Customer-Led Network Revolution

Customer experience of demand side response with smart appliances and heat pumps

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AUTHORS
Klara Anna Capova, David Lynch, Durham University

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Table of Content

Glossary of Terms

CLNR	Customer-Led Network Revolution
DEI	Durham Energy Institute
DSR	Demand Side Response
HP	Heat Pump
NEA	National Energy Action
PV	Photovoltaic
TC	Test Cell
ToU	Time of Use (Tariff)
WWG	Wet White Goods

1. Introduction

The transition to a low-carbon economy presents both opportunities and challenges for the electricity industry and its customers. The CLNR project seeks to develop cost-effective solutions that will ensure the UK electricity network is fit for the future and able to cope with mass uptake of electricity dependent, low-carbon technologies, such as solar panels, electric vehicles and heat pumps.

This document provides a basic analysis of the DSR data provided by National Energy Action (NEA) and proceeds by presenting an analysis of findings concerning their use of wet white goods and heat pumps. It offers evidence of factors affecting use of these technologies in domestic energy practices in the following test cells:

- TC10a WWG General load (Restricted hours wet white goods)
- TC11a WWG General load (Direct control wet white goods)
- TC14 Heat Pumps (Direct control)

The report is based on preliminary results from 21 semi-structured interviews with domestic customers located in rural or sub-urban areas.

1.1 About the Demand Side Response

This report describes findings from the CLNR demand-side response (DSR) wet white goods interventions (TC10a WWG, TC11aWWG) and heat pump direct control (TC14). This trial is part of the Learning Outcome 2 series of trials investigating electricity consumer flexibility and willingness to engage with tariffs and general load control systems.

During the TC10a WWG General load (Restricted hours wet white goods) trial, the 'smart' washing machine was install in participant's household. The participants were encouraged to use the washing machine's 'energy control' function. In the 'energy control' mode, the machine automatically scheduled the wash cycle to take advantage of the cheapest available rate over the next 24 hours and ensure participants avoid using the appliance during peak rate hours. Alternatively the 'smart' washing machine allowed them to program a 'delayed start' or 'finish by' time. The machine displayed an estimated price according to the selected settings, giving them an opportunity to adjust the time to one which is both convenient and economical. The participants could easily override the 'energy control' mode by switching the function off.

In the TC11a WWG (General load, Direct control wet white goods) trial was aimed to take some of the strain out of the electricity distribution networks at peak times of demand in by introducing targeted pauses in the availability of the washing machine to start its cycle or by sending out a request to pause the washing machine if it is in use at that time. During the DSR trial, a message was sent to the customer 30 minutes before the direct control is scheduled to start; if the customer responded acknowledging a willingness to engage in the demand response event then the system was able to remotely halt any present or future loads. During the trial period, the first call was made at 3:30pm each day via a gateway which shows on a home display and communicates to the appliance. Once the

device was enabled there was no reset program after the DSR period had finished, the gateway remained in its new state but only operated in the DSR period of 4-8pm. Outside of this period the device would be operated as a normal washing machine except for when a DSR event was present.

TC14 (Heat Pumps, Direct control) contains heat pumps with an ability to be shut down remotely by British Gas. This is achieved through an online tool ("heat pump asset manager") which allows heat pumps clusters to be selected and achievable duration of heat pump shutdown to be reported and activated. The process begins with a command sent to the heat pump requesting a load control. If communication is successful, the load control will occur unless a user refuses it or forces restart of the heat pump.

2. Research Methodology

The social science team at DEI developed the qualitative home visits research methodology to help understand the social dimensions of the CLNR trial.

2.1 Qualitative Face-to-Face Research

The semi-structured face-to-face interviews focused on building rapport with the participant while discussing their household's energy use in general terms. These conversations include information about occupancy, major electrical loads, heating regimes, washing and cooking practices, thoughts and feelings about electricity use, seasonality and other temporal factors as well as experiences of and attitudes to new and existing tariffs and technologies.

During the tour of the premises led by the participant, he or she was prompted by the researcher to talk about all aspects of electricity use in the household by focusing on electrical equipment as a catalyst for conversation. The participant led approach is reflected in the instrument design, which does not constrain participants or presuppose factors they consider to be most relevant.

