SDRC 8.4 and 8.7

DATA INFORMED ENGAGEMENT AND PRICE SIGNALS REPORT

SAVE
Solent Achieving Value from Efficiency

Scottish & Southern Electricity Networks

Solent Achieving Value from Efficiency

Solent Achieving Value through Efficiency (SAVE) is an Ofgem funded project run by Scottish and Southern Electricity Networks (SSEN) and partnered by the University of Southampton (UoS), DNV GL and Neighbourhood Economics (NEL). The innovative programme evaluates the potential for domestic customers to actively participate in improving the resilience of electricity distribution networks and thereby defer the need for traditional reinforcement. The government has forecasted an increase in electricity demand of 60% by 2050 meaning peak demand is likely to grow to six times higher than what the network was designed for.

CONTENTS

EXECUTIVE SUMMARY

This report presents the design, implementation, analysis and results of the data informed engagement and price signal trials conducted in the Solent Achieving Value from Efficiency (SAVE) project. The methods discussed ran from 2017 to 2018 in three distinct trial periods and aimed to educate and engage with customers to reduce their consumption during peak times.

1.1 Trial design

The overall goal of the SAVE project has been to investigate and understand what approaches can lead to the most significant electricity reduction at lowest cost. The SAVE project robustly tested energy efficiency and customer engagement approaches in a randomised control trial (RCT) of over 4,000 households. RCTs are generally considered the 'gold standard' of trials, useful in minimising bias and examining the cause and effect relationship of a given intervention. The SAVE sample is representative of the general population in the region, and does not suffer from opt-in biases as its initial recruitment process was not dependent on agreeing to a specific treatment. Because the SAVE sample was random and representative, the project's results are generalizable to the wider customer base.

The SAVE project used more robust methods for indicating statistical significance than previous projects, some of which used small samples and many do not report if findings are statistically significant. This study is of a significantly higher standard than past research on behaviour change and energy efficiency in the UK and provides more robust results.

The SAVE trials covered in this report tested three main customer engagement techniques between 2017 and 2018:

- **Data informed engagement** where the SAVE project provided energy savings advice to customers. This also includes specific days where customers were asked to reduce their consumption for a short time period.
- **Data informed engagement and price signals**. This provided the same advice and events days as above, but also offered customers a financial incentive to reduce their consumption.
- A dynamic tariff strategy called **banded pricing**, where customers were offered financial rewards to keep their consumption under a custom threshold. The banded pricing trial was deployed with two groups; one was offered the trial and asked to opt in and the other was automatically enrolled and could opt-out. For the first half of the trial, participants were paid £0.10 per hour they could stay below a custom kW threshold. Midway through the trial this increased to £0.30 per hour for both groups.

1.2 Electricity savings

The majority of engagement approaches tested in the SAVE project resulted in lower peak electricity use. Full reductions are shown for each trial group (TG) below in Table 1. TG3 also received financial incentives to change their consumption and is noted with '£'. Negative values show a reduction in peak electricity use and are highlighted green (consistent with the trial's hypothesis); positive values show an increase in peak electricity use and are highlighted red (inconsistent with the trial's hypothesis).

Table 1: Summary of results

Event	Delivery Mechanism	Reduction target	Duration	Incentive	TG2	TG3 (£)	TG4
TP1 Event 1	Email	10%	1 day, 4 hours	£10 gift card to all	-3.6%	-3.4%	-
TP2 Event 1	Post	10%	5 days, 4 hours a day	Raffle for £100 gift card	-	-5.5%	-3.8%
TP2 Event 2	Email	10%	5 days, 4 hours a day	Raffle for £100 gift card	-	-0.8%	-1.3%
TP2 Event 3	Email	20%	2 days, 4 hours a day	Raffle for £1,000 gift card	-	+3.0%	+2.4%
TP2 Event 4	Email	10%	1 day, 2 hours	£10 gift card to all	-	-7.0%	-3.0%
TP3 Event 1	Text	None	1 day, 4 hours	None	+2.1%	-	-
TP3 Event 2	Email	None	5 days, 4 hours a day	None	-2.2%	-	-
TP3 Event 3	Post	None	5 days, 4 hours a day	None	-2.9%	-	-
TP3 Event 4	Text	None	1 day, 4 hours	None	+1.1%	-	-
Banded Pricing – whole group	Post	Varied	4 hours, every weekday	£0.10/hour, then £0.30/hour	-	-2.6%	-7.1%
Banded Pricing – participants only	Post	Varied	4 hours, every weekday	£0.10/hour, then £0.30/hour	-	-4.2%	-7.1%

Besides the peak reductions, there was additional evidence that treatment groups responded, especially in the case of event days. Treatment groups tended to use more electricity before and after the event while having lower consumption during the event. Events where notifications were delivered in the post had more consistent reductions than other notification methods (email, app notification or text).

The impact of price signals on events was limited. Participants that were offered a price signal generally had slightly higher reductions than those that were not; these small increases in savings are unlikely to warrant the additional cost of incentives. Participants were also more likely to be out of the house during an event than the control group. This suggests that for some, the easiest way to reduce their consumption was simply to stay out of the house. Offering an incentive to stay out, such as discounted cinema tickets or meal vouchers, may be an effective way to reduce peak electricity use in the future.

In the banded pricing trial, the opt-in group had peak electricity use that was consistently lower than the control group. This was not radically changed by the price increase. The opt-out group responded better to the price increase, with lower consumption during the period with the higher price, suggesting they were more motivated by higher financial incentives.

1.3 Network impact

The increasing penetration of distributed generation and low carbon technologies such as electric vehicles and heat pumps have the potential to create challenges for Distribution Network Operators (DNOs) in the future. SAVE methods represent an important tool for network management. Because network upgrades can be triggered by a peak demand event that occurs only a very small number of times per year, the ability to reduce peak demand by means other than replacing electrical infrastructure can result in cost savings and equipment longevity.

If the typical distribution substation size is 500 kVA, the estimated savings of up to 7% on a typical substation could result in up to 35 kW savings at peak loading. Across of all of SSEN's territory, this could be up to 130 MW of peak reduction.

Information only events specifically were very inexpensive to run, at less than £1 per customer (plus any incentives). This makes them a low-risk solution well suited for occasional network issues such as short-term maintenance or extreme weather events.

1.4 Recommendations

In implementing any similar interventions in the future, DNOs should incorporate lessons learned from these interventions, specifically:

- Customers often need some prompting to save energy; treatment effects were generally highest after engagement of some kind. However, this needs to be balanced with messaging fatigue as too frequent messaging can lead to disengagement. Both trial period 2 and trial period 3 showed evidence of fatigue by the end of each trial, with consumption increasing to the same level (or above) the control group.
- Postal communications are the most consistently effective communication method when communicating one-off reduction 'asks', as postal communication will reach more customers than text or email communications. Postal notification could be used to reduce consumption during planned maintenance events or other issues that can be foreseen in advance. Postal communication is easily deployable in a business-as-usual scenario and can reach a wider audience, as generally DNOs do not have up to date mobile phone numbers or email addresses for all their customers. Unique packaging (such as the bright pink envelopes used in SAVE) and addressing envelopes to the occupant by name help the message stand out from junk mail or other circulars.
- Due to its short lead time, email notification is best suited to unplanned issues and could be used in post-fault situation when the DNO needs a reduction in the demand following a network fault. Email could be also appropriate for restoration support, when following a loss of supply the DNO can instruct sites to lower demand until the supply is re-established.
- Shorter events worked better than longer ones. Its likely customers find it easier to reduce their electricity load for a couple hours than across multiple days.
- Enticing customers to stay out of the house during critical peak periods may result in even larger peak reductions than asking them to shift or cut. DNOs could offer incentives specifically designed to keep people out of the house, such as discounted cinema tickets or gift cards to restaurants only valid during certain times or days.
- Single day events were able to produce peak reductions of up to 7%, which DNOs could use to address short-term critical peaks in their network that may lead to thermal overload, such as those resulting from short planned maintenance or extreme weather.
- Longer, multi-day events were able to produce peak reductions of up to 5.5%. DNOs could use these to address network issues lasting longer than a single day, such as a network fault or other maintenance situations, for example where customers have been back fed and the substation leading is higher than under normal circumstances.
- A banded pricing or similar time of use (TOU) approach could be utilised by DNOs on networks where peaks are harder to predict in advance or where the network is constantly near capacity. In the SAVE trial, the banded pricing was able to produce peak reductions of up to 7%. Banded pricing could also mitigate voltage control issues caused by the increased penetration of distributed energy sources. For example, when PV systems generate significant amounts of electricity but demand is low, banded pricing could stimulate demand to avoid voltage issues.
- Peak savings were higher in the opt-out banded pricing trial, as long as the incentive is sufficiently high to motivate participants. For the opt-in trial, peak savings were more consistent and predictable but lower as there was a smaller percent of the group participating. Cost per Watt of reduction was lower in the opt-in group than the op-out group.

In conclusion, the techniques tested in SAVE have the potential to provide small reductions to peak electricity use at a low cost per household. SAVE methods should be further investigated by DNOs to determine where they can best integrate them into business as usual (BAU).

1.5 Business as Usual conversion

One way in which SSEN is exploring utilising SAVE methods is through the evolution of Constrained Managed Zones (CMZs) into Social Constrained Managed Zones (SCMZs). An SCMZ looks to remove barriers to entry in flexibility markets for non-conventional means of demand response. This includes measures which encourage behaviour change from domestic customers such as the SAVE trials. The results of SAVE will be used to effectively evolve SCMZs in four key ways:

- Provide evidence to third parties in 'best practice' engagement and messaging techniques and how to create a cost-effective domestic demand response (DDR) tender application.
- Provide evidence to third parties and DNOs around the level of demand reduction that can be procured through behavioural mechanisms.

- Provide evidence to DNOs around the expected longevity of behavioural interventions to ensure targeting at the correct network scenarios.[1]

- Using the SAVE project's statistical rigour to provide DNO planning teams with the resources needed to understand likelihood of achieving given levels of demand response and hence carry out the appropriate analysis (with regards the network's capacity to run over thermal limits for a limited time[2] or back-up options for immediate response where DDR does not deliver) to maintain security of supply.

The SAVE trials discussed below are also utilised by SAVE's Network Investment Tool (NIT) to provide DNOs direct insight into the level of DDR they could expect across different areas of their network based on customer demographics. DNOs can use this tool to:

- Determine value of engaging customers with given DDR methods

- Show methods that are likely to be most effective

- Predict likely tender responses to running an SCMZ tender in a given area of network

Full details on the Network Investment Tool are available in SDRC 8.2.[3]

1 Networks will peak at different times of day, for different durations (hours) and at different frequencies (days). Based upon these network scenarios a network planner can start to anticipate how likely SAVE interventions are to solve a given network constraint.

2 Whilst a DNO would not want to do this regularly, networks can be run over thermal capacity for a short period of time with no noticeable impact in customers, providing a risk margin to any uncertainty around SAVE interventions.

3 See SDRC 8.2, available at https://www.ssen.co.uk/save/

2

INTRODUCTION

This Successful Delivery Reward Criteria (SDRC) Report presents the design, implementation, analysis and results of the data informed engagement and price signal trials conducted in the Solent Achieving Value from Efficiency (SAVE) project. The trials ran from 2017 to 2018 in three distinct periods with an objective to educate customers about the winter peak period and to encourage them to shift or cut their electricity consumption during this period.

2.1 Background

Energy efficiency and demand reduction can provide multiple benefits to both consumers and DNOs. Ofgem has calculated that a 5% reduction in energy use at peak will result in energy market cost reductions of £219m per annum, some of which would benefit customers in the form of lower energy bills. At the same time, a 5% reduction at peak will result in infrastructure cost savings of between £143m and £275m. This directly correlates to savings for the customer, in addition to the direct savings from lower household energy consumption.[4]

Reviews of global energy efficiency-based projects have found clear evidence that technology alone does not produce the most consistent, sustainable route to permanent energy efficiency but that a combination of technology and customer engagement is also required.[5]

The overall objective of the SAVE project has been to investigate and understand what approach(es) could lead to the most significant load reduction and at lowest cost. The SAVE project has built on the evidence and thinking described above to robustly test energy efficiency and customer engagement using a randomised control trial (RCT) of over 4,000 households in the Solent region.

