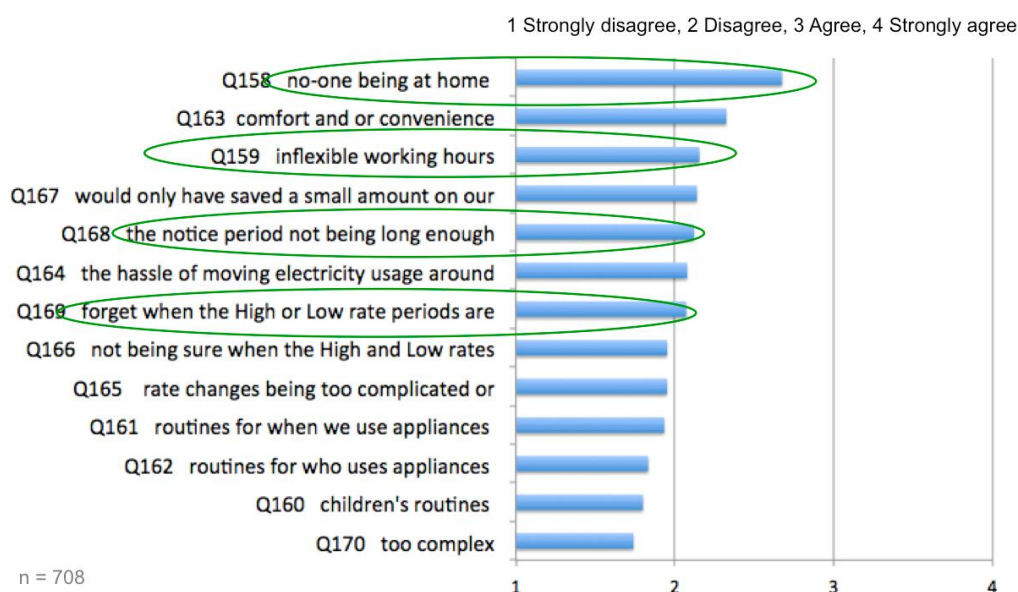


Figure 4.27: “Our response to Economy Alert High and Low rates has been limited by...” (ranked averages, non-responses ignored, n=708)

Two other points worth noting from Figure 4.27 concern the tariff design and delivery: household flexibility being limited by “the notice period not being long enough” was also mentioned by some interviewees but it is perhaps at odds with “forget when the High of Low rate periods are”, though improvements in the notification systems could probably resolve this (e.g. sent to mobile phone for all households).

Some potential solutions to the limitations identified above are suggested by the responses to a question asking about possible additional support for flexibility imagined in the future (Figure 4.28). Again possible improvements to feedback and notifications figure strongly in responses, many of which have mean score between “A little helpful” and “Very helpful”, indicating strong interest among respondents. All of these offer potential insight into how DR might be further increased through appropriate additional support.

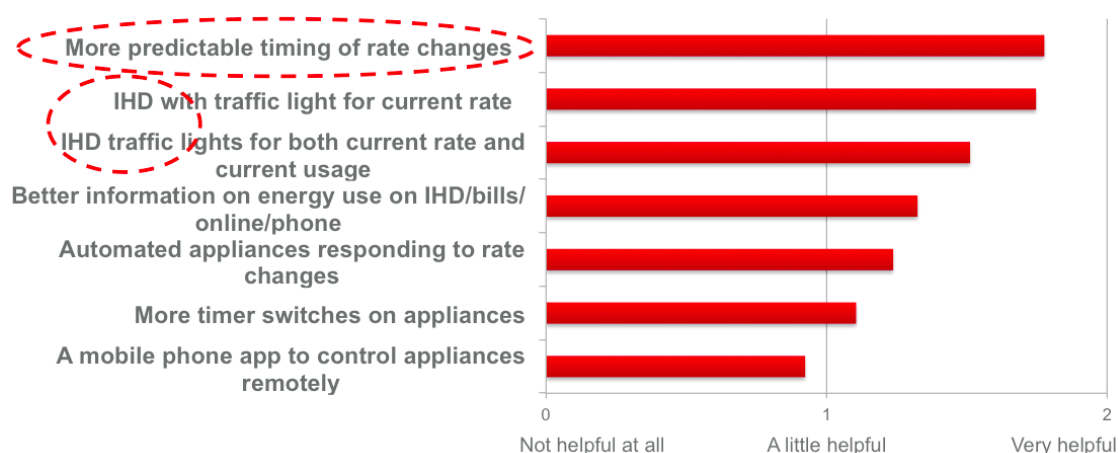


Figure 4.28: Which of the following do you think your household might find helpful in the future for responding to High/Low electricity rates? (n=708)

The most strongly endorsed suggestion for helping households respond, however, is for the schedule of rate changes to be more predictable and this raises a fundamental question for dTOU. The defining characteristic of dTOU for supply-following is its unpredictable nature which distinguishes it from fixed TOU aimed at shaving static peaks. It appears a potentially serious issue that having **more predictable timing** of rate

changes was the most commonly endorsed suggestion (from a list of seven) of things that might help their household respond better in the future.

In a similar survey item, trialists were asked, “How would the following possible variations to the tariff affect your interest in signing up?”. 68% responded that they would be ‘more likely’ or ‘much more likely’ to sign up, “If the High and Low rates were more predictable, e.g., Low rate every Sunday” (Figure 4.29).

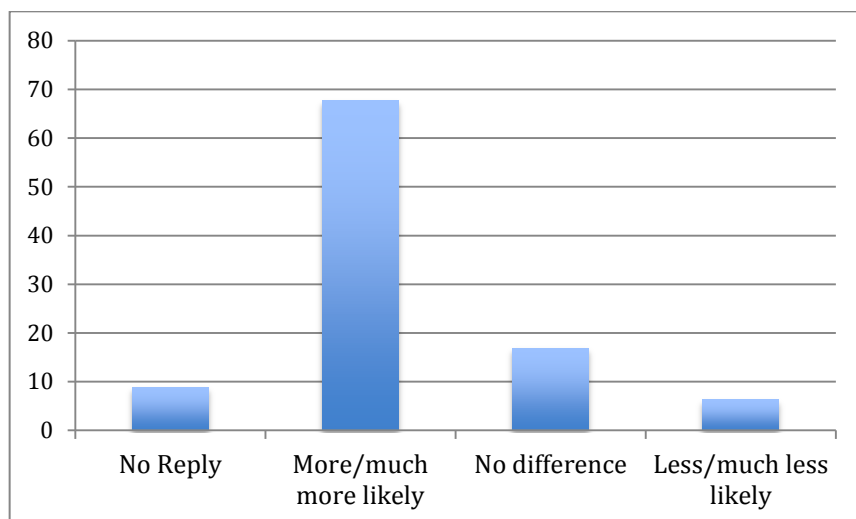


Figure 4.29: How would the following possible variations to the tariff affect your interest in signing up? If the High and Low rates were more predictable, e.g., Low rate every Sunday (% , n==708)

However, this does not mean that they would not sign up and responses must be seen alongside other survey responses such as the very common wish to remain on dTOU and also other more positive interpretations of aspects of dTOU such as unpredictability, complexity and difficulty. These will be discussed in the following section.

4.6 The need to communicate reasons for dTOU rate schedules

The price change schedule for the dTOU trial aimed to mimic scenarios of price fluctuations due to supply-following and also network constraint event. Households on the trial did not receive an explanation of why retail prices may fluctuate based on different scenarios in the energy systems and no mention was made of renewable energy informing, even in a simulation, the price signals they received. The schedule, of course, did not follow the set pattern of a fixed TOU schedule aimed at peak time consumption and was unpredictable.

This unpredictability and lack of explanation behind the scheduled events lead many trialists to speculate in the interviews and surveys about the possible reasons and motivations of EDF Energy for, as they saw it, choosing the timing of the High and Low rate periods. There were some comments about spotting, or trying to spot, patterns in the more-or-less random schedule and many comments such as those below which revealed scepticism and cynicism about the supplier’s motives:

- **I don't feel, how do I say, this is all been done with consumer in mind or with the environment in mind** and I suspect there's also a healthy amount of, well, if we play around enough, we will probably be able to **increase our profits** in the future because people won't really know what's happening. (interview)
- **I just need to know that it's been done for an efficient reason**, if the efficient reason is the wind, that's good, it could be another efficient reason which I would be equally happy with. (interview)
- I sense that there are times when Low rates are **given** at inconvenient times, and there are high rates **aimed** when appliances have to be used
(dTOU Survey free text response)

There was clearly frustration with the combination of unpredictable events and no forthcoming explanations. The comments are unsurprising in the light of the prevailing lack of trust in energy markets and suppliers: Ipsos MORI (for DECC, Oct 2013) noted public scepticism that benefits of smart meters would be shared with customers and other reports have highlighted cynical attitudes towards energy companies and complex tariff structures (Navigator for DECC, 2012).

One of the clearest implications for dTOU from the trial is that to maximize engagement with dynamic, unpredictable schedules there should not be a vacuum of explanation or scepticism and cynicism will tend to rush in, especially regarding the inconvenient timing, frequency and duration of high rate periods.

A key follow-up question to this finding concerns which reasons would motivate households to accept and engage with dTOU tariffs? Trialists were asked the following question, *"If in the future, you were offered a multi-rate tariff similar to Economy Alert, which of the following would describe your motivations for signing up?"* (tick any/all that apply)" (Figure 4.30). Unsurprisingly, "reduce energy bills" was the most commonly endorsed motivation (~87%) but 69% of the 708 respondents indicated they would be motivated by "help society use energy more efficiently" and 59% by "support more renewable energy".

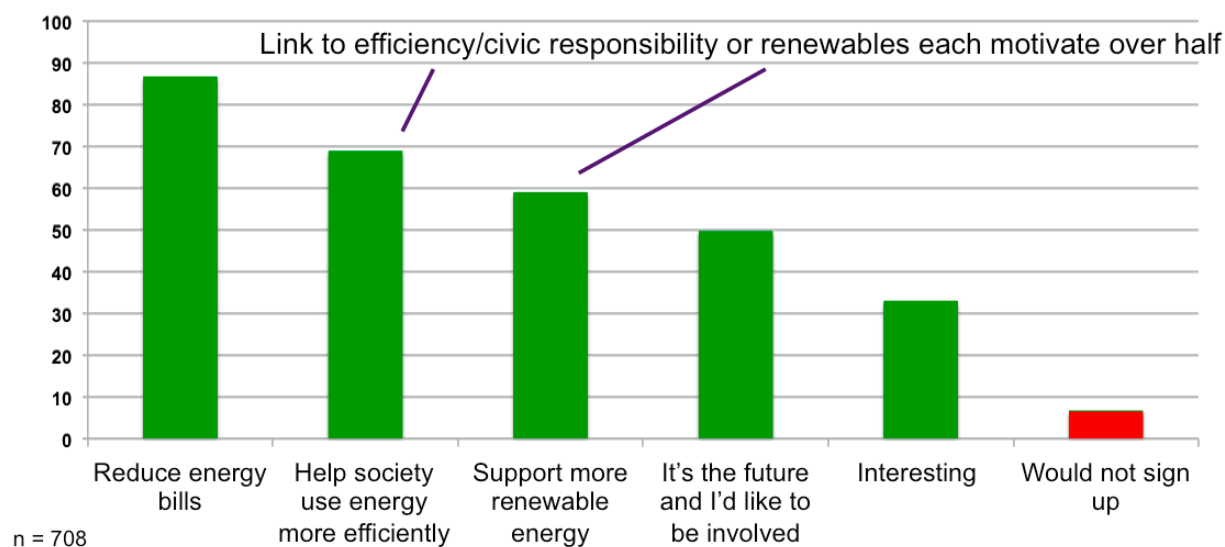


Figure 4.30: If in the future, you were offered a multi-rate tariff similar to Economy Alert, which of the following would describe your motivations for signing up? (tick any/all that apply; 5 options + 'would not sign-up')

Attitudes to renewables

Recent studies of public attitudes to energy report very strong public support for renewables (UKERC, 2010). A 2014 study found wind to be the most popular energy source in the UK (Harris Interactive, 2014)

In an 'Any other comments' free-response item on the Post-Trial Survey the following comment was made:

- *I like the idea of using electricity when it is being generated cleanly*
(Survey free-response)

Looking at this potential to engage consumers in dTOU through their support for renewable energy, when trialists were asked if linking dTOU rates schedule to renewables would make them “more likely to sign up to the tariff”, the majority (59%) agreed (Figure 4.31).