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

2.2 Qualitative Analysis Methodology

The face-to-face interviews produced a wide range of data: audio recordings, photographs, interviewers' reflections and scanned notes that include diagrams of load curves and in some cases floor plans. The data were analysed using the data analysis software package NVivo. NVivo enables researchers to collect both the text-based (transcripts of interview, sheets used to record technology ownership and household details, notes and reflections) and multimedia information (audio files, photographs, drawings) and organises it around 'nodes'. A node, consisting of a collection of references around a specific theme, was created for each interview. A node associates the data generated at each visit with a unique interview ID.

3. Research Findings

The research team collaborated to develop a set of themes to structure analysis of the qualitative data. These themes were developed through repeated discussions of the qualitative research process and literature reviews.

The researchers also sought to quantify the socio-demographic characteristics of heat pump customers on the trial; to explain the effectiveness of the heat pump interventions and assess the acceptability of heat pumps as from a customer perspective.

3.1 Queries

NVivo queries can be viewed as similar to queries run in a conventional SQL database – they are repeatable structured searches for data (segments of audio, photos, scanned documents) that have been tagged (coded) by the social science researchers as related to Participant IDs and one or more themes. This process enabled us to navigate and attune to the data and to extract data relating to particular research questions.

The social science team developed seven queries (listed below) to explore and analyse a range of topics emerging from the fieldwork debriefing session and preliminary analysis:

Q1 DSR Heat Pumps
Q2 DSR Washing Machines
Q3 DSR The Grid
Q4 DSR Technical Novelties
Q5 DSR Role of Policy and Government
Q6 DSR Seasonality
Q7 DSR Direct Control

3.2 Findings

To enhance the qualitative analysis and to enhance our understanding of the participant's viewpoints, the interview transcripts were structured around themes emerging from the interviews. This enabled us to identify outstanding topics of interest. These include practices related to participation in the trial, what participants regard as their post-trial responses to the smart technology (solar panels, washing machine, heat pumps), and seasonality of energy practices. The qualitative analytic themes are listed below:

#Seasonality
#Heating
#Washing
#Hot Water
#Norms
#Investment
#Habits
#Health & Safety
#Planning
#Heat Pumps
#Washing Machines
#Solar Panels
#Tariff
#Timers
#Comprehension
#Feedback
#Problems
#Energy Bills
#Engagement
#Materiality
#Practice Innovation
#Direct Control

Following the approach outlined above, this analysis is organised by common everyday practices and types of technology involved in the trial.

3.2.1 Direct Control

The sample of respondents reflecting on direct control at the point of the machine consists of four households, three of which were families and one single person household. None of the respondents could recall seeing a message or code on the machine to say it was being directly controlled.

> RES(f): No, I didn't notice any events on the washing machine. It never stopped working. (WWG12_TC11a)

Only one respondent could recall the fact the machine would not turn on and was unconcerned about the delay:

> RES(f): Initially before it started sending messages you could just turn it on anytime but then sometimes now it will say waiting to start and it will put it on at certain time. So as long as you happy for it to come on at whatever time; and it's fine, really. [Did you get any messages on the machine saying don't wash?] No, I don't recall getting any messages via the machine, no. Like delayed starts and things like that; so if I put it on for like ten o'clock [10:00], I don't know if they've done something to say alright we won't let people to do their washing until two [14:00] then you might have to wait; so I press start and nothing will happen. But then it will come on at two [14:00] but for me it's not really an issue. (WWG06_TC11a)

The research team reported issues with communication. At the wired in broadband level there were often connectivity issues and these intermittent issues reduced the probability that a participant might actually witness direct control of their machine. Some respondents could tell the machine was being monitored by a telecoms signal appearing on the top left of the digital screen indicating that the machine was online.

None of the interviewees believed the direct control element had any influence on decisions about when to do the laundry. With all four asserting that there has been no change to their previous washing regimes.

3.2.2 Heat Pumps

By 2010 an estimated 30,000 Air Source Heat Pumps (ASHPs) were installed in the UK; the majority being located in residential buildings (Fritsch 2011) and in situations where dwellings are without mains gas supply (Energy Saving Trust 2010). The DEI's social science team examined the impact of heat pumps and user's experiences with the heat pump technology.