At point of bid submission, the SAVE project identified key knowledge gaps and learning outcomes to be addressed by project activities. The specific project objectives considered in this SDRC are set out below.

Learning outcomes:

- To gain insight into the drivers of energy efficient behaviour for specific types of customers.
- To identify the most cost effective channels to engage with different types of customers.
- To gauge the effectiveness of different measures in eliciting energy efficient behaviour with customers.

Knowledge gaps:

- What do DNO led energy efficiency campaigns look like and how can they be run successfully?
- How enduring are the impacts of each measure and what costs if any are associated with sustaining the impacts?
- Can energy efficiency make an effective and economic contribution to network management?
- What is the potential for peak demand reduction and overall demand reduction achieved through energy efficiency measures to off-set the need for traditional network reinforcement?

The trial periods ran as follows:

- Trial period 1 (TP1): from 1 January to 31 March 2017
- Trial period 2 (TP2): from 1 October 2017 to 31 March 2018
- Trial period 3 (TP3): from 1 October 2018 to 31 December 2018.

4 Ofgem. Assessing the Impacts of Low Carbon Technologies on Great Britain Distribution Networks.
5 See SDRC 1, available at https://www.ssen.co.uk/save/

2.2 Method definition

The SAVE project bid document (SSET206) has outlined four main methods of intervention tested in this project. These were originally named as follows:

- Method 1 (M1) - LED engagement
- Method 2 (M2) - Data informed engagement
- Method 3 (M3) - Data informed engagement and price signals
- Method 4 (M4) - Community Energy Coaching.

This approach, however, did not provide a reference number to the project's control group population. Therefore, to ease identification of the methods being trialled throughout the delivery of the project each was re-named as follows:

- Trial Group 1 (TG1) - Control Group
- Trial Group 2 (TG2) - LED Lighting
- Trial Group 3 (TG3) - Data informed engagement and price signals
- Trial Group 4 (TG4) - Data informed engagement
- Community Energy Coaching Trials (CEC or M4).

The SAVE project utilised an iterative development approach to allow learnings from each trial period to inform the design and approach of subsequent trial periods. At the end of TP2 (31 March 2018), the SAVE team concluded that since the project had already rolled out LEDs to over 76% of the trial group there was minimal value in further testing LED-based approaches with TG2 (for more information, see SDRC 8.3, LEDs). The take-up of the offer of free LEDs was exceptionally high, which meant there was limited value in testing other means of engagement with the small number of participants that did not have any LEDs installed in their homes. This allowed the SAVE team to test something new with TG2 in the final trial period.

Learnings from the first two trial periods (TP1 and TP2) informed the design of the third trial period (TP3) which applied new approaches to each trial group. The participants of each group were not changed. In TP3, the methods trialled on each group were:

- Trial Group 1 (TG1) - Control Group
- Trial Group 2 (TG2) - Energy reduction events[6] (previously LED lighting)
- Trial Group 3 (TG3) - Banded price incentives (opt-in)
- Trial Group 4 (TG4) - Banded price incentives (opt-out)
- Community Energy Coaching Trials (CEC or M4).

To avoid confusion and the risk of mismatch between delivery and reporting the project came to the conclusion that the groups were better referred to by these names (TG1, TG2, etc.). Within this report all interventions will be referred to under these revised names.

2.3 Sample design

The SAVE project adopted a best practice design by implementing a randomised control trial (RCT). RCTs are generally considered the 'gold standard' of trials, and useful in minimising bias and examining the cause and effect relationship of a given intervention.[7] Past energy efficiency and demand side response studies have not been able to provide robust evidence[8] in support of savings claims and many energy related evaluations do not use best practice approaches[9] common in other sectors. In the response to the shortcomings of other similar trials, the SAVE project adopted a best practice approach with the following key elements:

- **Hypothesis and statistical power:** A number of studies have suggested that sample sizes in previous energy efficiency studies may be too low to provide adequate power and so statistically robust conclusions cannot be drawn.

6 Designed as business as usual engagement.
7 Hariton, E. and Locascio, J. 2018. Randomised controlled trials—the gold standard for effectiveness research. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6235704/
8 Torriti, J., 2017. Understanding the timing of energy demand through time use data: Time of the day dependence of social practices. Energy Res. Soc. Sci. 25, 37–47. https://doi.org/10.1016/j.erss.2016.12.004
9 Delmas, M.A., Fischlein, M., Asensio, O.I., 2013. Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. Energy Policy 61, 729–739. https://doi.org/10.1016/j.enpol.2013.05.109

- **Program design:** Randomised and representative samples must be drawn from the target population to avoid self-selection or other biases. Once the sample has been established, participants are then randomly allocated to treatment and control groups. The SAVE sample is designed to be representative of the general population, and does not suffer from opt-in biases as its initial recruitment process was not dependent on agreeing to a specific treatment. A non-random sample may lead researchers to conclude that an intervention had an affect when this may not have been the case.
- **External testing:** demographic data of the SAVE sample was compared to data from the high-quality Understanding Society Survey[10] to assess the extent to which the sample is representative of the population of the areas from which it was drawn.

All of this ensures that SAVE and its findings are robust and defensible.

2.4 Trial design and approach

DNV GL used the Cabinet Office's '6Es – MINDSPACE' framework[11] as a guideline when developing the data informed engagement and price signal trials. The 6Es refer to the actions needed to be undertaken by an organisation implementing a strategy to drive behaviour change. The actions are: Explore, Enable, Encourage, Engage, Exemplify and Evaluate. DNV GL used this framework as a structure to analyse lessons learned from previous research (e.g. other LCNF projects). While several key findings were identified from this (see SDRC 1, for full results and details on literature reviewed[12]), the most relevant findings for the purpose of the campaigns in this project are:

- Customer segmentation(s) should actively assist in targeting campaigns effectively by focusing on differences in energy use, personal values and preferred methods of communication. Customers connected to the electricity distribution network cannot be engaged with as one group; the way in which people react to attempts to change their energy behaviour differs and engagement needs to be tailored appropriately without resulting in prohibitative costs.
- Customers need to understand how they can reduce their energy usage and be educated appropriately. This can be through a combination of physical equipment, information and advice.
- Parties delivering messages to customers need to be seen and recognised as both trustworthy and authoritative in the subject matter. These attributes are not necessarily found in one entity and partnership between energy companies and trusted groups such as local organisations and community groups can be a way to overcome this. Allowing multiple organisations to deliver messages that are consistent on a theme yet approached from their different perspectives is also effective.
- Financial incentives can be effective but potentially need to be relatively large and impacts are often not sustainable over time; non-financial incentives should also be considered.
- Opt-out designs should be applied where possible as they are typically more effective than opt-in approaches, for example if offering energy advice visits or competitions.
- Novel and creative techniques for sharing information can be used to effectively capture customer attention.
- A delicate balance needs to be struck between using negative concepts such as 'waste' or 'loss' while also making customers feel good about themselves.
- Customer commitments through setting goals and targets can be very effective to achieve longer-term behaviour change, but often need strong incentives to give them meaning.

The first trial period, TP1, focused on general education around the peak period and energy efficiency. It introduced the idea of a peak period (16:00 to 20:00) to consumers and explained why the electricity network is sometimes stressed at this time. TP1 asked customers to shift their electricity consumption to outside of this peak period. Note that TG3 and TG4 received the same engagement content with the exception that TG3 also participated in 'event days' where customers were financially incentivised to shift or cut their reduction on certain days.

The second trial period, TP2, expanded on the education aspect of TP1 and asked customers to cut their electricity consumption during peak times by providing them with specific electricity savings ideas. In this trial period, both TG3 and TG4 participated in 'event days'. Note that TG3 customers were financially incentivised to meet reduction targets while TG4 customers were not offered any monetary incentives.

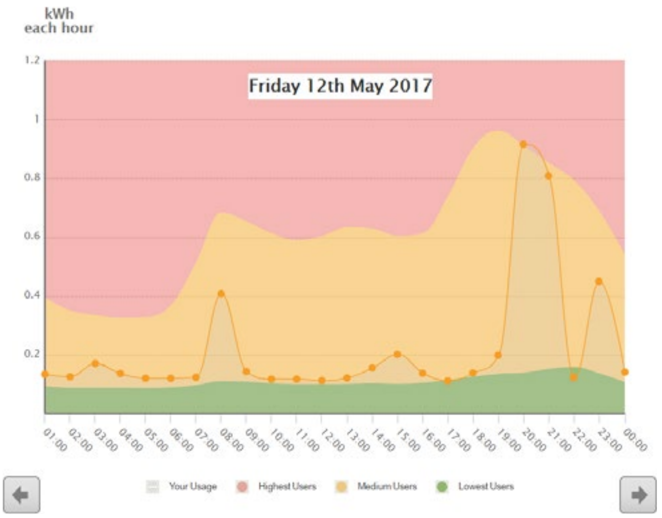
10 Institute for Social and Economic Research, 2015. Understanding Society: Waves 1-5, 2009-2014 (SN: 6614 No. 7th Edition). University of Essex.
11 Cabinet Office. MINDSPACE: influencing behaviour through public policy. 2010. https://www.instituteforgovernment.org.uk/sites/default/files/publications/MINDSPACE.pdf
12 Available at https://www.ssen.co.uk/save/

The third trial period, TP3, explored a different approach to that of TP1 and TP2. TP3 introduced the idea of banded price incentives to TG3 and TG4. This trial asked customers to keep their electricity consumption during peak hours below a personalised threshold; they were then paid a small rebate for every hour they were below this target threshold. Unlike the two earlier trial periods, TP3 also tested engagement approaches with TG2, which had previously been an LED group. Note that TG2 participated in 'event days' like those in the first two trial periods, but without any general education element to test if TG2 customers would respond to the 'event days' even without education about peak times or electricity saving strategies.

2.4.1 Electricity consumption monitoring

The SAVE project installed an internet-connected 'Loop' electricity monitoring device on all homes in the trial. All participants had a Loop account online where they could track their consumption. The default view showing electricity consumption is displayed below in Figure 1.

Figure 1: Loop portal 'explore' page



The Loop website / app could also be used to send messages to participants.

For additional details, see Section 6.1.3.

2.5 Trial goals

All trial periods attempted to persuade participants to use less electricity during peak times (16:00 to 20:00) either by cutting their overall consumption and/or by shifting their activities to either side of the peak period. Each trial period built on learnings from the previous period to improve and refine the approach.

While the primary focus has been to determine the impact(s) that education and engagement can have on the network, the trial has also aimed to gain insight into the drivers of energy efficient behaviour and how results (i.e. energy, carbon and bill savings) vary between different types of customers. Customer engagement has been a central component of these trials and the SAVE project has sought to identify and understand the most effective way of engaging with different types of customers in order to maximise the response.

The SAVE project has also investigated the cost efficiency of each approach that informed the Network Investment Tool (for information on the Tool, see SDRC 8.2[13]).

The overall results and findings from this trial will help inform future Government energy efficiency schemes and DNO-led engagement and outreach work to provide innovative approaches to network management.

2.6 Report layout

This report has the following structure:

- Chapter 1 presents the executive summary of the report.
- Chapter 2 introduces the background of SAVE project and defines the methods and trial groups used. It provides a high-level overview of the trial design and the trial goals.
- Chapters 3, 4 and 5 present the design and approach of each trial period.
- Chapter 6 details the analysis methods and data sources.
- Chapter 7 presents results of these analysis methods.
- Chapter 8 shows the impact of the SAVE trials on the electricity network.
- Chapter 9 outlines considerations for commercial deployment of SAVE methods in the future.
- Chapter 10 presents overall findings and conclusions.

13 Available at https://www.ssen.co.uk/save/

3

TRIAL PERIOD 1

The first trial period, TP1 ran from 1 January to 31 March 2017—as outlined in the June 2016 updated SAVE project bid document (Appendix 8 of Change Request 2). The trial periods were subsequently amended in order to most effectively maximise project learnings through the addition of a third trial period, TP3, as outlined in Change Request 2.

3.1 Design and approach

The first trial period, TP1, explored how customer engagement techniques could be used to shift electrical consumption out of the peak period. TP1 focused on general education around the peak period and energy efficiency. It introduced the idea of a peak period (16:00 to 20:00) to consumers and explained why the electricity network is sometimes stressed at this time.