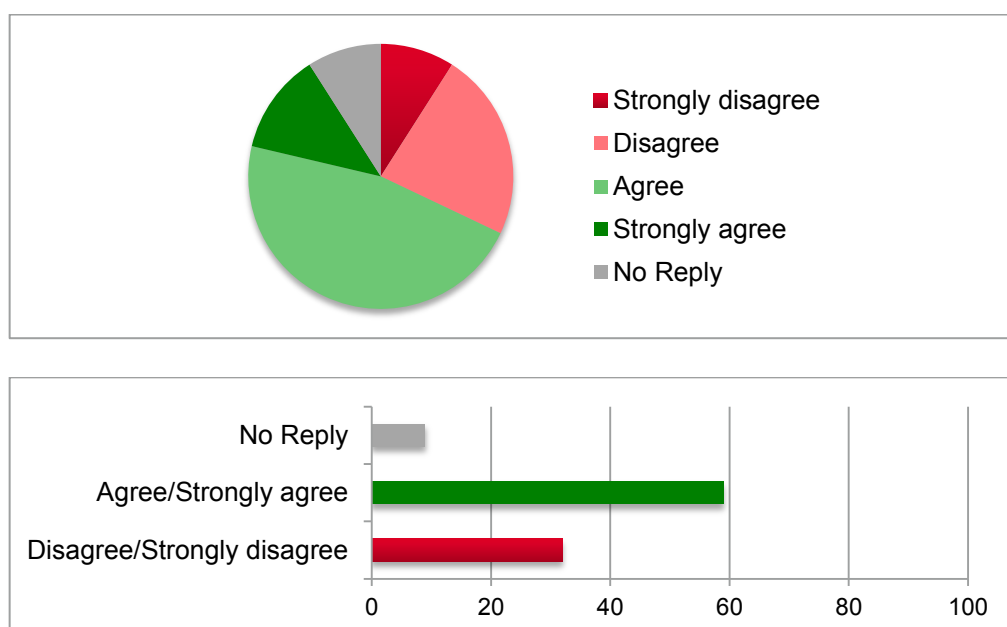


Figure 4.31: How would you feel about the price changes being linked to the varying generation of wind and solar power in order to support more renewable power? This would make me more likely to sign up to the tariff (n=708)

Furthermore, when they were asked if such a link would make them “more likely to try to adapt my behaviour to the price changes” (Figure 4.32), 60% indicated either agreement or strong agreement. This is further indication of the potential of engaging consumers with dTOU with narratives which are not only about financial savings they can make but which invoke their values about efficiency, citizenship, long-term goals and renewable energy [5].

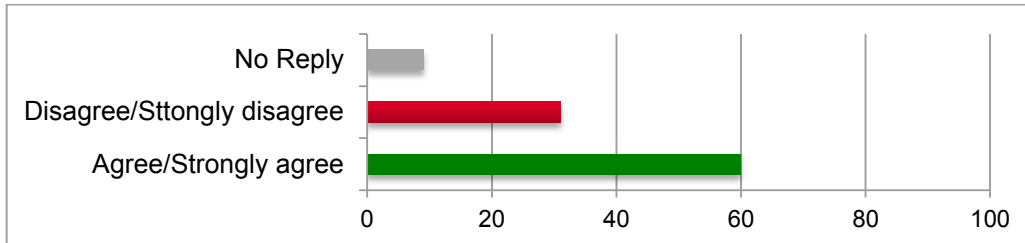
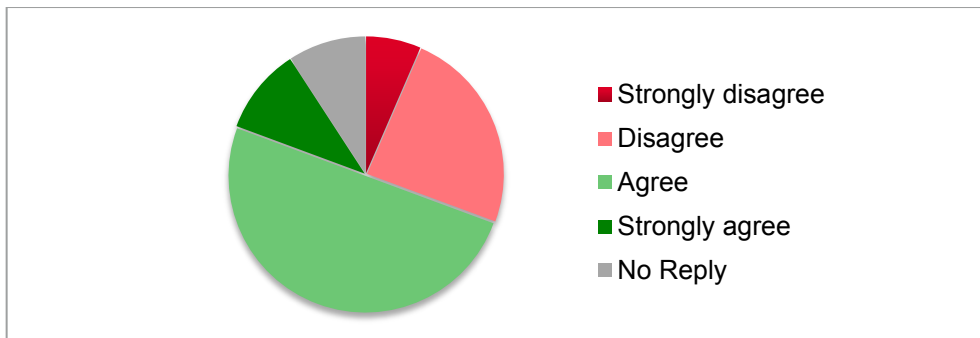


Figure 4.32: How would you feel about the price changes being linked to the varying generation of wind and solar power in order to support more renewable power? This would make me more likely to try to adapt my behaviour to the price changes (n=708)

It is likely that motivation and engagement would be enhanced further if motivations were combined: the earlier finding that trialists found the price signals helpful for motivating them to get household activities/chores done might well be amplified if the High and Low rate periods had the added meaningfulness of also being linked to supporting renewables and efficiency.

Having established that households might be engaged with dTOU for financial savings or to support renewables and or be a responsible citizen, the following two section of this report will examine questions around whether trialists found dTOU difficult, complex and too much hassle, or perhaps found some personal satisfaction, benefits or enjoyment in the experience.

4.7 Complexity, challenge and motivation

4.7.1 Complexity

There has, rightly, been much attention by the regulator in recent years in the UK on simplifying over-complex energy tariffs in order to make them more transparent, fairer and more competitive [29]. Dynamic TOU, with its multi-rate structure and unpredictable schedule of rate change is by no means a simple tariff and accurately estimating future costs without knowing either the schedule or the degree of household flexibility is difficult. Many interviewees admitted that calculating costs on dTOU and comparing with other tariffs was far from simple but the dominant view was of finding the tariff simple to live with:

- Trialist:** Funnily enough **the tariff itself is very straightforward** isn't it? It's very expensive or middling or very cheap.
Interviewer: Yes.
Trialist: And **I find that very easy to follow**. The thing that's difficult is to check your consumption because of the way the billing comes through. And that's not actually that tariff

(Interview)

- *Trialist*: Yes, I don't think it is ... **it doesn't come across to me as complex**, in fact what I was saying to this guy on the phone was I would love to be able to see some options. (Interview)

In survey responses (Figure 4.33), 79% of respondents disagreed with the statement, “*Our household finds the Economy Alert tariff too complex*”. In the current UK context of efforts to make energy tariffs simpler and more transparent under Ofgem’s retail Market Review, findings suggest that greater consumer engagement supports greater acceptance of, or even an appetite for, some types of complexity and the two need to be seen in tandem. The previously-discussed finding on the importance of communicating to trialists the *reasons* underlying rate changes in the schedule underscore the need for transparency more than simplicity. Consumers may prefer a more complex tariff if they see clear benefits to it and have trust in it.

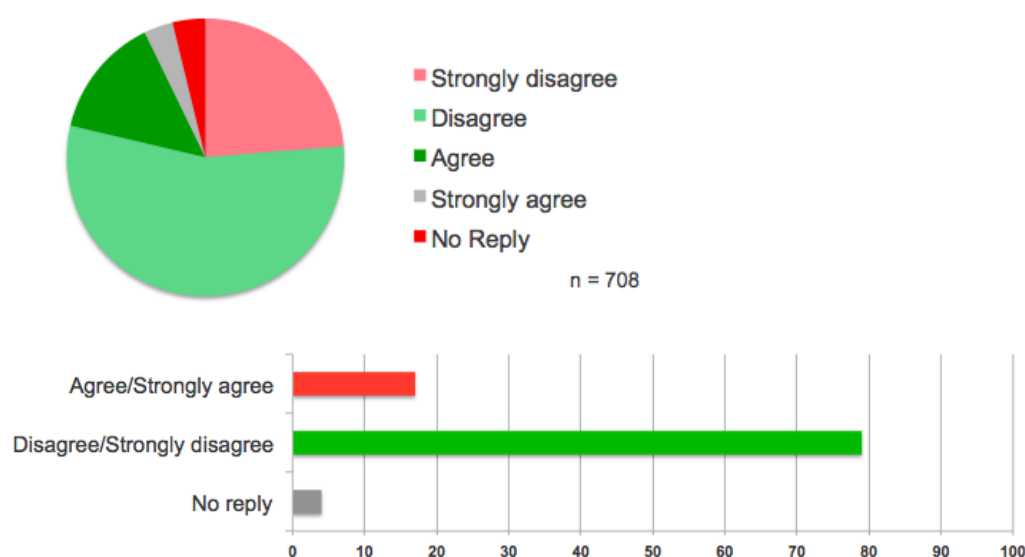


Figure 4.33: *Our household finds the Economy Alert tariff too complex* (n=708; dTOU Survey)

4.7.2 Ease/difficulty of responding to rate changes

An issue related to the perceived complexity of the dTOU tariff is how difficult it was for trialists to respond to the price signals. Interviewees’ comments on this subject included:

- *Trialist*: I think you just do try if you are aware then you do change your habits but it is not difficult to do so, not at all. (Interview)
- *Trialist*: Oh yes, after six months it comes pretty much part of daily life.
Interviewer: And not sort of weird?
Trialist: No not at all. (Interview)

Survey responses to the question, “Taking advantage of the Low rate electricity is easy”, indicated that 60% of respondents agreed with or strongly agreed with the statement with only 5% strongly disagreeing (see pie chart Figure 4.34).

Taking advantage of the Low rate electricity is easy

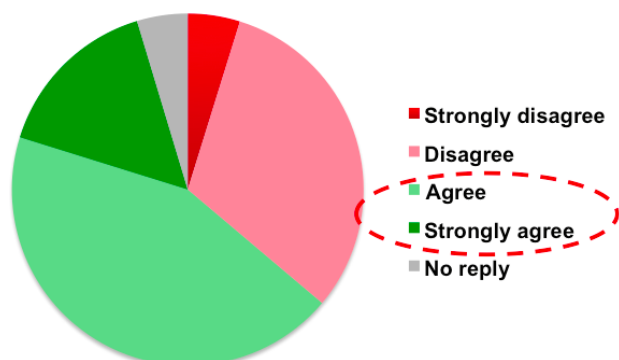


Figure 4.34: Taking advantage of the Low rate electricity is easy (n=708)

Similarly, for survey responses to the question, “Avoiding the High rate electricity is easy”, 50% of respondents agreed with or strongly agreed with the statement with 8% strongly disagreeing (see Figure 4.35).