Qualitative analysis shows that users judged the heat pumps installed in the trial were to be unreliable. Respondents reported issues such as problems with hot water supply and increase in energy bills due to technology malfunction as illustrated in the quotes below:

> RES(m): This morning I got up and the bloody water is boiling. I never touched the thing! [...] It was on and off [hot water] from the day they put it in [heat pump]. [...] When they all came up that morning, they were fifteen people, they were all stood in our bloody house, eighteen months playing around, bloody different people. Sat in that room for hours, you know. [...] I know three or four people I know are sick of it [the heat pump system]. (SMARTHP_03)

Similarly, another respondent reported the ongoing problems with hot water:

> RES(f): It weren't my choice to get the heat pump, it was the council who were putting it in. It could be year and a half, two years now I think. I've had nothing but trouble from day one. The heating hasn't worked. You see when they finished putting it in, it was a cold weather. And with me not used to switches, on and off, whatever you did with it, I couldn't cope with it and it wasn't working. Now [summer] I don't need the heating but I'm having trouble getting hot water. (SMARTHP_02)

> RES(m): What we find is that when the water reaches certain temperature, and if we don't throw the water off or if nobody's had a bath or a shower, seems once that water is on constant temperature it will just flick the machine off. It just trips out.
> RES(f): You know, if you want to plan to have a bath or a shower in the morning you've got to get there and check the water is working. So it's that inconvenient.
> RES(m): And what we find, you know it's got a large vessel sort of thing. But the trouble is it still. You can't have a bath or a shower otherwise it will go cold on you. If we all come in, you're quite wet or muddy you know what I mean, you can send the kids and then we'll have to wait for it to warm back up.
> RES(f): It's not ideal for a family, no! (SMARTHP_06)

The perceived complexity of the technology is one of the key concerns and reasons offered for performance malfunction. One respondent provided his feedback on the heat pump technology:

> RES(m): Those problems ran on for quite some time. The system is massively complex; it might be not over-complex for what it's actually doing. I understand why they're trying to do it, I understand all of the complexity and my background is software anyway. The hardware is relatively straight forward but it's the software controller they've got there and I think it's overly complicated and I really don't think the software is mature. But the principle is good. And in terms of the effectiveness of it in this building, it's very good. (SMARTHP_05)

The most serious problem however was reported by participants who reported the 66% increase in energy bills due to the heat pump system (software) malfunction:

> RES(f): You know it's ... you give it a trial and we've had numerous people in and out, different appointments and it's time is money. And when it's still not right! [...]
> RES(m): But in the beginning what annoyed us a little bit was the fact that we get the radiators all put in and then they told us to turn two radiators off because it was taking too much power, to heat the whole house. So I think they underestimated it which is what the guy said, that the unit wasn't quite powerful enough. (SMARTHP _06)

Another problem reported by the same household was the noise level:

> RES(m): It was very very noisy but since they've redone it now (it's ok). It used to be like you know like a diesel generator, really growling. (SMARTHP_06)

It is no surprise then that if the technology does not work or does not satisfactorily replace the previous system, respondents perceive it to offer an inefficient and unreliable service.

3.2.3 Washing Machines

The qualitative analysis has prioritised adoption of the new washing machines and the impact of it on washing practices. Respondents perceived the washing machines positively as described below:

> RES(f): I were amazed how easy it is [to use, the wash machine], it tells you how long, the heat ... It's quiet as well, the machine it's really. I have put it on timer, the chap who put the booster on told me about it, I didn't know until after six months ago. [...] I've never had problems with leaving it on while I'm away [about the timer]. Well I've never had no problems. (WWG04_TC10a)

Our previous research has shown (Social Science Team Report April 2014) that variability in clothes washing and drying is affected by several factors – most notably, the weather, habit and routine, extent of planning and contingency (for example, having an alternative means of drying laundry) and the householder's own understandings of home management.

Participants were asked how easy it was to understand the new technology and how this has been implemented into their established washing practices:

> RES(m): The washing machine is fantastic. I can tell you all the reasons why we like it. It's big. That means you can reduce the number of wash loads. And also with this slow heat up, I think that's probably more economical. It's also the sixteen hundred spin speed which is brilliant, the stuff comes out really dry because we don't often use the tumble drier we very rarely ever use it. [...] If there is a downside, we put some stuff in the other day and it was the three hours twenty minutes cycle. But there is a fast cycle as well so ... But other than that, you still have the clock so there is a countdown so you see how long you have left to go. It's nice and quiet as well so... I can't really think about anything negative to say about

> the wash machine other than the fact that it can take an awful time to wash loads. (WWG09_TC10a)