TG3 customers also participated in 'event days' where customers were financially incentivised to shift or cut their reduction on certain days.

3.2 Engagement materials and messaging

TG4 received hardcopy materials through the post. TG3 received the hardcopy materials in the post and also received selected materials digitally through emails and the Loop app. TG2 also received materials through email and the Loop app.

An overview of the messaging schedule is provided below in Figure 2. Highlighted cells show weeks where participants received messaging, 'E' marks an event day. Grey weeks show school breaks (half term). See Sections 3.2.1, 3.2.2, 3.3 for additional information.

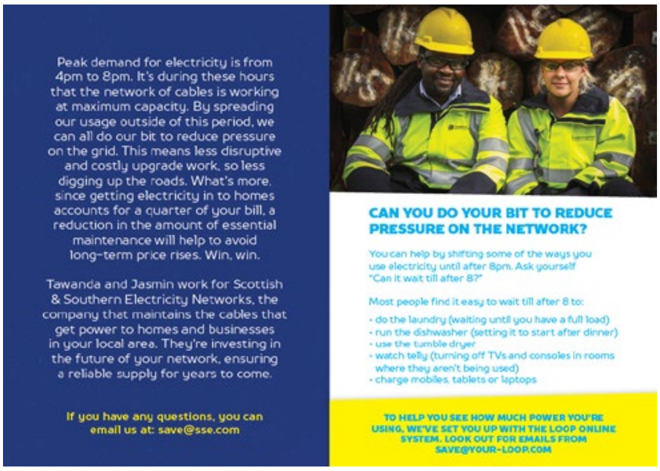
Figure 2: TP2 messaging schedule

	Jan				Feb				Mar				Apr
	2	9	16	23	30	6	13	20	27	6	13	20	27	3
Booklet														
Postcard														
Email/Loop notification											E			
Text											E			

3.2.1 Postal

The engagement campaign started with an informative introductory booklet that asked participants to 'help keep the power flowing'. The booklet introduced two SSEN employees to the participants and explained how they work hard to keep power flowing to consumers. It also explained what SSEN does and the basics of how electricity is provided to households. The booklet also posed the question and tagline, 'can it wait 'till after eight?' and provided tips on simple ways to reduce pressure on the network.

Figure 3: Interior page of initial engagement booklet



Over the next nine weeks, this booklet was followed up with one general knowledge postcard and five postcards with specific requests, such as:

- Waiting until after 20:00 to do the washing or running it only with full loads
- Waiting until after 20:00 to charge mobiles and tablets
- Waiting until after 20:00 to use the tumble dryer
- Waiting until after 20:00 to run the dishwasher or using its timer/delay function
- Waiting until after 20:00 to watch television or turn the television off in rooms that are not being used.

As a rule, the engagement campaign shared informative and generic messages with participants and sought to facilitate change rather than just simply telling participants to reduce their consumption. The campaign specifically targeted the idea of shifting energy use behaviours to outside of the peak period, as this was believed to be a new message for consumers, who as the projects community energy coaching trials evidenced (see SDRC 8.8 Community Energy Coaching[14]), have typically been given simple 'cut energy use' messages.

Figure 4: Front and back of sample post card

The email address for the SSEN project inbox was provided in all materials. A reminder of the web portal, where participants could see details of their energy consumption was also provided in all materials. The SAVE project design team sought to minimise the use of the SSEN brand to avoid the material sent to participants as coming across as sales material. The team designed a '4 to 8' logo to represent the campaign and the 16:00 to 20:00 peak period. This logo appeared on all the consumer engagement material.[15] All mailings were addressed to the named contact on file and were sent in bright pink envelopes.

Figure 5: '4 to 8' logo

4 TO 8

3.2.2 Email

Email addresses were collected through the set-up process of installing the Loop kit. Engagement emails included the same messages as the post cards in a digital format. TG3 and TG2 could also see these messages on the newsfeed of the Loop website. All emails included links to the Loop website to encourage participants to view their consumption.

3.3 Event days

In addition to the messaging material described above, TG3 also received notifications about an 'event day' through emails and Loop notifications. This was designed to test the ability of participants to reduce their consumption on a specific (singular) day when the network was under pressure. In a business as usual (BAU) scenario, this might be due to equipment failure(s), exceptionally high electricity use, maintenance work (and taking equipment offline), weather, etc. In the future, this could be deployed as a 'critical peak pricing' tariff or rebate scheme.

The SAVE project team selected Wednesday, 15 March 2017 as the event day to test a 'regular' weekday. TG3 participants were asked to reduce their load by 10% during the peak period (as compared to the previous Wednesdays) and they were offered a £10 high street voucher if they were able to respond to the extent required.

Through an error, TG2 also received email and Loop notifications of the event day and were asked to reduce their consumption by 10%, although they were not offered an incentive to do so. TG2 can therefore provide an additional comparison group.

Figure 6: Event day email message

PLEASE USE LESS ELECTRICITY AT PEAK TIME THIS WEDNESDAY

We're anticipating a peak in electricity consumption in your local area this Wednesday. So please help us manage this by shifting any non-essential electricity use to before 4pm or after 8pm on Wednesday.

If everybody uses just a little bit less at peak time the effect will add up and ease pressure on the network. We've set a target of 10% below your usual usage. We'll let you know if you managed to beat it!

Reduce your usage by 10% or more between 4 and 8pm on Wednesday and we'll send you a £10 LOVE2SHOP voucher in the post, which you can use to shop on the high street.

Thanks from Tawanda, Jasmin and the team.

14 Available at https://www.ssen.co.uk/save/
15 The web portal for TG1 and TG2 was not branded with the 4 to 8 logo.

3.4 Trial outcomes

A complete analysis of the energy consumption data for TP1 is available in Section 7.1 of this report. Non-energy impacts are discussed below.

3.4.1 Participant feedback and comments

All communication material sent to participants had an SSEN email address that they could use to contact SAVE staff directly with questions or feedback. While very few participants expressed any concerns or other feedback with the trial process, a number did state that the frequency (weekly) of the engagement process was too high. Some of these participants also felt that the weekly postcards were an excessive use of paper and that this was not in line with the conservation message the trial was advocating.

3.4.1.1 Open days

After the conclusion of TP1, the team held two 'open days' that invited participants to a workshop where they could provide feedback on the trial. One was held with TG3 and one with TG4 (separately). Overall feedback was generally positive, with a number of customers stating they had not known about the 'peak' period before the trial. Similar to the feedback received through the SSEN project inbox, a number of attendees felt the postcards were too frequent. Attendees noted that they liked the pink envelopes that SAVE communications were sent in, as it did not look like 'junk mail'. Some also requested stickers or other physical items, which were already planned for delivery in TP2.

However, these events had a small number of participants (less than 20 people at each, or about 2% of the trial) and so results should not be considered representative. Additional information is available in SDRC 4.[16]

3.4.2 Unsubscribe rate

Participants could also use the SSEN email address to request removal from the mailing list. In TP1, 17 TG3 participants and 9 TG4 participants requested to be removed from the mailing list. This is an unsubscribe rate of approximately 2% for TG3 and 1% for TG4.

3.4.3 Event day

The email notification sent to TG3 for the event day had an open rate of 41%. The open rate for TG2 was 44%.[17]

The TP1 event day had a success rate of 58%, with 1,082 households successfully reducing their consumption by 10% when compared to the previous week. Of this, 512 households were in TG3 (a success rate of 55%) and 570 households were in TG2 (a success rate of 61%).

16 Available at https://www.ssen.co.uk/save/

17 This does not include participants who had opted-out of any email communication prior to the trial.

4

TRIAL PERIOD 2

The second trial period, TP2, ran from 1 October 2017 to 31 March 2018. It included engagement messaging to reduce electricity consumption during the peak period and specific 'event days' with reduction targets.

4.1 Design and approach

TP2 utilised a variety of messaging approaches through online and postal communication including a 'welcome pack' for TG3 and TG4 that included a booklet and other small promotional materials.

Building on feedback from TP1 where some participants felt overwhelmed by the volume of communications, TP2 reduced the frequency of engagement messages. Unlike TP1, email and postal messages did not replicate one another. A message was sent by either post or email, but not both.

The first half (October 2017 to December 2017) of TP2 focused on postal engagement as this is an approach currently available to DNOs in their 'business as usual' (BAU) approach. The second half was a digital-only approach with all communications sent to participants through Loop and by email to test lower cost options that may be available in the future.

TP2 also included specific 'event days' where participants in TG3 and TG4 were given a target reduction for a set time period. Ramping up from TP1, these 'event days' grew in frequency and varied in intensity. Participants in TG3 were also offered financial incentives to meet their targets, while TG4 did not receive any financial incentives.

4.2 Materials and messaging

TP2 built on the general information and content that was distributed to participants in TP1 and focussed more on cutting energy use during the peak period (rather than shifting it outside the peak, as investigated in TP1). An overview of the messaging schedule is provided below in Figure 7. Highlighted cells show weeks where participants received messaging, 'E' marks an event day. Grey weeks show school breaks (half term and Christmas). See Sections 4.2.1, 4.2.2 and 4.3 for more details.

Figure 7: TP2 messaging schedule

	Oct					Nov				Dec				2018 Jan					Feb				Mar			
	2	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29	5	12	19	26	5	12	19	26
Welcome pack																										
Postcard							E																			
Loop email and notification																	E						E		E	

4.2.1 Postal

Since DNOs only have access at present to postal addresses and limited access to other more direct contact information (such as emails or mobile numbers[18]), the first half of the trial (October, November and December 2017) focused on a postal engagement process.

The postal mailings started with an initial 'welcome pack'. This included a small booklet with general information on reducing electricity usage during the peak periods as well as physical items (with the purpose of staying in the home longer). All materials sent made use of a cartoon character (named 'Arthur Tate') to deliver the messaging, as seen in the images below. This character was designed to be appealing to both adults and children to engage multiple members of the household.

Both TG3 and TG4 received the welcome pack in October 2017; it included:

- A booklet with ideas on how to use less electricity at home. This focused on how energy is used and how reductions in energy use can be made when cooking, cleaning and relaxing in the home. The booklet also gave some general information about the winter peak period and how reductions during this time are especially helpful to the DNO (See example page below in Figure 8).
- A small note book, with helpful electricity saving tips on some of the pages.
- A package of sticky-notes with instructions to use them as reminders of energy saving behaviour (such as 'run it on eco' or 'turn it off').
- A pencil with the '4 to 8' logo.

18 DNOs may have some access to customer phone numbers and email addresses, however this information may be outdated.

Figure 8: TP2 welcome pack

While a postcard may be discarded after being read, a notebook or pencil will likely persist and be used in the home. These items were then able to provide more subtle and persistent reminders to cut energy consumption without being overly obtrusive. Arthur Tate, the sticky notes and the pink pencil were specifically designed to be engaging to both adults and children.

While consumers could still log onto the Loop portal and view their energy use during TP2, it was not used to send messages to consumers during the first half of TP2. Email messaging was also not used during this time. This approach was used to reflect the methods of engagement currently available to DNOs.

4.2.2 Email

The second half of TP2 used a digital communication format and all messaging was sent through Loop and email. These messages included content similar to the welcome pack described above but in a different medium and format (i.e. email and Loop, see example below in Figure 9). This was used to test the effectiveness of digital engagement and if it could provide similar results at less cost. Note the 'cut' message was a constant throughout both portions of the trial period.

Figure 9: TP2 email

Feel like you're wasting energy at dinner time?

Planning, shopping, chopping, stirring, pouring, serving. A lot of energy goes into dinner time so don't waste any more of that precious stuff on the things you're not using. This week, I've loads of ideas to help you pinpoint where you might be able to make an easy change.

Turn it off

- Is the oven still on, or the lights, or maybe nobody's watching the telly in the other room? Don't forget to turn them off, their work is done for now.
- "I love listening to the sound of computer games when I'm eating my dinner", said nobody, ever. Is that console still on upstairs...?
- Fridges use LOADS more power when the door is left open, so a quick nudge to make sure the door is shut tight will save you electricity and keep your cheese cool.