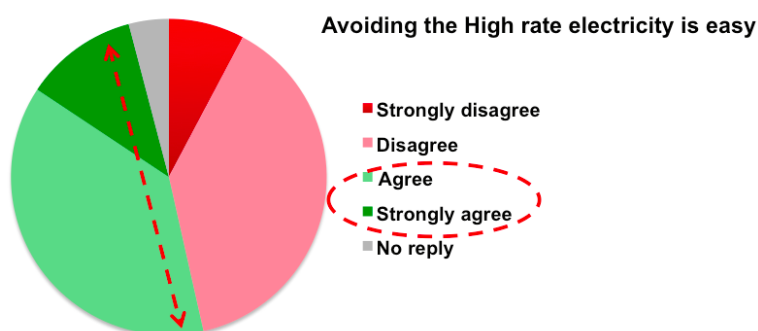


Figure 4.35: Avoiding the High rate electricity is easy (n=708)

It may yet be argued that a sizeable minority reported not finding dTOU easy to adapt to but two points can be made in this regard:

Firstly, easy or not, only 18% of responding trialists reported that they did not want to remain on the tariff if it had been possible. This is again illustrated by responses to the survey item, “Avoiding the High rate and chasing the Low rate periods is more hassle than it's worth”, Figure 4.36. Only 28% disagreed that the tariff was worth the hassle though awareness of the benefits, at least financial, was imperfect at that time.

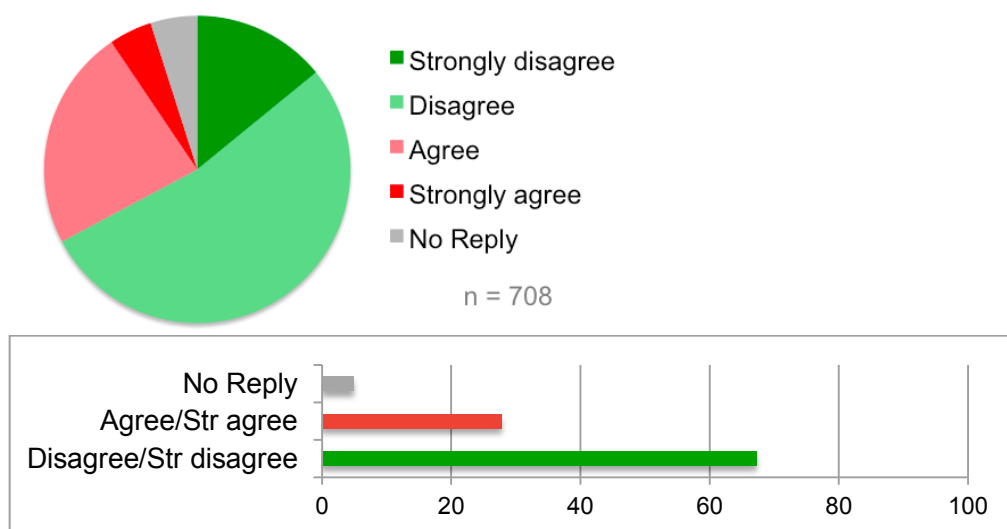


Figure 4.36: *Avoiding the High rate and chasing the Low rate periods is more hassle than it's worth* (n=708)

Secondly, just because adapting to the dTOU was not easy for some households, does not mean it was considered too difficult or that a degree of difficulty or challenge is always experienced negatively, as will be discussed in the next section.

4.7.3 Challenge/game/task/project

Although there has been a clear need to reduce the number of tariffs on the market and make them easier to compare, the drive towards simplifying tariffs should not assume the best tariff is the simplest tariff. Some interesting comments from interviewees and from surveys indicates that some trialists enjoyed some aspects of adapting their behaviour to the rate changes and that the effort required to meet the challenge was a necessary part of that.

- I'm very happy to go along with it but saving a few quid isn't the motivation really, it's partly environmental and partly just an interest in it as a **project**. You know and if we're doing it and wanting to do it well, you know. (Interview)
- Well I wanted to see ... there was a **challenge** to it, I wanted to see that we could actually make a difference with it and so we did talk about it and I said it might be a bit of a pain at some time but I want to see if we can make it work and see what the difference is. (interview)
- So there's really nothing to lose which is quite nice really, it makes it like I was trying to explain earlier it makes it seem a little bit more like a **game** you know, to try and play it in a good way but there's nothing to lose if you couldn't care less or if you've got it wrong, you still can't lose out. (Interview)
- Yes all those three things I think yes. Yes treating it as a **project** you know. (Interview)

A survey item was included in the last survey in order to gauge what proportion of the trialists experienced the price signals/schedule as feeling in some ways like a challenge or game. Unfortunately, due to errors in printing copies of the survey this question was left out of version sent out but this remains an interesting avenue to explore in dTOU.

4.7.4 dTOU helped in organising, planning and motivating activities

Husband: *Well when you were- you have got a lot of ironing and washing –it was on a Saturday and we were on a low rate on a Saturday **and I got the ironing board out and was racing through my shirts and it was five to eleven** and because it wasn't going to go to high it was only going to go to normal and it got to five past eleven and I had one more shirt and I was like 'oh my God I am going over my budget, I am going over my time. [laughing]*
 Wife: *I don't do that.*
 Interviewer: *It's a great image.*
 Husband: *But I was all very aware of it, you know and **I was quite pleased that I got through it in that time.***

Partly on the strength of interview comments such as these items were included in the survey asking about whether dTOU price signals actually helped consumers to plan and get chores done. 80% reported that dTOU did help motivate them to get chores and other household activities done, with only 7% disagreeing (see Figure 4.37).

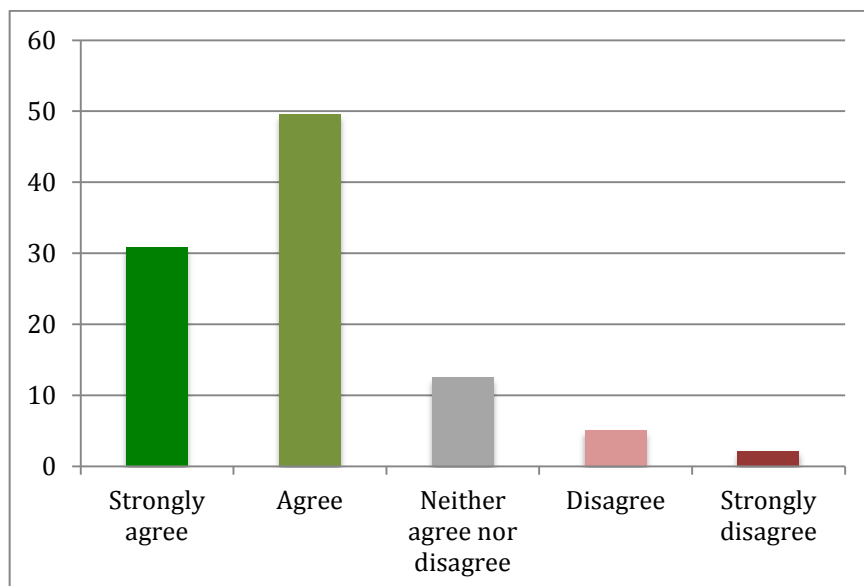


Figure 4.37: The Low rate alerts were good for motivating us to get household activities/chores done (%n=416)

In a more general sense, trialists also overwhelmingly (76%) reported that the price signals do help with planning and organising household activities/chores (see Figure 4.38).

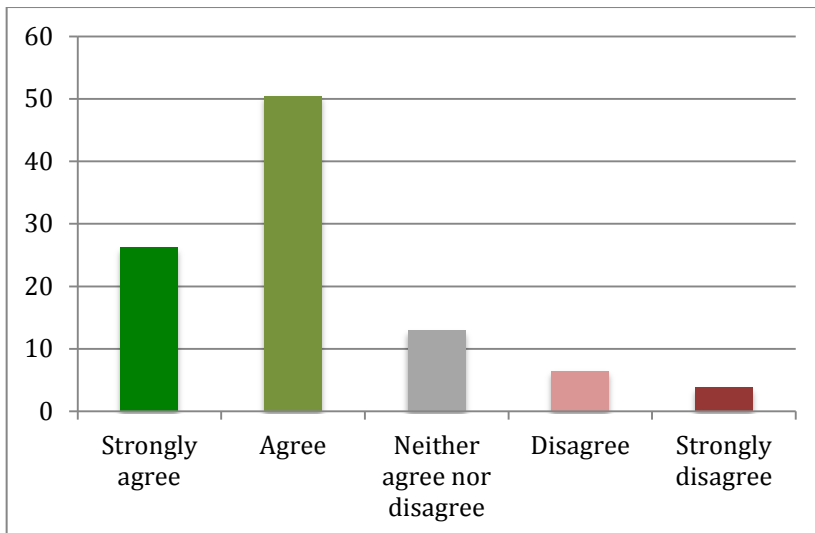


Figure 4.38: The Low and High rate alerts helped our household in organizing, planning or remembering to do household activities/chores (% , n=416)

In an 'Any other comments' free-response item on the Post-Trial Survey the following comment was made which further underlines the perceived benefit of the structure the price alerts gave for planning, organising and motivating activities/chores:

Motivation

- *Yes motivating us to do household chores*
- *organising chores – motivation*

Organisation

- *Again washing. Doing washing on a low rate helped me keep up with the weekly load*
- *Helped us all to be more organised with using appliances etc.*
- *The greater organisation from throughout the household*
- *Being organised re washing etc.*
- *Working out low energy and trying to do everything using electric at this time*
- *low tariffs where I got a lot done. The planning element - even with 24 hr notice you could still plan some things ahead*
- *It was strange going to regular tariff that I had to think for myself (Wash on)*

The final comment above ("*I had to think for myself*") is interesting as it turns on its head the more common depiction of planning activities around day-ahead price alerts as requiring *more* thinking and conscious planning. Here, the price alerts are heard as helping to make decisions and plan activities/chores.

While dynamic TOU does not foster or permit pre-planning, organising and developing a *fixed routine* for activities the price signals are considered helpful in some way for structuring when things get done. It is possible that the unpredictability of dynamic price signals is more motivating than those of fixed TOU which might become routine. This is one of the perhaps unexpected sources of potential satisfaction to be derived

from the dTOU but it would be interesting to explore the possibility that dTOU lends itself to some subtle forms of gamification in order to increase engagement. The next section looks at other indications that trialists found some aspects of being on Economy Alert positive and enjoyable.

4.8 Benefits and positive experiences of dTOU

Some of the benefits of dTOU have already been discussed –for example, financial savings and the reports that the price signals helped motivate and organise chores –but many other benefits were reported by trialists and include the following.

4.8.1 Increased sense of control over energy bills

The message used during recruitment of households for Economy Alert was, “Control how much you save”. A question was included in the dTOU Survey to assess whether trialists indeed felt more in control (Figure 4.39). 71% agreed or strongly agreed with the statement and only 4% strongly disagreed with the statement “I/We feel more in control of my electricity bill by being on the Economy Alert tariff”. More work is needed to explore further this increased sense of control but it may include the better feedback and awareness about their consumption and the sense that they are able to respond to price signals and thereby and make savings.