> RES(f): So there is the beast [showing the washing machine]. I used to spend ages trying to switch it on before I realised that you just had to cover it up and it came on. It wasn't a case of a button you press, they haven't mentioned that. I'd be pressing this button and it wasn't working because you need to cover it up. Another think I like, it's a silly little thing; when it switches off, and it whistles at you to tell you it's off. And it's off! I can open the door straight away. It used to drive me mad if I was in the hurry and I wanted to be somewhere else ... waiting for the lock! (WWG02_TC10a)

The adoption of a new washing machine might be a slow process; one participant has kept their old washing machine while gaining confidence in using the new device:

> RES(f): I kept mine [wash machine] for quite a while to check until I was happy [with the new one]. I kept it till the end of the year I think, for about three months, just to make sure what's happening. But I'm very pleased with it. (WWG13_TC10a)

In general, participants do appreciate the technological novelties the smart washing machine offers (timer, child lock). The outstanding feature is the 11 kilograms drum which enables bigger loads. This resulted in a change in the frequency of washes for some; while for others frequency of loads remained unchanged especially families with small children for whom the frequency of washes is more important than size of load.

Some changes to the washing practices are observed as households make greater use of the washing machine. Our findings suggest that the dimension of the drum enables increasing washing of heavy textiles such as certain types of clothes, curtains, bed linens, towels etc.:

> RES(f): The one of the good things that I've learned by this and tell everybody is the big drum. More bedding goes in. So instead of doing two washes, you could do it in one. You can put more towels in coz we use loads of towels. I do bedding as one and towels. So instead of having two beddings wash, I'd do one bedding wash and instead of perhaps two or three towel washes, I do one. I'd always buy now a big drum. (WWG13_TC10a)

The dimension of the drum also impacts on established washing and drying routines as illustrated in following quote:

> RES(m): Well I think what they should do is with the washing machine to give tumble drier of same size [laughs].
> RES(f): Yes [laughs], sometimes it takes three loads for one washing coz we only have a small tumble dryer. Especially if it's a nice day I do use the outside but in the winter? (WWG15_TC10a)

3.2.4 Seasonality

The social science team previously noted that seasonal changes are an outstanding influence on energy consumption and drive household energy practices (CLNR Social Science Report April 2014).

The DRS data demonstrates how specific seasonal factors affected the use of smart technologies, especially heating related devices, for example in a mild winter less heating is required. As our respondents noted, the effect of a mild winter can be observed in their energy bills:

> RES(f): Now that quarter is finished we can go back and look at what we paid for the two quarters, basically the September to December and December to March. I'm just thinking how mild the winter was so maybe we haven't used the central heating as much. We've certainly not used the central heating as much this year as we have done the last couple of years or so. Because this year was unusual. (WWG02_TC10a)

> RES(f): Yeah definitely [there is a difference in electricity bills], we got quite a bit of credit last year. And I've noticed this big difference between last winter and this winter as well, for the overall use. This was such a mild winter. It was a lot cheaper than we thought. (WWG12_TC11a)

4. Conclusion

The CLNR team find the presence of low carbon technologies has significant potential to change energy practices, with smart washing machines in particular having a strong influence on how households think about and manage their electricity use.

The data suggests low levels of interaction with any signal from the direct control element of the trial and those who participated did not feel inconvenienced nor did their behaviour around washing change. Although the direct control sample is small, the findings suggest people are willing to engage with the network directly controlling their washing regimes during peak periods. This seems to be an energy efficient solution under one condition that no additional action or repeated concern is requested from the participants, especially in 'busy' households such as families with young children or households with low interest in new technologies.

The analysis of the DSR supports our earlier findings (Domestic LO1 & LO2 Qualitative Paper), where heat pumps were found to be challenging for end users and their successful domestication was sensitive to context. Problems such as interrupted supply of hot water, noise levels, participants' lack of 'know how' with regard to optimal heat pump configuration together with the malfunctions of the heat pumps resulted in negative feedback regarding the installation and technology as such. The heat pump technology performance seems to depend on three factors; a) design of the installation, b) match to the heating needs of the building and c) the location of the heat pump a number of metres away from the building to minimise any effect on household and neighbours. Although the experiences of using the heat pumps are not all negative, the focus on overcoming problems with new

technology made it impossible to explore the sociocultural dimension of heat pump technology and the household's energy practices.

The 'smart' washing machines on the other hand, were almost universally welcomed and were appeared to be readily integrated into domestic life giving the participants the benefits of and confidence in using smart technology and implement it into their washing practices.

Contact info@networkrevolution.co.uk

www.networkrevolution.co.uk