4.3 Event days

In addition to the provision of general energy consumption reduction ideas, TP2 also asked both TG3 and TG4 to reduce their consumption by a set percentage for a short time period. Participants in TG3 were also offered a financial incentive to do so, which varied by event. Events were advertised by postcards in the first half of the trial and through email and Loop for the second half.

The events are shown below in Table 2.

Table 2: Trial period 2 event days

Event	Reduction target	Date	Time active	Delivery method	Prize (TG3 only)
1	10%	Monday to Friday w/c 20 November 2017	16:00-20:00	Postcard	Raffle draw for one of 20 £100 Restaurant Choice gift cards
2	10%	Monday to Friday w/c 29 January 2018	16:00-20:00	Email and Loop	Raffle draw for one of 20 £100 Restaurant Choice gift cards
3	20%	Tuesday and Wednesday 6-7 March 2018	16:00-20:00	Email and Loop	Raffle draw for a £1,000 Sainsbury's gift card
4	10%	Tuesday 20 March 2018	17:00-19:00	Email and Loop	£10 Costa Coffee gift card to all successful

While TG3 participants were provided with incentives when they met their targets, as detailed above (or the chance to win, as in the raffles), the TG4 participants were given 'good job' feedback through the post or Loop portal and email.

Figure 10: TP2 'event day' notification

The Loop portal also showed a target line on the consumption graph to show what a 10% (or 20%, depending on the event) consumption reduction would look like for that specific household. This enabled us to show household specific kWh targets and it let customers track their consumption in real time during the digital phase, shown below in Figure 11.

Figure 11: Target line for event day

4.4 Trial outcomes

The success rate of each trial for each group is presented below in Table 3. Interestingly, the pass rate of most events was higher for TG4, who did not receive any incentives. Full results, including load reductions, are available in Section 7.2. It should be noted that a positive pass rate does not guarantee demand (kW) savings; demand savings are determined by comparison to the control group while pass rates are calculated by comparison to past consumption of the same trial group.[19]

19 For example, lower energy use may be seen in both the control and treatment groups during the event (perhaps due to weather effects) that would result in high pass rates but negligible demand savings.

Table 3: TP2 'event day' success rates

Event	Description	Pass rate TG3	Pass rate TG4
1	Reduce energy consumption by 10% during the peak period Monday to Friday in w/c 13 November 2017	28.0%	30.7%
2	Reduce energy consumption by 10% during the peak period Monday to Friday in w/c 29 January 2018	19.8%	20.3%
3	Reduce energy consumption by 20% during the peak period for two days in w/c 5 March 2018	21.0%	19.7%
4	Reduce energy consumption by 10% between 17:00 and 19:00 on Tuesday, 20 March 2018	29.3%	29.1%

Full energy analysis is available in Section 7.2.

4.4.1 Unsubscribe rate

Participants could also use the SSEN email address to request removal from the mailing list. In TP2, 74 TG3 participants and 86 TG4 participants requested to be removed from the mailing list.[20] This is an unsubscribe rate of approximately 10% for TG3 and 12% for TG4.

4.4.2 Open days

Similar to the first trial, the team held two more 'open days' at the conclusion of TP2. The team invited participants to a workshop where they could provide feedback on the most recent trial. One was held with TG3 and one with TG4 (separately). Overall feedback was positive, with participants reporting using the materials provided in the welcome pack (sticky notes, pencil, notepad) and referring to the booklet as needed. A number of participants reported that the sticky notes were popular with their children. Some participants also reported that they were unaware of the Loop app; this feedback was built into messaging for TP3.

The team also explored what level of incentives would be encouraging for a time-of-use incentive (like that deployed in TP3 as 'banded pricing'). Responses were variable, but most people reported that payments between £15 and £50 would be sufficiently motivating.

However, these events included only a small number of participants and so do not reflect opinions of the entire trial population.

20 Note: these are participants who unsubscribed from communications but stayed in the project. These are not project drop outs.

5

TRIAL PERIOD 3

The third trial period, TP3, ran from 1 October 2018 to 31 December 2018. This trial period included two intervention approaches:

- The first approach tested 'event days' similar to those deployed in the first two trial periods. These events were without incentives and looked to build on learning from TP1 and TP2 to explore an approach that a DNO could roll out in a business as usual scenario
- The second approach was a simulation of a dynamic tariff that SAVE termed 'banded pricing' tested with TG3 and TG4.

5.1 Event days

The LED trials did not extend past SAVE's second trial period, TP2, which allowed SAVE to test something new in TP3 with what was previously known as the LED group (TG2). The SAVE project sought to explore the impact of 'event days' if run as stand-alone events and not as part of a larger education and engagement campaign, as had been done in TP1 and TP2. This is seen as a possible BAU approach as it would be relatively low cost and quickly deployable.

TG2 received notifications of 'event days' through post, email and text message formats. These event days tested a slightly new approach, participants were asked to reduce their consumption for short periods of time but they were not given a specific reduction target. The approach did not include follow-up messaging (which would be required to inform participants if they succeeded). They did not receive any additional information concerning the peak period, DNOs or energy efficient strategies. This may be easier to deploy in a BAU scenario as it will also be less expensive.

The events are shown below in Table 4.

Table 4: Trial period 3 event days

Event	Date	Time active	Delivery method	Message
1	10 October 2018	16:00-20:00	Text message	Notification asked participants to use less electricity as the network was under extra pressure.
2	Monday to Friday w/c 29 October 2018	16:00-20:00	Email and Loop	Notification asked participants to use less energy as the evenings are darker and colder (sent out after Daylight Savings Time ended).
3	Monday to Friday w/c 19 November 2018	16:00-20:00	Postcard	Notification was co-branded with the Energy Savings Trust.
4	13 December 2018	16:00-20:00	Text	Notification asked participants to reduce their consumption because the electricity network was under pressure due to weather.

Figure 12: TP3 'event day' postcard sent to TG2 for event 3 (front and back)

5.2 Banded pricing design and approach

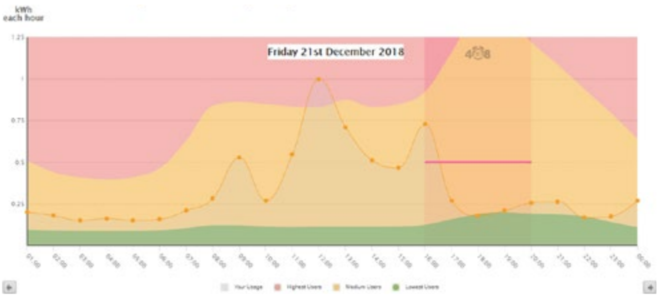
In TP3, the project sought to explore a dynamic tariff strategy with TG3 and TG4. Because the SAVE project did not involve energy suppliers and therefore had no way to bill participants, the trial was incentive only and participants could not lose money. The approach was set up to replicate what a DNO or third party (i.e. an aggregator) could do outside of charging mechanisms, for example in a Constraint Managed Zone.

In developing this approach, SSEN held an industry consultation and included energy suppliers, other DNOs, Ofgem and BEIS. Results from this consultation, along with input from project partners, informed the approach.

Participants were assigned a customised threshold based on their past consumption; for every hour during the peak period that they could keep their electricity consumption below this threshold they were paid a small incentive. Because different households have different consumption levels and patterns, a single threshold is not realistic or motivating for the entire participant group. For this reason, the trial had three thresholds: 0.2 kWh, 0.5 kWh, 1.0 kWh.[21] If past energy data was missing, participants were assigned a threshold based on the number of bedrooms in their dwelling, as this is a key determinant of electricity consumption and also represents data similar to what is available (in a business as usual approach) from Standard Assessment Procedure (SAP) records[22]. For additional information about dwelling (measured as numbered of bedrooms) size as a predictor of electricity consumption, see SDRC 2.3.[23] Participants could track their energy consumption using Loop. When using the daily view, participants could see their hourly consumption as well as a target line at their custom threshold (within the peak period only). The highlighted 16:00 to 20:00 peak period and an indicative target line (shown at 0.5 kWh below) can be seen below in Figure 13.

Participants also received a text message each week with their balance.

Figure 13: Electricity consumption viewed through Loop



At the end of TP3, participants received their total incentive in the form of a rebate cheque. The banded pricing trial ran from 1 October to 31 December 2018.

While previous research has found that opt-out campaigns generally have higher participation rates[24,25,26,] it has been noted that participants in an opt-out trial may be less engaged than participants in an opt-in trial[27], resulting in minimal demand response.

SAVE first approached TG3 with an opt-in offer to determine the response rate. If more than 50% of this group opted-in, an opt-in approach would be tested with TG4 also but with differing incentive levels. However, if response rates were low, an entirely opt-in approach may yield too few participants to determine robust savings estimates. In this case the project determined it would gather more learning from running TG4 as opt-out. In the end, response rates from TG3 were below 50% and so TG4 was tested as an opt-out trial with the same incentive levels offered for both groups.

5.2.1 Opt-in group (TG3)

TG3 participants were sent a booklet in early June 2018 which introduced the banded pricing trial. The booklet was delivered by post with a follow-up email and Loop notification and explained the incentive levels and the hours and days they would apply. The booklet came with a pre-paid return postcard that interested customers could use to opt-in to the trial. In July 2018, telephone calls were made directly to customers to encourage them to opt-in to the trial.

5.2.2 Opt-out group (TG4)

In late August 2018, a similar booklet to that described above was sent to TG4 participants to introduce the banded pricing trial. Unlike the booklet sent to TG3, this informed participants that they had been enrolled in the trial but gave them a website and phone number to use if they would like to opt out. The booklet was delivered by post and followed up by an email and Loop notification.

5.2.3 Pricing levels

The SAVE project aimed to test two incentive levels to better inform how customers respond to varying price signals in the Network Investment Tool (see SDRC 8.2). However, because TG3 was opt-in and TG4 was opt-out, there were already key differences between the groups; adding another variable (incentive level) would complicate the results.

For this reason, both groups received the same incentives at the same times. For the first half of the TP3, all participants were paid £0.10 per hour spent below the threshold, with a maximum payment of £20. Halfway through the trial, participants were informed that incentive rates were going up; they would be paid £0.30 per hour for a maximum payment of £50. Participants were notified by postcard and an email.

21 For full details on how these targets were chosen, see Appendix 11.2.1

22 SAP records (such as EPCs and DECs) include number of rooms and are available to the public at https://epc.opendatacommunities.org

23 Available at https://www.ssen.co.uk/save/

24 SDRC 1. Available at https://www.ssen.co.uk/save/

25 Ehrhardt-Martinez, K., Donnelly, K. and Laitner, J. 2010. Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities, American Council for an Energy-Efficient Economy (ACEEE)

26 Thaler, R. and Sunstein, C. 2009. Nudge: Improving Decisions About Health, Wealth and Happiness.

27 Carmichael, R., Gross, R., Rhodes, A. 2018. Unlocking the potential of residential electricity consumer engagement with Demand Response.

5.3 Banded pricing materials and messaging

The banded pricing trial utilised a mix of postal, email, text and video engagement materials.

5.3.1 Postal

Figure 14 and Figure 15 below show the initial booklet sent to all of TG3 and TG4. This booklet introduced the trial and asked participants to opt-in (TG3) or to opt-out (TG4). The booklet informed the participants of the threshold they would need to observe to be eligible for payments (customised to participants).

Figure 14: TP3 banded pricing booklet, cover page

Figure 15:TP3 banded pricing booklet, interior pages

Halfway through the trial, all participates enrolled in the banded pricing trial received a postcard that notified them of the price increase (described in Section 5.2.3).

5.3.2 Email

The email messages broadly followed the format of the postal materials and used the same graphics.

All households in TG3 and TG4 received an initial email informing them of the banded pricing trial (and in the case of TG3, asking them to opt in). The email also included a link to a video with additional information (see Section 5.3.4) and, in the case of TG3, a webform to opt-in to the trial.

Halfway through the trial, all participates enrolled in the banded pricing trial received an email that notified them of the price increase (described in Section 5.2.3).

5.3.3 Text message

Participants that had enrolled in the banded pricing trial received weekly text messages with balance updates.