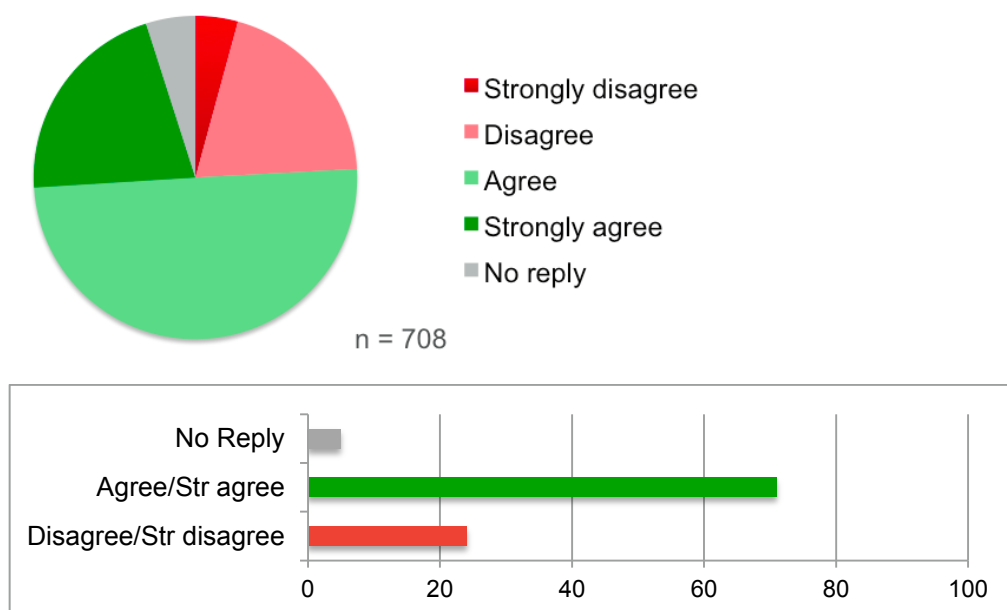


Figure 4.39: I/We feel more in control of my electricity bill by being on the Economy Alert tariff (n=708)

4.8.2 Enjoyment / Fun-factor

A number of trialists spontaneously used the word ‘fun’ to describe some aspects of their experience on dTOU (see interview quotes below).

*I think this trial has been great **fun** and of course we are, I believe financially better off. Thank you.*
(dTOU Survey free text response)

*But also just partly in as much as I’ve said it’s kind of a project with a certain amount of **fun** element in it.*
(Interview)

*So we’ve cooperated with it to quite a large degree, it’s been quite **fun** trying to make it work. So we now know that if we get a low tariff, if we get an advanced warning of a low tariff, we will never use the washing machine for any length of time you know.*
(Interview)

This fun-factor was not expected but when asked, over half (55%) agreed or strongly agreed with the statement, “I/We actually enjoyed some aspects of changing my/our routine or electricity usage for Economy Alert”, (Figure 4.40). For some respondents, the fun factor was linked to the previously-discussed accounts experiencing dTOU as a challenge, project or games.

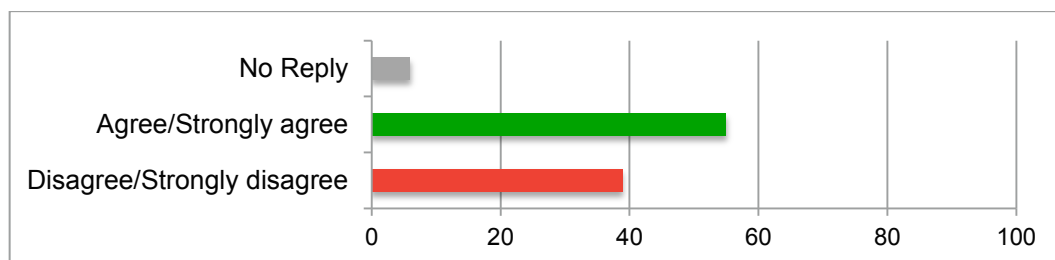
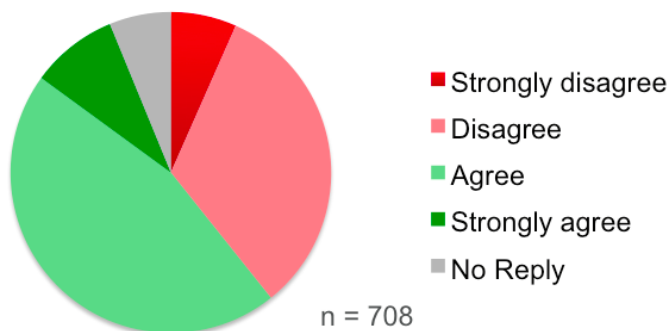


Figure 4.40: I/We actually enjoyed some aspects of changing my/our routine or electricity usage for Economy Alert (n=708)

Another survey item which aimed to assess, after the end of the trial whether trialists had enjoyed the dTOU experience asked, “Now that my household has switched back to a regular tariff I/we miss some things about the being on Economy Alert (apart from the savings)”, (Figure 4.41). 54% either agreed or strongly agreed with that statement.

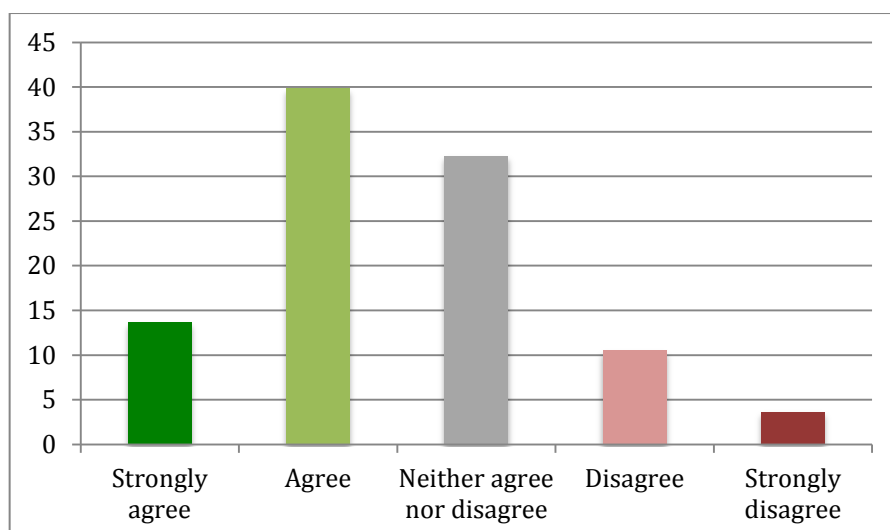


Figure 4.41: Now that my household has switched back to a regular tariff I/we miss some things about the being on Economy Alert (apart from the savings) (% , n=409)

In a free-response item in the Post-trial Survey asking about details of what trialists missed, examples of typical responses are given below. Very many respondents still mentioned the potential for financial savings despite the question asking for other aspects aside from savings. Also, many comments indicated that the added complexity of and effort of thinking about energy usage is not by any means always an unwelcome burden. Some topics asked about in other survey items also came out unsolicited in these responses, including organising/motivating doing chores and the link to renewables.

- *I miss having the opportunity to use appliances when electricity rate is lower*
- *Being forced to think about electricity usage*

One comment stressed the enduring, immediate effect of exposure to the dTOU high rate:

- *High rate was a wakeup call*

Many respondents volunteered comments on the survey about what they missed about the trial after it had ended – several other of these comments were quoted earlier in regard to helping people to organise, plan and motivate them to do their domestic activities/chores.

4.8.3 Educating younger household members

One final benefit which was mentioned by some interviewees and followed up in a survey item involved the educational and awareness-raising benefits of dTOU. The attitudes and behaviour of children, teenagers or young adults in family households sometimes exasperated their parents who struggled to impress upon them the cost of energy and the need to economise. Looking longer-term, parents commented that there was a real value to their offspring understanding the cost of energy before they left home and had to pay bills themselves.

In an 'Any other comments' free-response item on the Post-Trial Survey the following comment was made:

- *Allowed other family members to focus on energy usage*

77% of survey respondents who had young household members to whom this could apply (n=85) agreed or strongly agreed that, “Being on Economy Alert was a valuable experience for the teenagers/young adults in our household to learn about the costs of energy before they leave home and pay bills themselves”, (Figure 4.42).

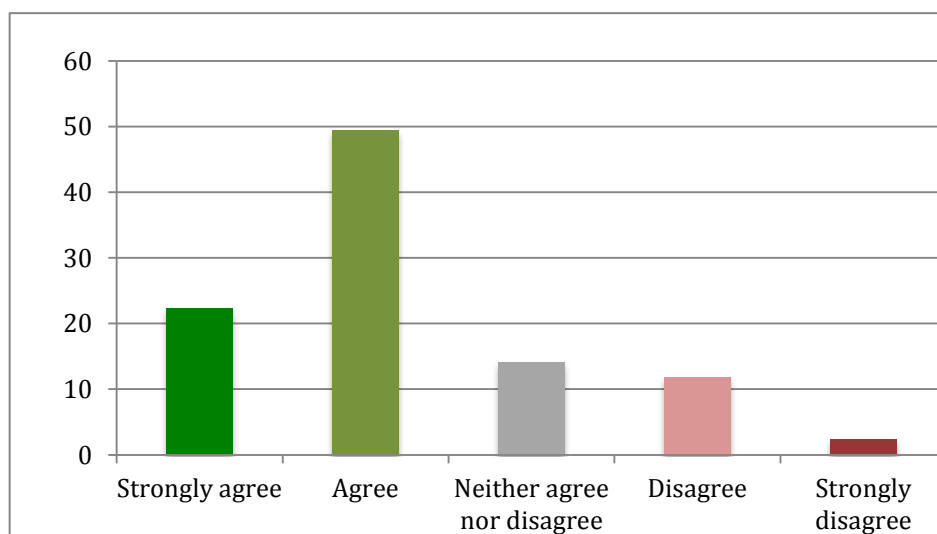


Figure 4.42: Being on Economy Alert was a valuable experience for the teenagers/young adults in our household to learn about the costs of energy before they leave home and pay bills themselves (% , n=85)

4.9 Other survey findings

4.9.1 Enduring effects

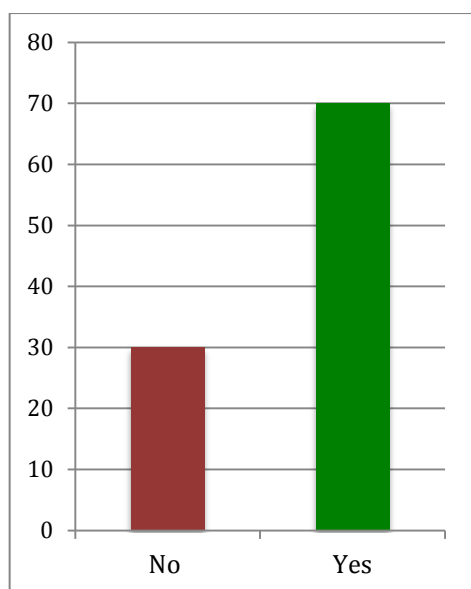


Figure 4.43: Thinking of the changes you made to the way you used energy while you were on Economy Alert, will any of these continue even though you have now gone back onto a flat-rate tariff? (% , n=416)

The responses to the responses on the Post-Trial Survey (see above figure), 70% of respondents made changes to their energy practices that would “continue even though you have now gone back onto a flat-rate tariff”, (Figure 4.43).