5.3.4 Video

The SAVE team developed an animated video to explain the trials banded pricing and how participants can maximise their rebate, as shown in Figure 16. The video featured the same Arthur Tate character used in other TP2 and TP3 materials. This video was available on the '4-to-8' website and on YouTube.[28]

The video focussed on three points and was structured so that it could be easily cut and the first two points could be re-used in a BAU scenario:

- Explanation of why the network sometimes experiences stress between 16:00 and 20:00.
- Why running appliances outside of this period can help ease the pressure. The video stated specific appliances to avoid using during the peak period, such as the washing machine, dishwasher, tumble dryer, the oven and charging an electric car.
- An introduction to the banded pricing and explanation of how the SAVE project would pay participants for every hour they are able to keep their consumption below their customised target. The video also showed participants how to use Loop to check their energy consumption.

28 Available at https://www.youtube.com/watch?v=1CQFrdmHsYc&t=42s

Figure 16: Still from TP3 Arthur Tate video

Participants were sent a link to the video in an email at the start of the trial (1 October 2018).

5.4 Trial outcomes

A full analysis of the energy consumption data for TP1 is available in Section 7.3. Non-energy impacts are presented below.

5.4.1 Opt-in and opt-out rates

The final opt-in rate to the banded pricing trial was 38% of TG3. This include those participants that signed themselves up using the postcards or website, as well as those that were contacted directly.

The final opt-out rate to the banded pricing trial was 2% of TG4, resulting in a participation rate of 98%.

As expected, the participation rate was much higher using the opt-out approach.

6

DATA AND METHODS

6.1 SAVE project data

6.1.1 Household survey data

This report uses household survey data collected by the fieldwork contractor (BMG Research). This dataset contains the socio-economic and demographic data for the participants in the fieldwork, along with other information about the dwelling occupied and appliances owned by each household. Update surveys were conducted at intervals during the trials where data was over 12 months old to ensure that basic household attributes such as number of occupants were accurate.

6.1.2 Time-use diary data

Time-use diary data was also collected by the fieldwork contractor during each trial period. The data collected consisted of a sequence of activities for each survey respondent, each with a start and finish time. The activities recorded by the survey were allocated to categories such as eating or cooking.[29]

Analysis of the time-use diary data is presented as part of the evaluation of the impact of the 'challenge' interventions during TP1 and TP2 and 'events' during TP3.

6.1.3 15-minute household electricity consumption data

The analysis in this report is based on the electricity consumption data collected via the internet-connected 'Loop' electricity monitoring kit (hitherto referred to as 'Loop' data). The 'Loop' data used in the analysis consists of watt-hour (Wh) readings observed at 15-minute intervals for each participating household. This data provides the measure of electricity consumed by individual households within the treatment and control groups during the trial periods. Before analysis, the Loop electricity consumption data was processed and summarised over a number of time periods and intervals: for example, producing hourly and weekly mean consumption values for each household. Data cleaning was also conducted to ensure that faulty installations of the Loop kits and erroneous consumption values were not included in the analysis. Further details of the cleaning conducted is included at the head of each section of the analysis that follows[30].

6.2 Third-party data

6.2.1 Weather data

Met Office weather data was used in the analysis to provide an estimation of household heating loads. The hourly data used was collected at Middle Wallop, UK between the dates 30-09-2016 and 31-01-2019 and was downloaded from the Met Office Weather Observations Website[31]. The hourly weather data was pre-processed prior to use to create daily and weekly average temperatures, and to calculate heating degree-days.[32,33]

6.2.2 Simulated daylight data

This report uses sun-path simulation data produced by the Transient System Simulation Tool (TRNSYS) software[34] to estimate local sunrise and sunset times. The simulation used Southampton as the location.

6.3 Methods

6.3.1 Experimental design

Given the randomised control trial (RCT) design of the SAVE trials, intervention effects have been analysed by comparing the difference between control and intervention groups. Given the successful randomisation and allocation of participants to treatment and control groups, the assumption is that prior to treatment, the groups would be equal in terms of both the outcome variable and household characteristics. Any difference in consumption between the control and intervention groups is therefore assumed to be a result of the intervention alone.[35] It is assumed that all households in the study experienced the same environmental conditions during the trial weeks and therefore there is no need to correct for any differences in environmental conditions. This means the results should be replicable and scalable to the wider population. Using a RCT approach limits biases that may be present in the trial groups by comparing results to a similar control group, instead of past behaviour of the treatment group.

29 This used a modified version of the Multinational Time-Use Survey coding system, see https://www.timeuse.org/mtus for more details.
30 Rushby, T. and Harper, M. 2018. "SAVE Loop Energy Saver Data Cleaning and Preprocessing." University of Southampton.
31 For more information refer to the Met Office website: http://wow.metoffice.gov.uk/
32 Heating degree days are a measure of how much heating is required on a given day. For more information, see https://www.weather.gov/key/climate_heat_cool
33 For details of data processing see Anderson, B. and Rushby, T. 2019. "Process Metoffice WOW data for the SAVE study region". University of Southampton.
34 TRNSYS is a graphical software tool used to simulate the behaviour of transient systems such as energy, or in this case, sun-path. The SAVE project used the TRNSYS software to model sunrise and sunset times to estimate daylight hours in Southampton during the trials. More information available here: http://www.trnsys.com/
35 Frederiks, E.R., Stenner, K., Hobman, E.V., Fischle, M. 2016. Evaluating energy behavior change programs using randomized controlled trials: Best practice guidelines for policymakers. Energy Research & Social Science 22, 147–164. https://doi.org/10.1016/j.erss.2016.08.020

The analysis in this report (along with previous analysis presented in SDRC 2.2[36]) indicates that the treatment groups show small but consistent differences in consumption to that of the control group. For this reason, the analysis also employs the difference-in-differences statistical technique for analysis (see Section 6.4.2 for more information).

Due to the design of the study, it is not necessary to control for potential confounding characteristics of the households in each treatment group. However, a selection of household attributes is included in the analysis to examine characteristics that are associated with the variability in treatment effect.

6.3.2 Assumptions and limitations

6.3.2.1 Experimental design and analysis

As with any experimental study, a number of limitations apply to the findings of the trial analysis. General limitations apply to the analysis of the interventions arising from both sampling and statistical analysis. In summary, limitations of this study are related to the following:

- Recruitment of trial participants: the analysis assumes the sample was randomly assigned to treatment groups and therefore the groups are representative of the sampled population with respect to both the mix of household socio-demographic and electricity consumption characteristics (see SDRC 2.2).

- Statistical power: the achieved sample size and variability of household electricity consumption limit the size of the effect that can be robustly detected (see Anderson and Rushby, 2018[37]). In general, the smaller the treatment effect, the larger the sample size required to observed that effect with confidence.

- Experimental conditions: it is assumed that all households experienced the same environmental conditions during the trial negating the need to correct for any differences despite local variation in environmental conditions (such as weather).

- Analytical assumptions: for example, parallel trend assumption of the difference-in-differences technique may not hold (see Statistical models, Section 6.4).

6.3.2.2 Measurement

The Loop electricity monitors used in SAVE project measure current (amps) only, without voltage measurement. Equivalent power (presented as Watts) is estimated based on the fixed voltage value of 240 Volts without phase reference. In effect, the Loop estimates are closer to apparent power (VA), not real power (W).

As a consequence, the wattage reduction as seen by the Loop data is slightly underestimated, although it does accurately represent the intervention thermal impact on the distribution network. This means that actual wattage reductions due to SAVE interventions is likely higher than reported by Loop device.

6.3.3 Metric of measurement

The metric of measurement used in the analysis of intervention impacts was mean 15-minute consumption summarised across various time-periods appropriate to the analysis conducted. As the distribution of household consumption was observed to be skewed, a log transformation was applied for statistical modelling.[38] The outcome variable of the models reported is therefore log-mean 15-minute consumption.

6.3.4 Analysis approaches

The evaluation of interventions tested within the SAVE trials involved using a number of analytical and statistical methods. A combination of methods was tailored to each intervention according to the nature of the hypothesised treatment effects. In order to examine the impact of each intervention, the trial analysis was generally configured using two approaches: ‘short-term’ and ‘longitudinal’.

6.3.4.1 Short-term

This form of analysis was directed toward those interventions that aimed at encouraging short-term reductions in consumption over a number of hours or days during a targeted period, known as ‘event days’. The events targeted varying lengths of time (one to five days) and periods of the day (4pm to 8pm and 5pm to 7pm) and therefore required a flexible and high-resolution analysis approach to detect changes in consumption. This approach was also used to examine in more detail the timing of any load reduction or shifting - between hours of the day and days of the week - during longer-term interventions.

36 Available at https://www.ssen.co.uk/save/

37 Anderson, B., Rushby, T., 2018. We Got the Power: Statistical Significance, Power, Study Design and Decision Making with A Worked Example. University of Southampton, Southampton, UK.

38 Transformation of the dependent variable is common practice for non-normally distributed outcome variables. See Field, A., Miles, J., Field, Z., 2012. Discovering Statistics Using R. SAGE Publications.

6.3.4.2 Longitudinal
Longitudinal (week-by-week) analysis was used to provide a higher-level analysis of the change in consumption over a longer timescale. This analysis generally involved using weekly summary data, i.e. the mean 15-minute consumption of households averaged by week. Analysis examined the weekly summary data for changes in consumption measured during the whole day (all-hours) and during the targeted peak period of 4pm to 8pm only (peak-hours). Some interventions required separate measurements to be constructed for weekdays and weekends: for example, in TP3 the time-of-use rebate intervention targeted only peak-hours on weekdays, therefore the main measurement of consumption tested was the mean consumption recorded for weekdays only.

6.4 Statistical models

For the analysis contained in this report, two statistical techniques are used to investigate the change in consumption attributable to the interventions tested in the second and third trial periods:

- 'Treatment-only' models: single-variable linear regression modelling to investigate the differences in mean consumption between the treatment and control group;
- 'Difference-in-differences' (DiD) models: to investigate the change in the differences in mean consumption between treatment group and the control group, and the relationship of these differences to household characteristics.

As noted above, statistical models were run on the consumption data summarised across a number of different temporal scales according to the hypothesised treatment effects.

6.4.1 Treatment only model
The treatment only models were run to examine the differences between the treatment and control groups at a number of temporal scales:

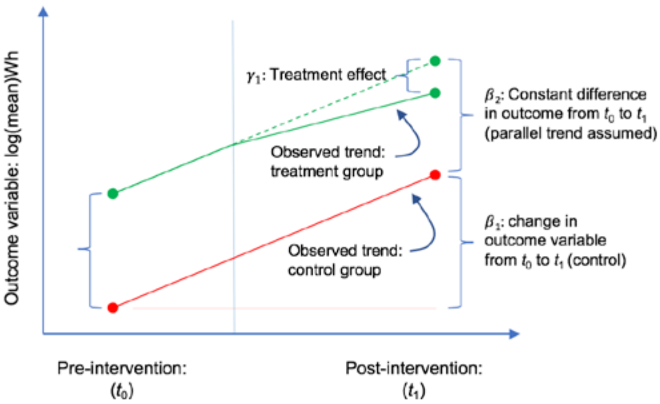
- Weekly: to understand how the treatment effect varies across longer timescale, for example how the effect from LED installation varies with the reduction in daylight availability during winter;
- Hourly: to understand how the treatment effect varied by hour of the day and/or day of the week, for example according to active occupancy.

For full details, see SDRCs 3.2 and 3.3.[39]

6.4.2 Difference in difference model
Difference-in-difference is a commonly used statistical technique used to compare two groups that have been shown to be unequal in terms of the variable of interest (outcome or dependent variable) prior to the intervention; in this case, electricity consumption: (log(mean Wh)). The technique relies upon the assumption that although the treatment and control groups are not equal, the trend of the dependent variable over time is the same for both groups (i.e. the parallel trend assumption).

An estimate of the trend in the control group (the difference mean from the reference week to the week under consideration) is given by β_1. The estimate of the difference between the consumption of the control group and the expected consumption in the treatment group is given by β_2. Finally, γ_1 is the difference-in-differences estimate: the difference between the (unobserved) expected and observed consumption in the treatment group, i.e. the treatment effect. These coefficients are illustrated in Figure 17 below.