In a free-response item in the Post-trial Survey asking about details of enduring changes made, examples of typical responses are given below. Most fall in the area of reducing overall energy consumption, sometimes referring to better awareness of energy consumption and costs, but some also report the intention to continue to shift load off-peak even though the price signals and potential financial savings have ended. Although there is considerable overlap between them, the following attempts to break down these enduring changes in practices into a few sub-categories.

Reducing waste:

- *Boil Kettle water to quantity required. [...] Switch off lights where/when not required.*
- *More aware of using power wisely*
- *Checking the monitor & saving by boiling enough water for a cup of tea*
- *We are much more conscious of turning off lights*
- *Better use of washing machine and dishwasher and more economical i.e. kettle and lighting*
- *Turning off lights and general awareness about use of electricity*
- *I'm much more aware of the cost of each electrical appliance and use them accordingly*
- *Do not leave TV skybox dvd on standby anymore*

Doing things less:

- *Mainly, the immersion water heater will be switched on less often*
- *Not to heat up oven too long before using it. Switching lights off when leaving a room*
- *Only have hot water tank on half an hour instead of one hour*
- *Don't use washing machine so much*
- *Made us very aware of high cost usage i.e. electric fires, kettles, and washing clothes*

Doing things differently

- *Outside wind drying of clothes*
- *I try to cook in batches and always turn iron off before finishing.*
- *Not to heat up oven too long before using it*
- *use light wash [cycle] more*

Buying more energy-efficient appliances

- *energy efficient light bulbs*
- *Most bulbs changed to LED Bulbs.*
- *Using lower wattage bulbs, switching off as many appliances as possible (when possible)*
- *going back to a regular tariff gave me the impetus to have a Solar system installed*

4.9.2 Overall reduction

Earlier it was reported that the most commonly-reported action taken by survey respondents on the dTOU (“to take advantage of the Economy Alert rate changes”) was to use less lighting. In addition, many of the comments discussed in the previous section on enduring changes made concerned being less wasteful in their energy practices.

Unfortunately the smart meter consumption data collected on the trial was insufficient to adequately assess actual reduction in overall usage as a result of the trial. It is best practice to obtain smart meter consumption data for an extended period before the trial intervention, ideally 12 months. Even this does not control for possible differences in weather (in aggregated data) and occupancy patterns (for individual households) from one 12-month period to the next though could have been useful to help assess changes in overall consumption and in consumption patterns. As noted earlier, the meter installation schedule meant that the period available for obtaining baselining consumption data ranged from a few weeks only for some households to not more than a few months for any one household. However, some self-report data was collected via the surveys on overall reduction in consumption. Approximately 73% of respondents reported reducing their household’s overall electricity consumption due to dTOU (Figure 4.44).

*Being on the Economy Alert tariff has lead to our household **using less electricity overall***

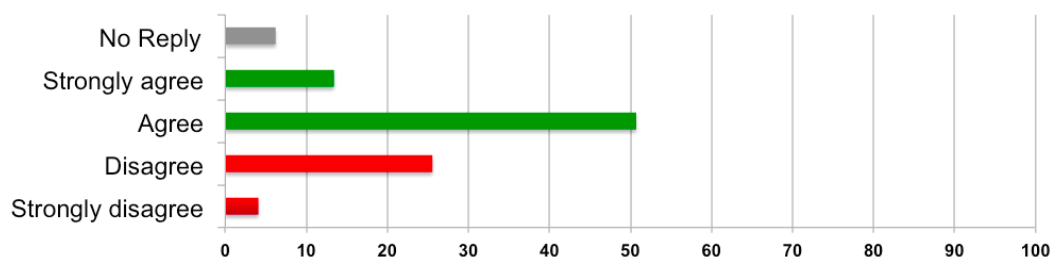


Figure 4.44: Using less electricity overall (n = 708)

4.9.3 Community energy

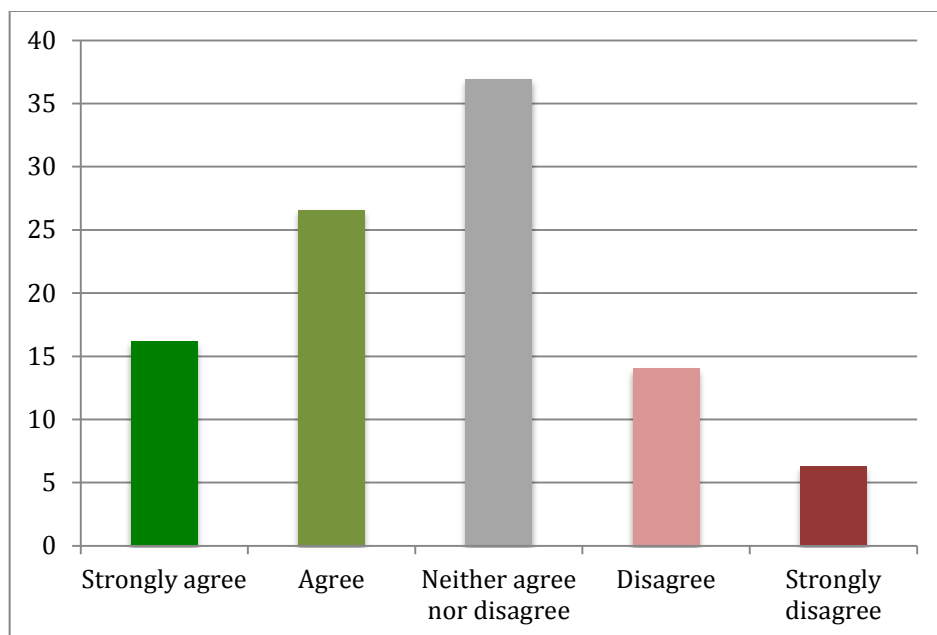


Figure 4.45: Our household would probably be more interested in going back onto a tariff like Economy Alert in the future if a group of local people got together to do it (% , n=414)

This survey item was added to explore in some small way the issue of community energy, which is attracting increasing attention in the UK, and to gauge the potential for this to make dTOU tariffs more acceptable to consumers. For over 40% of respondents (Figure 4.45), signing up to a dTOU tariff as part of a group of local people would be more attractive than doing so alone. The approximately 20% who disagreed may or may not be interested in dTOU but would not necessarily be put off dTOU due to a community-level offering. On this basis such an approach could have no downside for take-up rates. The perceived benefits and or lower risks of acting with a group could be explored further.

4.10 Characterising flexible and inflexible households

There is great variety and complexity in the electricity consumption levels and patterns across UK households. An important question for many stakeholders in the demand response area is how to identify which households or which types of households are likely to be most responsive to smart tariffs and which will be least responsive. This would be useful to inform suppliers about take-up of these tariffs and for both suppliers and DNOs to predict the DR delivered at different times and in different areas.

4.10.1 Variation in household responsiveness

There was considerable variation in the size of response seen in different households:

- Overall, the range of DR performance was large; the best 25% households produced three times the DR of the mean
- For Low-rate events more than High-rate events better responders far outstripped the full group mean in their demand increase.

- For events mimicking constraint management scenarios (with high and low pricing being combined into the same event) resulted in peak reductions ranging from 4% to 10%, while the best quarter of responders achieved about 40% reduction in demand (almost 10 times that of the lowest responders)
- Better responsiveness to High rate events was associated with better response to Low rate events but this correlation was of medium strength only (Pearson r-value -0.356^{**} ; significant at 0.01 level, two-tailed; $n=922$).

The lowest-responding 25% of households actually respond in the wrong direction to High and Low price signals. Further analysis and investigation is needed to understand why these households actually use more electricity during High-rate periods or less electricity during Low-rate periods. It is unlikely to be due to confusion over the timing of events (at least some households had an issue with the IHD and the price schedule not being in synch due to changes for British Summer Time). It is also doubtful, though not inconceivable, that it is due to these households concentrating on reduction rather than shifting load (as though this could decrease DR for High events it would be likely to increase rather than decrease observed DR during Low rate periods). Alternatively, it may indicate one effect of the guarantee given to households that they would not be worse off, or might indicate a limitation with the model used for analysis. Also, whether the households who respond badly to High rates are the same as those households who respond badly to Low rates has not yet been established. The correlation between DR for Highs and DR for Lows is only of medium strength (-0.356) – far from a perfect correlation and allows for some households to respond differently to the High and Low price signals.

4.10.2 Responsiveness and demographics

Household ACORN Groups

<i>Household ACORN Group</i>	<i>ACORN Category</i>
A	Wealthy executives
B	Wealthy greys
C	Flourishing families
D	Prosperous professionals
E	Educated urbanites
F	Aspiring singles
G	Starting out
H	Secure families
I	Settled suburbia
J	Prudent pensioners
K	Asian communities
L	Post industrial families
M	Blue collar roots
N	Struggling families
O	Burdened singles
P	High rise hardship
Q	Inner city adversity

Table 4.4: ACORN Groups and Categories

Figure 4.46 shows the DR for Highs and for Lows for each of the ACORN groups A to Q.

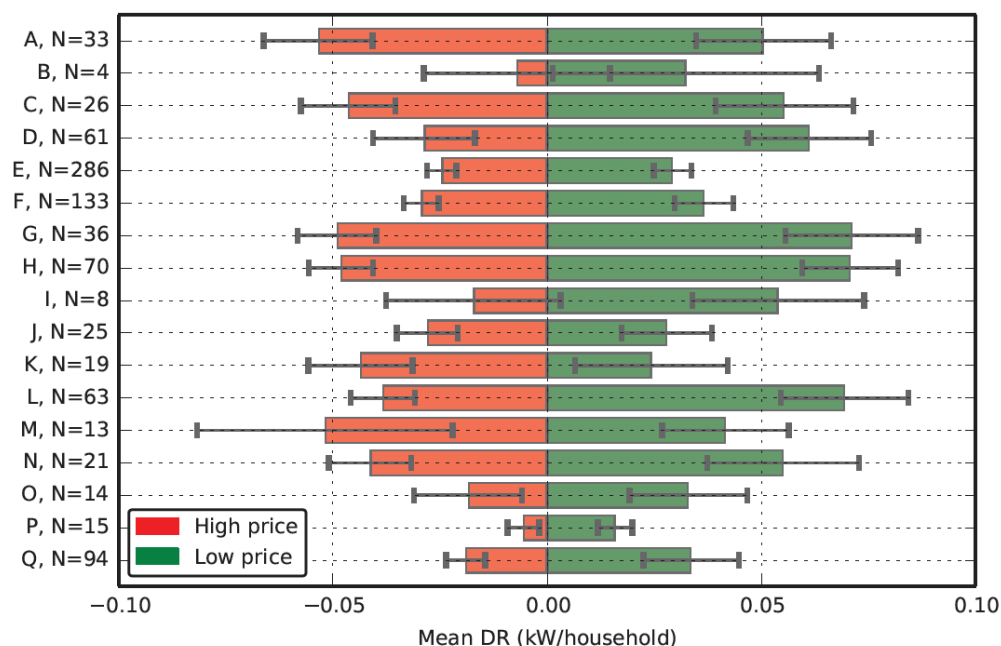


Figure 4.46: Mean DR by Acorn group. SF events only. N is the number of households in each group

Best responding ACORN Groups:

L (Post-Industrial Families), C (Flourishing Families), N (Struggling Families), A (Wealthy Executives), G (Starting Out), H (Secure Families)

Lowest responders:

P (High-Rise Hardship) (may be due to low n or low consumption?)
 B (Affluent Greys)
 O (Burdened Singles)
 Q (Inner City Adversity)

More responsive to High than Low:

K (Asian Communities)

More responsive to Low than High:

P (High Rise Hardship), B (Affluent Greys),

Breakdown by LCL Acorn Categories (Table 4.4) suggested a slight increase in DR as wealth increases. This is probably due to their higher initial consumption levels.