Figure 17: Illustration of the 'difference-in-difference' linear regression model coefficients



The influence of a number of additional household characteristics were modelled by the analysis, including the interaction with customer type. This was conducted to examine how the estimated treatment effect, and receptiveness to each measure, varied across different household types.

Note: generally, the linear regression models consider the whole of the treatment group, despite not all of the households in the group receiving treatment. This analysis therefore gives an estimate of the treatment effect, given the sample population and uptake rate as achieved in each trial. Analysis was conducted this way to show results that would be expected across a population as a whole, should the DNO scale the methods tested on SAVE.

For full details, see SDRCs 3.2 and 3.3.[40]

39 Available at https://www.ssen.co.uk/save/
40 Available at https://www.ssen.co.uk/save/

6.4.3 Statistical power and confidence intervals

The sample size for the SAVE trials was evaluated using commonly accepted values for statistical power of 0.8.[41] Confidence levels (p-values) of model results are reported where significant and, unless noted otherwise, confidence intervals shown on charts are at the 90% confidence level.

6.5 Vulnerable customer analysis

The Energywise project, run by UK Power Networks, also looked at domestic demand side response (DSR) but focused on vulnerable customers only to understand how such customers can interact with domestic DSR and provide insight to ensure 'fairness' in business as usual approaches to customer engagement. For this reason, Energywise provides an interesting comparison project. SAVE has completed similar analysis of vulnerable customers in order to be comparable.

Energywise trialled both energy efficiency measures and price signals (much like SAVE). As a result, the SAVE project conducted additional analysis on how the SAVE trials effected vulnerable customers. SAVE looked to test if vulnerable customers interact with the SAVE interventions differently than the general population.

The selection of criteria adopted to identify vulnerable customer from SAVE's sample was built to be similar to that of Energywise.

Table 5 below shows the criteria for vulnerability identified on each project. Additional details on how these categories were defined are available in Appendix 11.3.

Table 5: Vulnerability criteria

Vulnerability identified	SAVE	Energywise
Rural Setting	✕	
Lone Parent	✕	
Age	✕	✕
Working status	✕	✕
Tenant	✕	✕
Electricity bill payment method	✕	✕
Qualification	✕	✕
Long Term Sick	✕	
Income	✕	✕

Within the SAVE project, customers with three or more of the criteria above were categorised as 'vulnerable' for the purposes of the analysis below.

In addition to using survey evidence to categorise vulnerability as above, SSEN also carried out a fresh cross-check of Priority Service Register customers against the project population to provide a subset of 'vulnerable'. No matches were found.

The analysis evaluates the impact of SAVE on vulnerable customers as compared with the wider project population.

41 Statistical power indicates the probability of a Type II Error (false negative). This should not be confused with confidence interval, which indicates the probability of a Type I Error (false positive).

7

ANALYSIS AND RESULTS

7.1 Trial Period 1 analysis

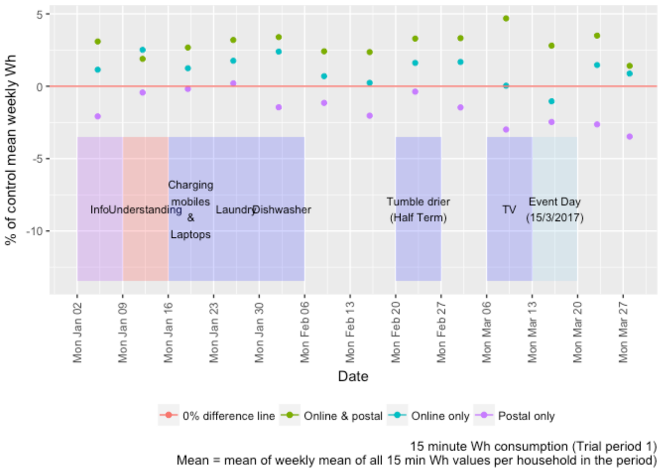
The following section provides analysis of the impact of the first period of trial interventions. This analysis focuses on providing an understanding of if, and how, treatment effects vary across intervention types. SAVE SDRC 2.2 provides additional analysis on TP1.[42]

7.1.1 Consumption of all trial groups

As previously mentioned in Section 3.2, TG4 received hardcopy materials through the post. TG3 received the hardcopy materials in the post and received selected materials digitally through emails and the Loop app. TG2 also received materials through email and the Loop app. For this reason, the figures below compare three treatment groups (postal only, TG4; postal and online, TG3; and online only, TG2).

Figure 18 shows the differences between mean Wh for the peak period by week and intervention group relative to the control group. Some intervention groups show a consistently higher level of consumption than others, and the 'postal only' group (TG4) is the only one to (broadly) show a consistently lower consumption than the control group, especially towards the end of the period. These findings pointed towards a need for a difference-in-difference approach to analysis in trial periods 2 and 3. The highlighted weeks in the graph below show weeks when participants received SAVE messaging.

Figure 18: Difference in mean weekly consumption relative to the control group



The results show that membership of one of the treatment groups (when compared to the control group) does not predict any significant difference in consumption. Whilst the results are not statistically significant, the 'online and postal' group has consistently higher consumption than the control group and that the difference increases over the trial period. In contrast, the 'postal only' group has consistently lower consumption than the control group.

7.1.2 Event day interventions (TG2 and TG3)

This section provides analysis of the impact of the 'event day' in TP1 using household survey data and Loop energy consumption data. The event occurred on Wednesday, 15 March 2017 between 16:00-20:00. TG3 participants were asked to reduce their load by 10% during the peak period.

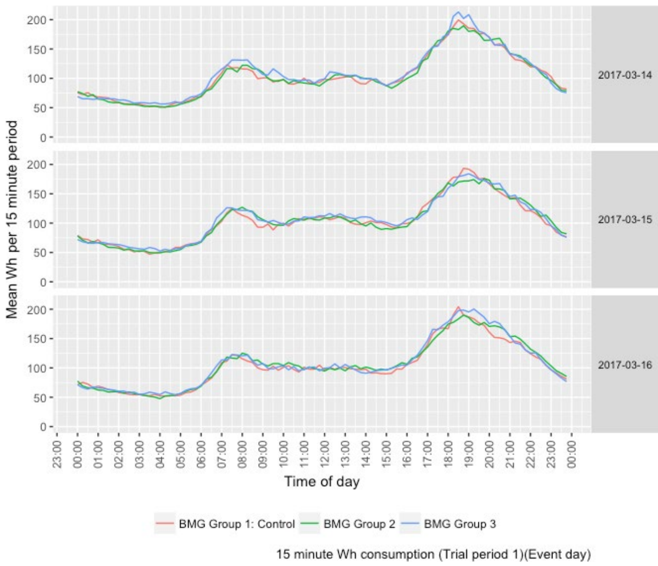
As noted in Section 3.3, the intervention was originally planned for TG3, but TG2 also received notification of the event through email and Loop notification. For this reason, both groups are included in the analysis.

Overall, on the event day:

- **TG2 (online only) consumption was 3.6% or 23 Wh/h lower than the control group**
- **TG3 (online, postal and price signal) consumption was 3.4% or 21 Wh/h lower than the control group**

Figure 19 below shows the mean consumption in each 15-minute period for the event day and the day before and after to provide a visual depiction of any shifting of consumption to periods outside the event. However, differences between the groups are not statistically significant.

Figure 19: Mean 15-minute Wh consumption profile by trial group – event day (+/- 1 day)



42 Available at https://www.ssen.co.uk/save/

In summary, the results provide the following observations:

- On the day preceding the event day: TG3 used more than the other groups during the evening peak period; this would be the case if consumption had been shifted to this day from the event day.
- On the day of the event: TG2 and TG3 used slightly less than the Control group during the targeted peak period. TG3 used more in the period just prior to the peak period. Both TG2 and TG3 appeared to use slightly more than the Control in the period just after the peak. This provides evidence of shifting load to outside the peak period. Those that opened the email had slightly higher reductions, although this was not statistically significant.
- On the day after the event: TG3 again used slightly more than the other two groups during the peak period which would be the case if consumption has been shifted to this period from the day before.

While these results were not statistically significant, they do provide additional evidence that participants are trying to reduce their energy consumption during the event.

7.1.2.1 Time-use data

TG1 (control) and TG3 were questioned about their energy-using activities on the event day (for additional details on the time-use diary data collection, see Section 6.1.2). The analysis counted all electricity-using acts reported.

TG3 reports fewer electricity using acts during the event period than TG1, although these differences are not statistically significant. The survey also asked about respondent location to determine time spent in the house or outside of it. **The results show that TG3 was more likely to be out of the house during the peak period on the event day. This is a statistically significant effect for TG3 and especially for those who opened the loop email**. This confirms that these households were less likely (11% groupwide and 16% for the subgroup that opened the email) to perform energy acts at home than those in the control group.

7.1.3 Household characteristics

Analysis examined the relationship of household characteristics to the magnitude of treatment effect in each group and in each trial period. The results show that while differences were found in electricity consumption between groups, no statistically significant differences were found in *treatment* effects. There were, however, small but consistent differences in treatment effect based on heating fuel. Houses heated by electric (non-storage) heaters has slightly greater treatment effects, suggesting this group had more ability to reduce their electricity consumption. For additional details on this analysis, see SDRC 2.2.[43]

7.2 Trial Period 2 analysis

The following section provides analysis of the impact of the second period of trial interventions. This analysis focuses on providing an understanding of if, and how, treatment effects vary across intervention types. SAVE SDRC 2.3 provides additional analysis on TP2.[44]

7.2.1 Longitudinal analysis (TG3 and TG4)

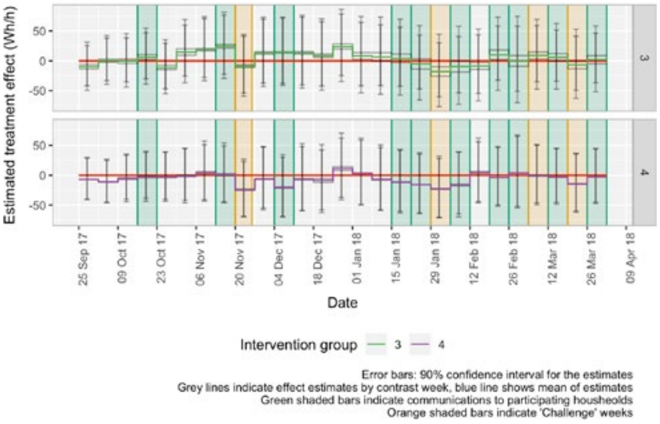
Initial analysis used weekly summaries of the 15-minute electricity consumption data to analyse the impact of the intervention across the full extent of the trial period. This initial analysis showed that prior to the start of TP2, mean consumption in TG4 is up to 6% lower than the control, clearly showing the requirement to use difference-in-difference models to account for the pre-treatment asymmetry between groups.

Figure 20 uses difference-in-difference estimates to show the average difference between the treatment and control groups during weekday peak-hours (16:00 - 20:00). The grey lines in each chart show results using different contrast weeks for the difference-in-difference analysis. The green (TG3) and purple (TG4) show the average results across all contract weeks. The vertical lines are error bars representing the 90% confidence intervals. Weeks with a green highlight show those weeks where TG3 and TG4 received engagement materials such as the welcome pack or an email; amber weeks show the event weeks where the groups were asked to reduce their consumption at a specific time. Additional details on the messaging schedule is available in Section 4.1.

It should be noted that weekly reductions presented in this section do not exactly match the reductions presented in Section 7.2.2 (event day analysis), as this section analyses total peak electricity consumption for each week and Section 7.2.2 analyses consumption from the event times only.