Strong associations between responsiveness and broad social classifications are as yet unconfirmed: the sample sizes are small for those ACORN groups who deviate from the mean. Further analysis of consumption and of survey responses for ACORN Groups B and P and others may suggest specific explanations for the observed differences in flexibility/responsiveness.

ACORN and household size (9-segments)

Figure 4.47 shows responsiveness to supply-following events according to a population segmentation using nine groups based on affluence and household size.

Comfortable 1-person households are the poorest responders to both High and Low-rate events. This segment was adequately represented in the dTOU group so the results above are not likely to be explicable by a small and anomalous sample of this type of household.

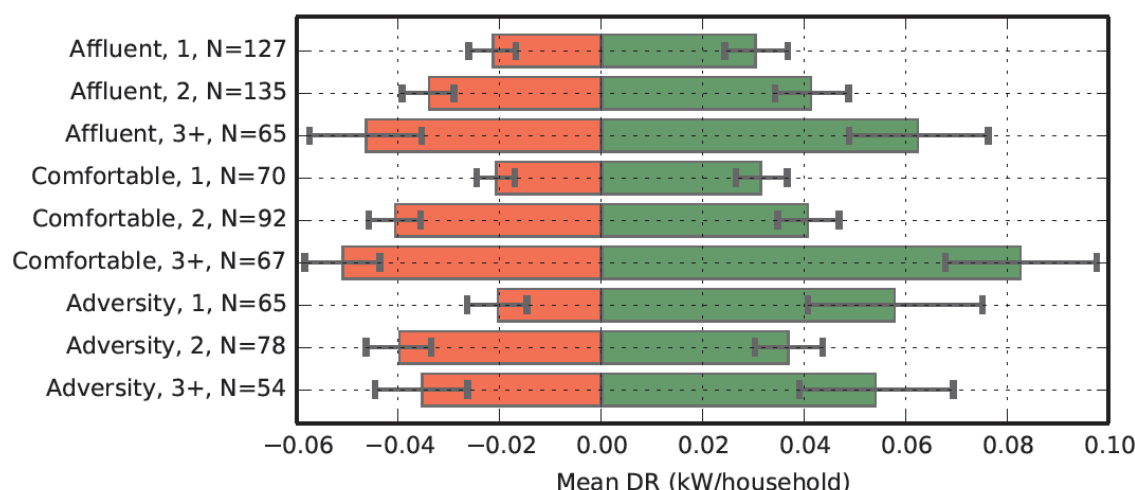


Figure 4.47: Mean DR (supply-following events only) by LCL ACORN and occupancy class
(Affluent: ACORN Groups ABCDE; Comfortable: ACORN Groups FGHIJ; Adversity: ACORN Groups KLMNOPQ)

Household size

The EDRP study found that larger households were less responsive to fixed TOU price signals than smaller households. There was a highly significant but very small correlation between the number of occupants in the household and the size of the DR for both High and Low rates (r -values around -0.1 , at 0.01 level for two-tailed test, pairwise deletion). Contrary to the EDRP findings, this small effect was such that larger households showed more, not less, DR for both High and Low rate events.

Larger households are also associated with greater annual consumption so the increased DR may be accounted for by the greater consumption: When DR is divided by annual consumption the correlation disappears. DR is linked to total consumption levels as much as household size is, though both are very weak predictors of DR.

Other associations between DR and household size are listed below – though it must be stressed *these are very weak links* which may emerge more fully with more detailed analysis.

Larger households have weak associations with:

- more responsiveness to High rate (-0.103) and Low rate (0.113)
- greater consumption (0.446)
- more full-time workers, working at home, and part-time workers but less Retired/Unemployed
- slightly less likely to want to stay on dTOU
- reported finding talking to other household members to plan DR more helpful but did it less often

- less limited by children's routines
- more appreciative of getting rate alerts sent to their mobile phone

4.10.3 Survey data and DR

Analysis was carried out to find correlations between DR and replies to survey items on the three surveys carries out with trialists. The strongest correlation was between DR for Highs and the sum across responses to items asking which appliances were shifted off the High-rate periods. The question asked was:

Q1. For this appliance, our household managed to avoid the High rate (Never/Occasionally/Half the time/Usually/Always)

And,

For this appliance, our household managed to move some consumption onto rate (Never/Occasionally/Half the time/Usually/Always)

The appliances in the question were: Washing Machine, Tumble dryer, dishwasher, Immersion water heater, electric oven, electric hob, ironing, electric shower, kettle, lighting, electric heater. All responses for appliances were summed for each responding household to give a metric for self-reported flexibility across appliances (Table 4.5).

		Pearson corr.	Sig. (two-tailed)	N	
DR_High/annual consump	Sum Q2–Q12 (avoiding Highs)	–.398	.000	608	Missing pairwise
DR_Low/annual consump	Sum Q2–Q12 (avoiding Highs)	.339	.000	608	Missing pairwise

Table 4.5: Metric for self-reported flexibility across appliances

Surprisingly, responses which report reducing load associated with various appliances during *High*-rate periods also correlate with DR_L but, reported shifting of extra load onto appliances during Low rate periods does not correlate with DR for Low or High rates. It is not clear why self-reports about shifting onto Low-rate should be less reliable, or less predictive of DR, than self-reports about shifting load off High-rate periods.

Other very weak effects between DR and survey data (Pearson r-value approximately +/-0.1)

- Self-reported behaviours about avoiding High-rate appear more reliable predictors of DR than reported behaviours during Low rate
- Households reporting retired/unemployed occupants are slightly better at moving onto Low rate (no effect on High rate)
- Noting alerts on a calendar was used more by households with Retired/Unemployed occupants
- Reporting finding dTOU enjoyable was weakly associated with DR for Lows but not DR for Highs

4.10.4 Summary

That only weak correlations/associations were found between DR and characteristics of the households is not surprising given the huge variation and complexity in household consumption patterns, appliance ownership, routines, needs, preferences, and resources for and barriers to flexibility. This variety further interacts with the variation in types and timing of price events (high/low rate, time of day, day of week, long-short duration).

Work on this topic will continue. Largely due to delays in data collection and storage it was not possible to pursue further this analysis in time for the report submission. Similarly, further work is also needed to characterise those households who tended to save most and those who lost financially in order to understand better the potential distributional impacts of savings from dTOU. Partly this extra work is needed due to issues in the design of the Economy Alert dTOU tariff price points which constrain the conclusions about savings made (see discussion of limitations of the trial findings in Section 5 Conclusions and Recommendations of this report).

Understanding the determinants of energy demand and demand profiles is notoriously difficult in the residential sector with family size, age, and lifestyle affecting both habits and appliance ownership. Demographic groups are valuable metrics because they can be applied to locations for which no other information is available except a postcode and thus could potentially be used by distribution network operators to identify likely patterns in demand. However, segmentation by behaviours rather than demographics may be more useful, though further work is needed here.

Other critical questions remain around how variation in responsiveness and the distributive effects of dTOU differ from those under fixed TOU tariffs.

It should also be noted that there are alternatives to approaches seeking to understand DR by characterising or segmenting at the level of households. Instead, insight comes from understanding patterns of needs and behaviours that cut across households and go beyond the simple characterisation and into the 'household dynamics' or 'what is going on in a household'[6] .

Analyses of the trial data are still on-going including work to explore the variety between households and associated practices and savings. This work will be disseminated in due course.

4.11 Caveats and limitations to trial findings

(See also Section 5.2: 'Recommendations for future dTOU trials and areas for further development')

No single trial can answer all questions and the LCL dTOU trial was the first of its kind in the UK. There are many areas for future work to improve and extend the findings of the LCL dTOU trial.

Also, a number of important limitations to the trial design should be noted which affect the conclusions that can be drawn from findings. Some were due to practicalities of delivering the trial in limited timescale and budget, some part of the compromises of a collaborative project, some caused by slippage in project timelines and some evident with hindsight. A few of these limitations have been discussed or introduced previously under sections on Trial Design or Findings but a more comprehensive list is attempted below:

4.11.1 Reasons why the trial may have under-estimated DR

How should the limitations of the trial affect the interpretation of the findings on responsiveness? There are a number of reasons to believe that the trial findings underestimate DR on dTOU.

1. **Exclusion criteria** for recruitment meant that potentially more cost-conscious and price-sensitive consumers (such as pre-payment metered and Dual Fuel customers) were not in the dTOU sample.
2. **Very broad sample** is likely to have decreased the mean DR as the trial sample included households not predisposed to dTOU who were incentivised to sign-up. DR among early adopters of dTOU is likely to be greater. A survey item asked trialists about the effect of the guarantee on their motivation to sign up and their effort to adjust their behaviour to the rate changes. The results (Figure 4.48) indicate that around 44% of trialists would not have signed up to the dTOU trial without the guarantee.

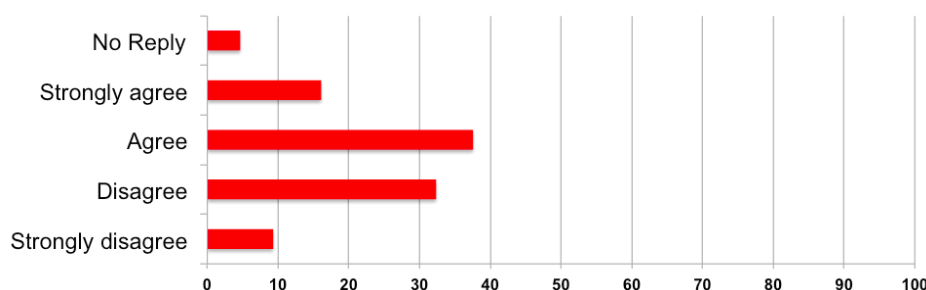


Figure 4.48: Without the guarantee that we will be reimbursed (if we spend more than the cost would have been on our previous tariff) I/we would never have signed up (n=708)

3. **Effect of guarantee on behaviour.** Further, the guarantee appears to have undermined the responsiveness of some households. Around 28% of respondents indicated that, “without the guarantee [...] I/we would have made more effort in responding to the High and Low rates”, (Figure 4.49) . If these self-reports can be taken to accurately reflect the effort households made with the dTOU tariff then the levels of DR seen on the trial would have been greater, at least for these households, without the guarantee.

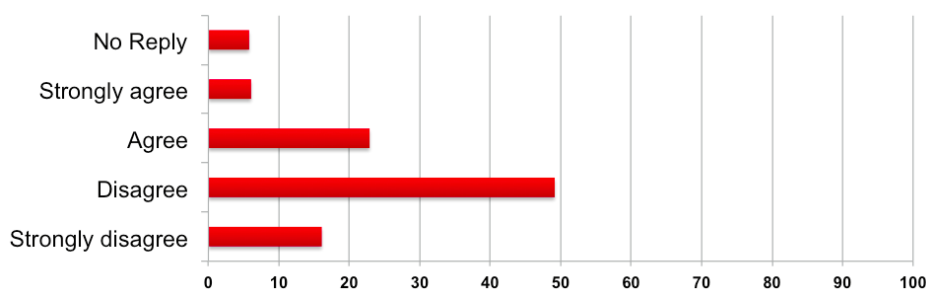


Figure 4.49: Without the guarantee that we will be reimbursed (if we spend more than the cost would have been on our previous tariff) I/we would have made more effort in responding to the High and Low rates (n=708)

4. **No explanation for tariff schedule and link to renewables** was given. A further reason to believe that greater effort on dTOU (and therefore more DR) could be seen in other trials is that 60% of survey respondents indicated that they would have been “more likely to try to adapt my behaviour to the price changes” if the tariff had been linked to supporting more renewable power.
5. **No on-going benchmarked feedback** on savings was given and so the motivating effects of good feedback were not seen in the trial.
6. **Advice on flexibility** and how to shift load was given on the trial. It is likely that some increase could be achieved if more information was given on the relative loads of appliances, and suggestions for changing practices, using timers etc.
7. **Time-limited nature of trial:** Trialists sometimes reported that they did not invest as much effort or resources into the trial as they would have done had it been longer-term. This could include buying energy-efficient appliances, bulbs etc. or appliances with functionality relevant to dTOU, such as timers. These actions include: buying energy-efficient appliances/bulbs etc.; investing in devices with timers or learning to use them; putting more effort into greater awareness of energy use; or trying to get uncooperative household members to be more flexible.
8. **Reduction in overall consumption** may have lowered measurement of DR for Highs. The high rate at least reportedly made many households reduce overall consumption. This reduction potentially has the effect of decreasing the load-reduction possible during specific high-rate periods. As the reduction in overall consumption was not measured (due to insufficient base-lining data) this emphasising effect of the High rate actually makes its local effects less apparent.
9. **Greater DR for dTOU in the future.** Whilst it is unavoidable that Looking to the future, it is extremely likely that the context for DR will be increasingly supportive in a number of ways.
 - *Technology to support shifting:* for feedback, automation and smart appliances; the development and take-up of more energy-efficient appliances for both non-shiftable consumption such as lighting may make even higher price points feasible. A virtuous circle is possible, or even likely, whereby innovation and take-up of technologies to support dTOU make more radical tariff design/price differentials acceptable in turn extending the cost-effectiveness of developing dTOU-supporting technology further.
 - *Increasing value of DR to the energy system* (and therefore size of price points and savings) will rise with increasing renewable energy capacity and therefore increase incentives for consumers to participate.
 - *The future electrification of heat and transport* will result in extra demand which will further support both of the aforementioned increasing value of DR (to DNOs perhaps especially) and the cost-effectiveness of the technology to help shifting.
 - *Changing norms:* as dTOU technology, tariffs and take-up advance together, greater public acceptance of the need, normality, fairness and feasibility of being flexibility in residential electricity consumption and perhaps ceding some control over some appliances (e.g. refrigeration) should see greater engagement with dTOU tariffs. There is little current awareness of issues such as the emphasising of costs of flat-rate tariffs and who gains and loses by them. Debates about cost-reflective pricing and the potential role for consumers to help in managing shared resources will unfold and are likely to support greater engagement.

4.11.2 Wider questions about the prospects of dynamic pricing

A final area beyond the scope of this trial report and an avenue for potential future research concerns the role of consumer attitudes to dTOU can play in the wider context of the energy system change. Studying consumer attitudes to time-varying pricing implies a tacit assumption that consumer attitude is a, perhaps *the*, limiting factor or driving force for such tariff-offerings to come to market. But how important are consumer attitudes, and what role do they have precisely, in the bigger picture of energy system reform and transformation? Knowing about consumer attitudes, though valuable, raises the question of the attitudes of other stakeholders to such smart tariffs and how these attitudes and the influence of these stakeholders may affect the chances of such new tariffs being offered, and in what form. Indeed, as Faruqui [13] points out, despite dynamic pricing attracting much interest among regulators and utilities and its potential for lowering costs “the deployment of dynamic pricing has been remarkably tepid” (p.13). The deficit model of behaviour change has been popular in framing consumer behaviour change. Is there simply a deficit in utilities’ understanding of their consumers and will demonstrable consumer support for dTOU lead suppliers to deploy it and other smart tariffs previously deemed too commercially risky?

Or will some consumers prefer to engage more actively with the energy market through community-based initiatives rather than waiting to take-up supplier-led tariff offerings? The much-discussed disengagement and disenchantment of the passive UK electricity consumer might actually come full circle if mistrust and cynicism at the main suppliers spurs consumers to re-engage through alternative arrangements.

5 Conclusions and Recommendations

The myths of dynamic pricing (Faruqui) assume that dTOU would be regarded by consumers as too complex, that savings are too small, that people do not want to have to think about electricity usage this much, and that they would not choose to stay on such a tariff or find it acceptable for others to be encouraged onto it.

None of these assumptions are supported by the self-reported data from trialists on Economy Alert who have been the first UK householders to actually experience first-hand, and for a whole year, a dynamic day-ahead electricity tariff. Indeed the opposite picture has emerged.

5.1 Main findings on consumer attitudes to dTOU

1. **Very positive trialist reaction to dTOU:** Perhaps the stand-out finding is the degree of positive reaction to dTOU from trialists who were, it is worth emphasising, quite heavily incentivised to sign-up to *Economy Alert* (as the LCL dTOU tariff was known) and therefore not necessarily pre-disposed in favour of dTOU at the outset. The list below shows the range of these positive endorsements of the dTOU tariff by trialists. It will be interesting to see, in the future, if these figures are affected by alternative price points and rate schedules but there is no reason to believe that these aspects of the Economy Alert tariff design were especially attractive. Indeed, certain changes to the tariff design used in the LCL dTOU trial could result in even greater levels of satisfaction (e.g., lower High-rate, fewer evening peak-time High-rate events, and better on-going feedback about savings). Findings include original insights into some non-financial and more psychological benefits to consumers.

Two points worth emphasising from the table below are:

- **Strong acceptance and support of dTOU:** One of the most impressive findings from the survey was the very high rate of endorsement of this item (91%) and, moreover, agreement that dTOU “should be the standard tariff for everyone” (81%). This indicates strong potential support for cost-reflective pricing which is viewed as fairer and/or promoting efficiency. Awareness and debates about cost-reflective pricing have some way to go but this is an extremely encouraging starting point.
- **dTOU was not experienced as complex:** Despite the admission that calculating costs and comparing with other tariffs is far from simple, 79% reported that Economy Alert was not experienced as complex in the course of living day-to-day with the tariff. In the current UK context of efforts to make energy tariffs simpler and more transparent (under Ofgem’s Retail Market Review), findings suggest that greater consumer engagement supports greater acceptance of, or even an appetite for, some types of complexity and the two need to be seen in tandem. The importance of communicating to trialists the reasons underlying rate changes in the schedule (see below) further underscores that in some cases transparency is more important than simplicity.
- **dTOU helps households in planning and organizing (77%) and motivating them (80%) to get chores done.** This was one of the most striking survey results. In contrast to fixed TOU price signals occurring at the same time every day, it is possible that some of the motivating aspect of dTOU is linked to the unpredictability and complexity of the schedule. Many trialists spontaneously reported experiencing an element of fun, challenge or game-like aspects to fitting behaviour around the dynamic High and Low rates suggesting that dTOU has greater potential than fixed TOU for subtle gamification.

- **Trialists valued the educational role of dTOU, especially for young household members.** 77% of survey respondents who had young household members to whom this could apply (n=85) agreed or strongly agreed that, “Being on Economy Alert was a valuable experience for the teenagers/young adults in our household to learn about the costs of energy before they leave home and pay bills themselves”.

Survey statements about dynamic-TOU tariff	% Agree or Strongly Agree	% Disagree or Strongly Disagree *
Greater sense of control	71	24
Worth the hassle	67	28
Enjoyed some aspects	55	39
No reduction in quality of life	75	19
Do not find tariff complex	79	16
Effort sustainable long-term	79	15
Good for motivating us to get chores/activities done	80	7
Helped planning/organizing/remembering activities/chores	77	10
Taught young about the cost of energy	71	14
We miss some things about being on dTOU	53	13
Some new practices persisting beyond end of trial	70	30
Reduced overall electricity consumption	63	30
Renewables link would make me more likely to sign up	59	32
Renewables link would make me more likely to adapt behaviour	60	31
Would want to stay on dTOU	77	18
dTOU should be offered to everyone	91	5
dTOU should be the standard tariff for everyone	81	14

Figure 5.1: Summary of trialists’ pro-dTOU attitudes and perceived benefits (n=708)

(* ‘No Replies’ and ‘Neither agree nor disagree’ not shown)

2. Explanation of reasons behind dynamic TOU is required:

- **Ambivalence about unpredictability:** The characteristic of dTOU for supply-following that distinguishes it from fixed TOU is that the times of rate changes are unpredictable. It appears a potentially serious issue that having more predictable timing of rate changes was the most commonly endorsed suggestion (from a list of seven) of things that might help their household

respond better in the future. 68% reported that they would be more likely to sign-up to dTOU if the rate changes were more predictable. But this must be seen alongside other survey responses – both the predominant wish to remain on dTOU and also more positive interpretations of superficially negative aspects of dTOU such as unpredictability and complexity.

- **Communicating the reasons behind the rate changes will increase engagement.** The schedule of rate changes on the dTOU trial was unpredictable and no clear explanation was provided to trialists for why the rate was higher at some times than at others. In interviews and surveys some trialists reported irritation with the schedule and its lack of transparency and the suspicion that the rate changes were scheduled to benefit the supplier. This is unsurprising in a context of consumer mistrust of suppliers [4] and scepticism that the benefits of the smart grid will be shared with consumers [2][18] but the unpredictability of dynamic TOU schedules brings these issues of trust to the fore. A strong piece of learning from the LCL dTOU trial is that consumers are likely to engage more with dTOU 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, and frustration to be expressed in the absence of explanations. If the rate changes are seen as happening at certain times for a good reason (“I just need to know that it's been done for an efficient reason”), then tolerance of the unpredictability, complexity, limited notice period, etc. appears to follow.

- **Efficiency, citizenship and support for renewables all have significant potential to engage consumers in dTOU**, as evidenced by the survey findings in this trial: 60% of survey respondents said they would be more likely to sign-up to dTOU and more motivated to be flexible if there was a link with renewables; almost 70% would be motivated by “helping society use energy more efficiently”. Earlier work on UK households’ attitudes towards energy system change also points to the importance of initiatives being seen as consistent with consumers’ values [5]. Survey responses also indicated that stimulating debate about fairness and efficient usage of resources would be a valuable step towards public acceptance and support for dTOU. This potential for engaging with households on the basis of their “civic relationship with the grid”[6], rather than purely narrow financial interests also has support from qualitative work for the another LCNF project, the Customer-Led Network Revolution.

3. Insights into what helped and limited households respond to rate-changes:

- **Feedback was well-received but improvements possible:** the IHD was found to be clear and useful for acting on rate-changes but suggestions for improvements were also common. Similarly, the monthly feedback letter was generally well-received but highlights even more the variation in preferences between different households. On-going feedback about financial savings made benchmarked against a flat-rate tariff was not given to trialists and this is considered essential for future trials (as it would undoubtedly be for a real-world commercial dTOU tariff). The most prominent suggestion for improvements to the IHD for dTOU were for it to have a traffic light display for present rate as well as or instead of for present load.