43 Available at https://www.ssen.co.uk/save/
44 Available at https://www.ssen.co.uk/save/

Figure 20: Estimated treatment effects by intervention group as mean change in consumption in peak-hours



From Figure 20, the following observations can be made regarding the responses of the treatment groups to the intervention:

- **The maximum estimated treatment effect in TG3 occurred during the week commencing 29 January, with a mean load reduction of 2.8% or -18 Wh/h (90% CI -69 to 38 Wh/h).**
- **The maximum estimated treatment effect in TG4 occurred during the week commencing 20 November, with a mean load reduction of 3.8% or -24 Wh/h (90% CI -69 to 25 Wh/h).**[45]
- TG3 appear to increase consumption in the 3 weeks prior to Event 1, in contrast to TG4 where there is very little increase. The cumulative effect is that impact during Event 1 is very small for TG3 using the longitudinal method of analysis.
- Following Event 1, consumption in TG3 increases consumption to above the expected level, while consumption in TG4 is below the expected level, indicating some persistence in the treatment effect within TG4 but not TG3.
- TG4 appear more receptive to the second educational postcard (sent w/c 4 December 2017), with a decrease in consumption this week that is not seen in TG3.
- **Both treatment groups show consistent reduction week-on-week through January (when SAVE sent multiple email notifications), with a maximum effect for the second part of the trial period observed during the week commencing 29 January.**
- **However, there may be some evidence of fatigue, as both TG3 and TG4 increase their consumption in February.**
- Consumption is variable across the treatment period, showing that engagement and education alone is not enough to provide consistent reductions in energy consumption.

The size of the confidence intervals around the effect estimates should be noted and none of the weekly results shown above are significant at the 90% confidence level.

7.2.2 Event day interventions (TG3 and TG4)

This section provides analysis of the impact of the TP2 events conducted with TG3 and TG4 using household survey data and Loop energy consumption data. Households in TG3/TG4 were prompted to reduce their electricity consumption during peak hours on event days. The targeted periods for reduced consumption during the TP2 events were as follows:

- Event 1: peak hours each day for weekdays during the week commencing 20 November 2017
- Event 2: peak hours each day for weekdays during the week commencing 29 January 2018
- Event 3: peak hours Tuesday and Wednesday 6-7 March 2018
- Event 4: 17:00-19:00 Tuesday 20 March 2018

The analysis examined household consumption during three time periods:

- Pre-peak: the four hours prior to the peak period (12:00 to 16:00)
- Peak: the four hours of the peak period (16:00 to 20:00)
- Post peak: the four hours following the peak period (20:00 to 00:00)

For each event, three weeks of consumption data is used: the week preceding the event, the week of the event and the week after. This allows any consumption shifted away from the event week (i.e. to hours and days before and after the event period) to be measured. The analysis below uses a week-to-week difference-in-difference approach.

A summary of the results is presented below in Table 6. A positive difference represents an increase in consumption relative to the control group, while a negative difference represents a decrease in consumption. The events were designed to decrease consumption, and so a negative value (highlighted green) is consistent with the goals of the trial.

45 Note both these weeks were event weeks also.

Table 6: Summary of TP2 event day reductions

Event	Delivery mechanism	Reduction target	Prize (TP3 only)	Duration	TG3 % difference	TG4 % difference
TP2 Event 1	Post	10%	Raffle draw for one of 20 £100 Restaurant Choice gift cards	5 days, 4 hours a day	-5.5%	-3.8%
TP2 Event 2	Email	10%	Raffle draw for one of 20 £100 Restaurant Choice gift cards	5 days, 4 hours a day	-0.8%	-1.3%
TP2 Event 3	Email	20%	Raffle draw for a £1,000 Sainsbury's gift card	2 days, 4 hours a day	+3.0%	+2.4%
TP2 Event 4	Email	10%	£10 Costa Coffee gift card to all successful	1 day, 2 hours	-7.0%	-3.0%

7.2.2.1 Event 1

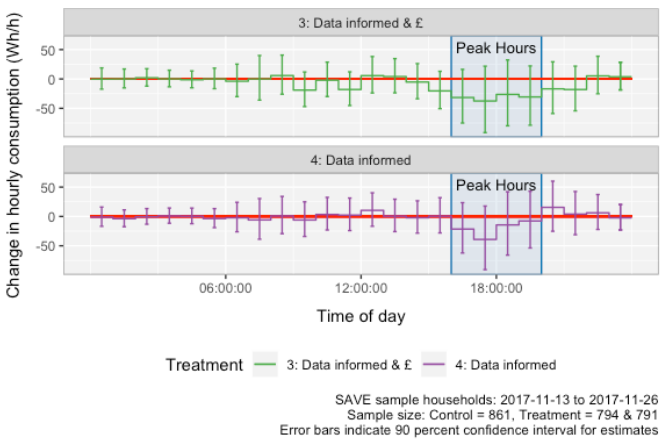
Event 1 took place every day Monday to Friday in w/c 20 November 2017 between 16:00-20:00 and asked participants to reduce by 10%. Participants were notified by post.

Figure 21 illustrates the results of the difference-in-difference analysis expressed as a change in hourly consumption (Wh/h). The purple and green lines represent the average change in consumption compared to the control group. The largest change occurs between 17:00 and 18:00 for both TG3 and TG4. The lower consumption continues outside of the peak hours for TG3. There is no evidence of load shifting to before or after the peak period.

Analysis of the consumption data shows a reduction in consumption in both TG3 and TG4 groups during Event 1 relative to the control group. **The mean reduction across the peak period was calculated to be 5.5% (-32 Wh/h) and 3.8% (-21 Wh/h) in TG3 and TG4 respectively.**

The extent of the confidence intervals show that the estimated treatment effects are not statistically significant at the 90% level.

Figure 21: Change in hourly mean 15-minute household consumption by group, converted to hourly equivalent (Wh/h), Event 1



7.2.2.2 Event 2

Event 2 occurred every day Monday to Friday in w/c 29 January 2018 between 16:00-20:00 and asked participants to reduce by 10%. Participants were notified of the event by email and Loop app notification. Figure 22 shows the results of the difference-in-difference analysis as change in consumption (Wh). The coloured lines represent the average change in the hourly consumption by treatment group. The largest change for TG3 occurs between 18:00 and 19:00 and for TG4 occurs between 19:00 and 20:00.

In this event, analysis shows that the response was smaller in both treatment groups than in event 1. There was also more variation in the hourly consumption for TG4 with both increased and decreased consumption observed during peak hours. The estimation of the treatment effect using the difference-in-differences analysis shows **mean consumption was reduced in peak hours by 0.8% (-4 Wh/h) and 1.3% (-7 Wh/h) in TG3 and TG4 respectively.** The results were not statistically significant.

There is evidence of load shifting, as the consumption of both groups was higher than the control before and after the event. Consumption before the event was 3.4% higher for TG3 and 0.9% higher for TG4. Consumption after the event was 2.3% higher for TG3 and 1.3% higher for TG4. This indicated that participants may be moving their consumption to before or after the event. However, these differences are not statistically significant.

Figure 22: Change in hourly mean 15-minute household consumption by group, converted to hourly equivalent (Wh/h), Event 2

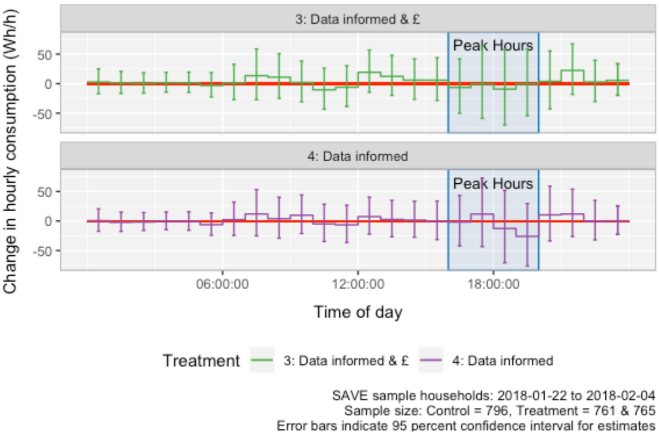
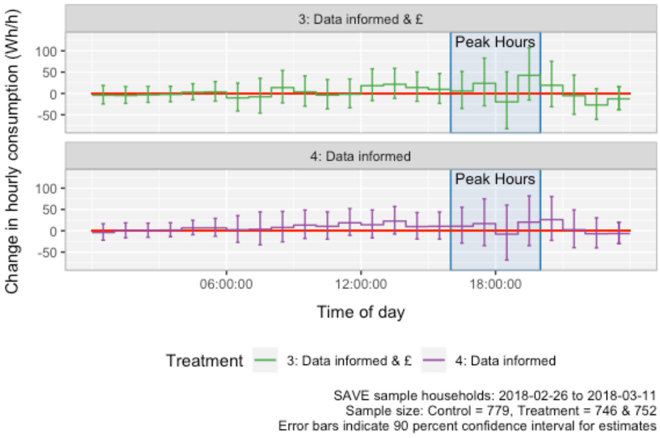


Figure 23: Change in hourly mean 15-minute household consumption by group, converted to hourly equivalent (Wh/h), Event 3



7.2.2.3 Event 3

Event 3 occurred on Tuesday and Wednesday, 6-7 March 2018 from 16:00-20:00 and asked participants to reduce their consumption by 20%. Participants were notified of this event by email and Loop app notification. Figure 23 presents the results of the difference-in-difference analysis.

In Event 3, analysis of the **consumption data shows that during peak hours, consumption in TG3 and TG4 increased relative to the control group (3.0% or 13 Wh/h and 2.4% or 10 Wh/h, respectively)**. There was substantial variation in the consumption compared to the previous events; there was a small reduction in consumption observed for only one hour in the peak period results (between 18:00 and 19:00). Results were not statistically significant.

It's important to note that these results were not statistically significant; it's unlikely that participants deliberately increased their consumption during the event. Rather, the results show that there is variability in consumption between treatment and control groups and also variability within groups. Care should therefore be taken when interpreting the results not to attribute treatment effects to the small differences arising from the noise of background variability (indicated by the wide confidence intervals).

7.2.2.4 Event 4

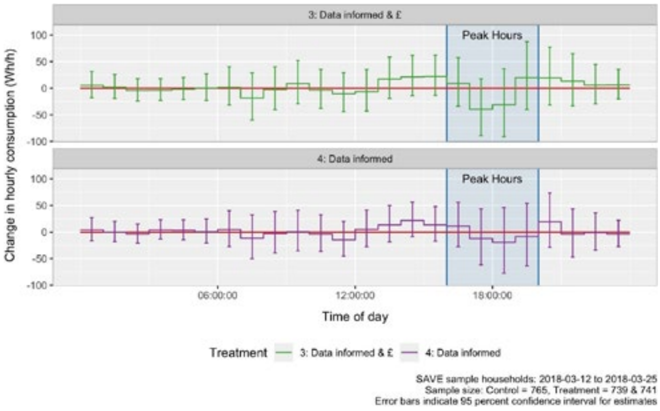
Event 4 occurred on Tuesday 20 March 2018 from 17:00-19:00 and asked participants to reduce their consumption by 10%. Participants were notified of this event by email and Loop app notification. Figure 24 shows the results of the difference-in-difference analysis.

Analysis of the peak consumption data shows an effect in both treatment groups. However, this event targeted only the hours between 17:00 and 19:00 hours (half of the peak period). The hourly results show that a much greater reduction was observed between 17:00 to 19:00 (with increased consumption in the first and fourth hour of the peak period). **The average reduction over these two hours for TG3 was 7.0% (-35 Wh/h). For TG4 the average reduction was 3.0% (-16 Wh/h).**

There was evidence of load shifting, as the consumption of both groups was higher than the control group prior to the event (4.9% for TG3 and 5.5% for TG4). TG3 also had higher consumption after the event (3%). This indicates participants may have been moving their energy consuming activities to outside the challenge period.

As with the other events, the results were not statistically significant.

Figure 24: Change in hourly mean 15-minute household consumption by group, converted to hourly equivalent (Wh/h), Event 4



7.2.3 Household characteristics

Analysis examined the relationship of household characteristics to the magnitude of treatment effect in each group and in each trial period. The results show that while differences were found in electricity consumption between groups, no statistically significant differences were found in *treatment* effects. However, there were, small but consistent differences in treatment effect based on heating fuel. Houses heated by any type of electric heater had slightly greater treatment effects, suggesting this group had more ability to reduce their electricity consumption. This is consistent with the findings from the TP1 analysis.