- **The use of timers for shifting was limited.** Timer functions/devices were reportedly used by only a small minority of households; even in households who owned appliances with timers, approximately 40% never used that function. Reasons for limited use of timers included their perceived complexity of use and the noise from wet appliances during the night. This suggests more user-friendly design, and improvements in acoustic insulation of appliances and or buildings could support greater use of

night-time surplus electricity.

- **Flexibility in who uses appliances is limited:** Although 21% of responding households on the trial reported making changes to who uses appliances in order to better respond to dTOU, approximately 20% of households agreed that having fixed roles for who uses appliances were a limiting factor and the fact that they were not able or willing to adapt these roles is potentially very interesting, both sociologically and from the point of view of increasing demand response (DR) in the future.

4. **The reported most/least flexible practices were as expected:**

- **Most flexible:** Wet appliances were reported to be the easiest to shift. Lighting, cooking and showering were reported as the hardest to shift, however some shifting of even these was reported.

- **Least flexible:** Interestingly, the supposedly hard-to-shift **cooking practices** are reported to be flexible (more than 'occasionally') onto Low-rate for 35–40% of trialists who owned electric oven or hob. However, further analysis will aim to check if these self-reports corresponds to actual shifting/ consumption behaviour.

5. **Reduction in overall consumption commonly reported but not yet assessed:** Further work is needed to corroborate this with actual consumption data but it is interesting in broadening-out the impact of dTOU beyond load-shifting practices and into a wider interest in greater efficiency, reduction/curtailment. Indeed, it is interesting that using less lighting came out as the most commonly-reported action to take advantage of rate-changes. This is a curtailment/reduction behaviour, not a shifting behaviour, which suggests potential links between dTOU and future take-up of low-energy (LED) lighting and other energy-efficient products and appliances.

6. **The self-reported data seems to be in agreement with the measured DR**, e.g., about which days/times were preferred for alerts but more cross-comparison of measured DR with survey responses will be carried out.

7. **DR on future trials should be greater.** For a number of reasons to do with trial design and the context DR should be greater in the future. These reasons include: the sample excluded some potentially price-sensitive types of households; recruitment was heavily incentivised so likely included households not disposed to dTOU (early adopters of dTOU would be more engaged and responsive); self-reports suggest that the guarantee of reimbursement if worse off may have reduced responsiveness in some households; better engagement and responsiveness are possible with better feedback and advice; the time-limited nature of the trial is likely to have reduced some forms of investment in the trial compared to an open-ended or longer-term commitment to dTOU; assessing the reduction in overall consumption was not possible and this is likely to have reduced the measured DR for high-rate periods; the future context for dTOU is likely to see increases in the value of DR and the technology and norms supporting dTOU engagement.

5.2 Recommendations for future dTOU trials and areas for further development

The following recommendations are made for future trials of dTOU tariffs. Some of the following points are discussed above.

1. **Provide a clear rationale and reasons for rate changes.** Clearly explaining the link between the rate changes on supply-following tariffs and renewable energy generation should increase engagement for the majority of trialists. This should also reduce frustration with unpredictability, complexity and the limited notification period. This will require a general increase in consumers' understanding and awareness of the energy system and market and the importance of resource management. Consumers should also feel (justifiably) confident about the fairness of both more cost-reflective pricing and also how the benefits from DR are being shared among stakeholders (consumer, supplier, DNO etc.), as suggested by the respondents and interviewees of this study and previous research [2],[5].
2. **Promote awareness and debate about the energy system.** Given very low levels of consumer awareness about almost all aspect of the energy system and the challenges it faces, promoting education and debate about these challenges, the need for change and more active consumers is highly recommended
3. **Link supply-following tariff to real-world conditions** of renewable generation (or a sample of past renewable generation data) so that the price signals are based on actual variability in renewables and demand. It would also be valuable in terms of trialling the back-office systems necessary to support this. It would be a challenge to add this layer is necessary to take learning towards a real-world, commercially feasible stage of development.
4. **Consider carefully the effect of price points on savings and feedback.** One of the clearest caveats concerns the limits to what should be inferred from the actual financial saving made by households on dTOU. This was largely a function of the competing aims of investigating responsiveness to dTOU and attitudes to it and the needs of recruitment. More detailed analyses of trial data are on-going and should produce some more definite insights but future trials should carefully consider the impact of tariff design and delivery on both the study of responsiveness and studying attitudes to dTOU tariffs. Better savings should lead to more positive, more motivating feedback to consumers.
5. **Participant Recruitment**
 - **Minimize exclusion criteria:** including some of households excluded from the LCL dTOU trial (pre-payment customers, dual fuel and some type of vulnerable customers etc.) would be recommended to allow better assessment of the range of distributional impacts especially for price-responsive or early-adopting households.
 - **Minimise effect of incentives on sample and behaviour.** In the LCL dTOU trial participants effectively self-selected to be in the dTOU group and also (by declining) to be in the non-TOU group. The preferred approach to recruitment depends upon the research questions and aims of the trial: if the trial wishes to see the distributive effects for a broad range of different types of households then recruiting a broad sample may be the main challenge and incentives justifiable. Ideally, random allocation of participants to control and TOU groups would be used but as this is often unfeasible, large incentives can also mitigate self-selection. If, however, the main interest lies in the behaviour of early adopters in a context as near to real-world as possible, then incentives should be avoided in so much as they could influence recruitment, behaviour and drop-out rates. There would be some merit in studying early adopters given that dTOU will be opt-in for the foreseeable future. LCL used

substantial incentives for recruitment to dTOU. While this helped recruit participants and also made a broader sample possible, minimizing incentives would be preferable due to the buffering effect of incentive payments on price signals and therefore behaviour. Recruitment in future trials should consider the possibility of dispensing with, or at least minimizing, incentives and guarantees. Dropping out of the trial would need to be possible, and uninfluenced by payments, in order to study churn rates, which was not possible on the LCL trial. As dTOU becomes less of a novelty, the need for incentives and guarantees should diminish.

- **Recruit directly onto dTOU trial.** In the LCL trial households were first recruited for smart meter installation and then dTOU trialists were recruited from this pool of households. As the smart meter rollout progresses it will be unnecessary to recruit in two phases and this will be more cost-effective, reduce self-selection issues (at least for the control group).

6. **Obtain baseline consumption data to assess overall reduction.** The period for obtaining baseline data for households was severely reduced in the LCL dTOU trial: ensuring a substantial period for baseline data is available should become much easier as the number of smart meters installed grows. Recruitment could be targeted at households for which 12 months of smart meter data is already available.
7. **Make the trial open-ended.** While this may be difficult in practice, a trial which does not have a predetermined end-date would be preferable as some participants indicated that they may have made some investments of effort or money to better respond to rate changes if the trial had not been a temporary situation. For example, investment in the up-front cost for LED lighting, or when replacing an appliance purchasing a more expensive model with a timer function; in non-financial terms, trialist may confront household members who are not cooperating with the rate changes.
8. **Improve feedback.** Throughout the trial period participants should receive monthly feedback on their savings benchmarked against both previous consumption (to reflect savings from reduction) and relative to a standard flat-rate. As this was lacking in the LCL dTOU trial it would be interesting to assess the impact this feedback has on motivation and engagement. Improvements to the IHD would also be ideal such as a traffic light indication of current tariff rate. If possible, disaggregated feedback on relative consumption of appliances would be ideal but as this is challenging, written advice on the relative costs of running different appliances would be worthwhile alternative. Further improvement to feedback for dTOU mentioned by trialists would be to have feedback available online and via smart phones. Comparative feedback –where households can see how their efforts compare to similar households in their area – would be another valuable form of feedback for dTOU. Studying preferences for different forms of feedback would be a worthwhile avenue for future research.
9. **Include advice on load-shifting and reduction.** Given dTOU trialists written advice suggesting ways of achieving DR would also enhance the trial. Information on the relative consumption of appliances would also be of interest and value to many consumers.
10. **Household dynamics:** Future work could also aim to explore whether dTOU might play a role in the possible loosening of fixed roles within the household governing who uses appliances and the potential to increase responsiveness accordingly.
11. **Clarity from the outset on all levels of trial aims and activities will improve quality and timeliness of outcomes and learning and help collaboration;** there are two inter-related aspects to this:
 - *Set detailed aims and research questions for trial at the outset.* This is crucial in collaborative projects. Suppliers' anxieties over potential perceived harm to their customer relationship, inconsistency in customer experience, or customers misunderstanding messages (e.g., with respect

to claims about links to renewable energy), or concerns about controlling their costs can dilute or derail the trial design or its delivery, or lead to lost time in prolonged negotiation over what is necessary and feasible.

- *Clarity of roles in responsibilities, accountability and boundaries* for activities, especially trial design and data collection is also crucial.

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Project Overview

Low Carbon London, UK Power Networks' pioneering learning programme funded by Ofgem's Low Carbon Networks Fund, has used London as a test bed to develop a smarter electricity network that can manage the demands of a low carbon economy and deliver reliable, sustainable electricity to businesses, residents and communities.

The trials undertaken as part of LCL comprise a set of separate but inter-related activities, approaches and experiments. They have explored how best to deliver and manage a sustainable, cost-effective electricity network as we move towards a low carbon future. The project established a learning laboratory, based at Imperial College London, to analyse the data from the trials which has informed a comprehensive portfolio of learning reports that integrate LCL's findings.

The structure of these learning reports is shown below:

Summary	SR DNO Guide to Future Smart Management of Distribution Networks
Distributed Generation and Demand Side Response	- A1 Residential Demand Side Response for outage management and as an alternative to network reinforcement - A2 Residential consumer attitudes to time varying pricing - A3 Residential consumer responsiveness to time varying pricing - A4 Industrial and Commercial Demand Side Response for outage management and as an alternative to network reinforcement - A5 Conflicts and synergies of Demand Side Response - A6 Network impacts of supply-following Demand Side Response report - A7 Distributed Generation and Demand Side Response services for smart Distribution Networks - A8 Distributed Generation addressing security of supply and network reinforcement requirements - A9 Facilitating Distributed Generation connections - A10 Smart appliances for residential demand response
Electrification of Heat and Transport	- B1 Impact and opportunities for wide-scale Electric Vehicle deployment - B2 Impact of Electric Vehicles and Heat Pump loads on network demand profiles - B3 Impact of Low Voltage – connected low carbon technologies on Power Quality - B4 Impact of Low Voltage – connected low carbon technologies on network utilisation - B5 Opportunities for smart optimisation of new heat and transport loads
Network Planning and Operation	- C1 Use of smart meter information for network planning and operation - C2 Impact of energy efficient appliances on network utilisation - C3 Network impacts of energy efficiency at scale - C4 Network state estimation and optimal sensor placement - C5 Accessibility and validity of smart meter data
Future Distribution System Operator	- D1 Development of new network design and operation practices - D2 DNO Tools and Systems Learning - D3 Design and real-time control of smart distribution networks - D4 Resilience performance of smart distribution networks - D5 Novel commercial arrangements for smart distribution networks - D6 Carbon impact of smart distribution networks



Low Carbon London Learning Lab



MAYOR OF LONDON



UK Power Networks Holdings Limited Registered office:
Newington House 237 Southwark Bridge Road London SE1 6NP
Registered in England and Wales Registered number: 7290590

innovation@ukpowernetworks.co.uk
ukpowernetworks.co.uk/innovation