For additional details on this analysis, see SDRC 2.3.[46]

7.3 Trial Period 3 analysis

The following section provides analysis of the impact of the second period of trial interventions. This analysis focuses on providing an understanding of if, and how, treatment effects vary across intervention types. SAVE SDRC 2.3 provides additional analysis on TP2.[47]

7.3.1 Event day interventions (TG2)

This section provides analysis of the impact of the TP3 events conducted with TG2 using household survey data and Loop energy consumption data. Households in TG2 were prompted to reduce their electricity consumption during peak hours on event days. The targeted periods for reduced consumption during the TP2 events were as follows:

- Event 1: peak hours during Wednesday 10 October 2018
- Event 2: peak hours each day for weekdays during the week commencing 29 October 2018
- Event 3: peak hours each day for weekdays during the week commencing 19 November 2018
- Event 4: peak hours during Thursday 13 December 2018

The analysis examined household consumption during three time periods:

- Pre-peak: the four hours prior to the peak period (12:00 to 16:00)
- Peak: the four hours of the peak period (16:00 to 20:00)
- Post peak: the four hours following the peak period (20:00 to 00:00)

For each event, three weeks of consumption data is used: the week preceding the event, the week of the event and the week after. This allows any consumption shifted away from the event week (i.e. to hours and days before and after the event period) to be measured. The analysis below uses a week-to-week difference-in-difference approach.

A summary of the results is presented below in Table 7. A positive difference represents an increase in consumption relative to the control group, while a negative difference represents a decrease in consumption. The events were designed to decrease consumption in the treatment group, and so a negative value (highlighted green) is consistent with the goals of the trial.

46 Available at https://www.ssen.co.uk/save/
47 Available at https://www.ssen.co.uk/save/

Table 7: Summary of TP3 event day reductions

Event	Delivery mechanism	Message	Duration	TG2 % difference
TP3 Event 1	Text		1 day, 4 hours	+2.1%
TP3 Event 2	Email		5 days, 4 hours a day	-2.2%
TP3 Event 3	Post	Co-branded with Energy Savings Trust	5 days, 4 hours a day	-2.9%
TP3 Event 4	Text		1 day, 4 hours	+1.1%

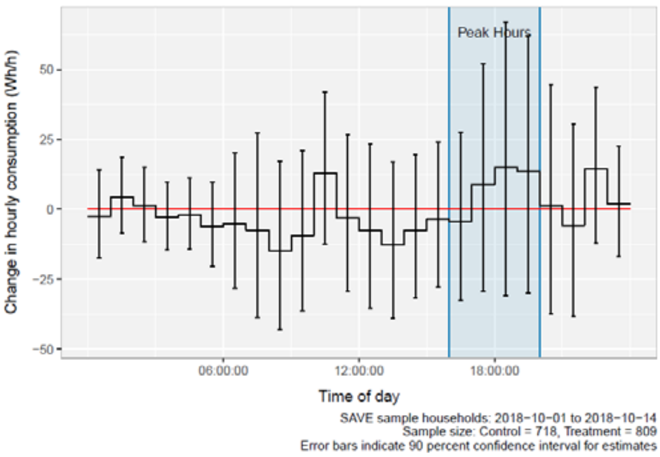
It is important to note that TG2 also had LED bulbs installed in TP2, and therefore event days were not the only intervention received by this group. It is not possible to determine **exactly** how much the reductions in Sections 7.3.1.1 through 7.3.1.4 are due to the events and how much is due to LED installations. These results should be treated with caution for this reason.

7.3.1.1 Event 1

Event 1 occurred during the peak hours (16:00-20:00) on 10 October 2018. The analysis used three weeks of data from 1 October 2018 to 21 October 2018.

The analysis compared the consumption of TG2 to that of the control group using a difference-in-difference approach. The results of this analysis can be seen in Figure 25, which shows the consumption of TG2 (black line) compared to the control group (red line).

Figure 25: Change in hourly mean 15-minute household consumption, converted to hourly equivalent (Wh/h)

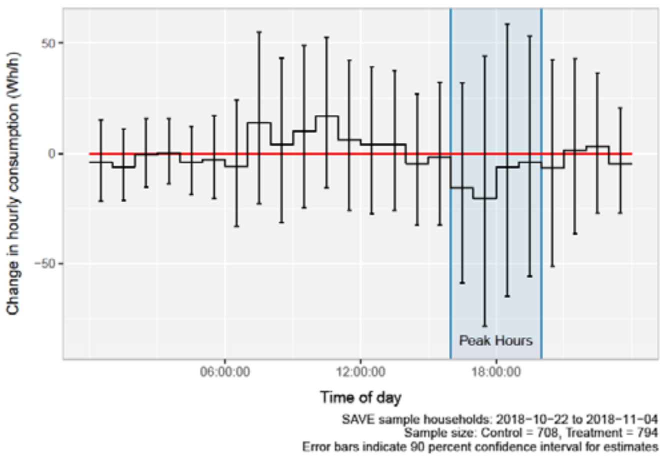


As seen above, the consumption of TG2 is higher than the control during the peak period. **The observed marginal increase in TG2 consumption during peak hours of 2.1% (8 Wh/h) is not consistent with the experiment hypothesis**. However, using a significance level of 90%, the results are not significant; it is unlikely participants are purposely using more electricity doing this time. There is no evidence of load shifting to before or after the peak period.

7.3.1.2 Event 2

Event 2 targeted peak-hours during all weekdays of week commencing 29 October. The analysis utilised 15-minute consumption data for the period 22 October to 11 November 2018. The analysis compared the consumption of TG2 to that of the control group using a difference-in-difference approach. The results of this analysis can be seen in Figure 26, which shows the consumption of TG2 (black line) compared to the control group (red line).

Figure 26: Change in hourly mean 15-minute household consumption, converted to hourly equivalent (Wh/h)

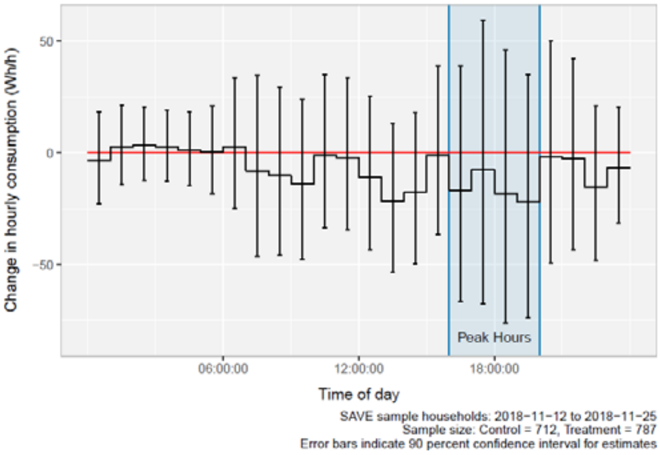


The analysis shows a reduction in electricity consumption of 2.2% (-12 Wh/h) when compared to the control group. There is no evidence of load shifting to before or after the peak period as consumption is roughly similar to the control group. Results are not statistically significant.

7.3.1.3 Event 3

Event 3 targeted peak hours each day for weekdays during the week commencing 19 November 2018. 15-minute consumption data for the period 12 November to 2 December 2018 was used for the analysis of Event 3. The analysis compared the consumption of TG2 to that of the control group using a difference-in-difference approach. The results of this analysis can be seen in Figure 27, which shows the consumption of TG2 (black line) compared to the control group (red line).

Figure 27: Change in hourly mean 15-minute household consumption, converted to hourly equivalent (Wh/h)

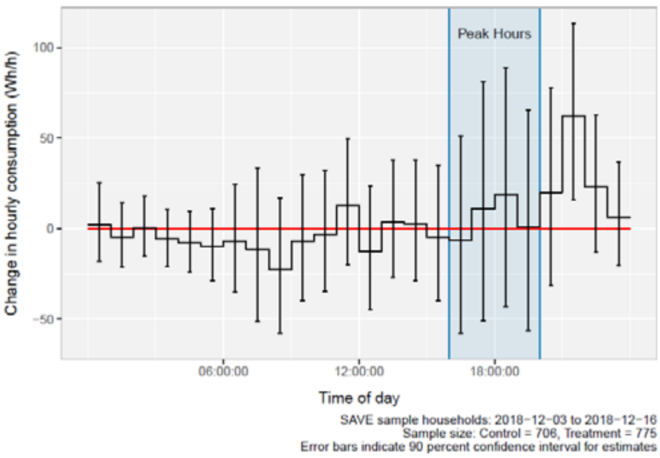


Consumption of TG2 was 2.9% (-16 Wh/h) lower than the control group using the difference in difference analysis. TG2's consumption was lower than the control before and after the event as well, so there was no evidence of load shifting.

7.3.1.4 Event 4

Event 4 targeted peak hours during one day only: Thursday 13 December 2018. 15-minute consumption data for the period 3 December to 23 December 2018 was used for the analysis of the event. The analysis compared the consumption of TG2 to that of the control group using a difference-in-difference approach. The results of this analysis can be seen in Figure 28, which shows the consumption of TG2 (black line) compared to the control group (red line).

Figure 28: Change in hourly mean 15-minute household consumption, converted to hourly equivalent (Wh/h)



Consumption of TG2 was 1.1% (6 Wh/h) higher than the control group using the difference in difference analysis. However, TG2's consumption was higher (by 7.9%) than the control group after the event, which may indicate an attempt to shift load to the post-peak period.

7.3.2 Banded price incentives (TG3 and TG4)

During TP3, trial groups 3 and 4 were exposed to a trial of dynamic tariff strategy. The two treatment groups experienced differential recruitment conditions as follows:

- TG3 (opt-in): by default, households in this treatment group received no treatment but were invited to opt-in to participate.
- TG4 (opt-out): by default, households in this treatment group were enrolled to receive treatment, and invited to opt-out if they did not want to participate.

As the rebate intervention ran for a period of three months, a longitudinal approach to evaluating the impact was used, with the treatment effect measured as the average change in 15-minute consumption during weekday peak-hours.

Household electricity consumption data from 1 September to 31 December 2018 was used to evaluate this intervention.[48] The 15-minute consumption data was summarised to provide weekly mean demand during weekday peak-hours for each household.

7.3.2.1 Difference-in-difference models

To estimate the treatment effects, two difference-in-differences analysis techniques were used. The first used the entire sample of households within each treatment group to estimate the effect while embedding the enrolment rate, i.e. accounting for the differential rates for each enrolment method. These results provide estimates of the expected effect of rolling out a similar scheme (under the same conditions and within a similar population) as it includes the non-participants.

The second used only those households within each group that were participating. These results provide an understanding of how the participants' responses (treatment effect) vary with the enrolment method used.

48 1 month of data prior to the start of the intervention was used to provide the reference weeks with which to perform the difference-in-differences analysis.

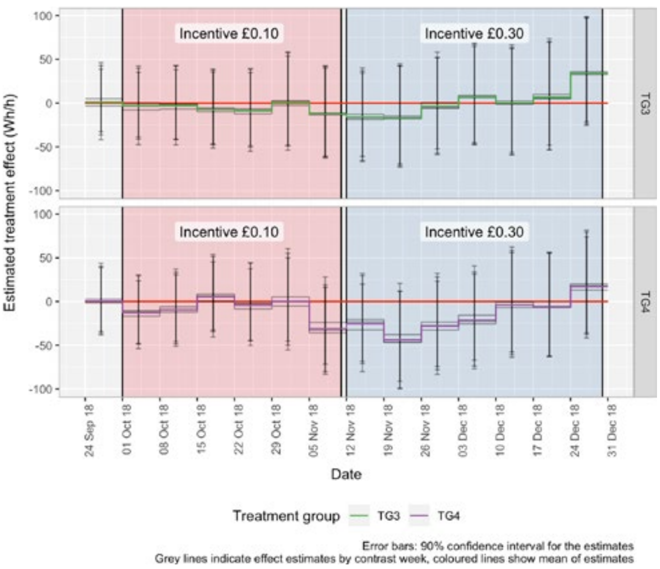
Entire Sample

The estimated treatment effects for the entire sample are shown in Figure 29. The treatment effects are presented as Wh reductions and calculated for each entire treatment group (including both participating and opted-out households); the participation rate is therefore embedded. The pink highlight denotes the period of low incentive payment (£0.10/hour) and the blue highlight shows the high incentive payment period (£0.30/hour). The grey lines represent different reference weeks used in the difference-in-difference analysis; the green and purple lines show the average effect.

The treatment effect is observed to be more consistent in the 'opt-in' group compared to the 'opt-out' group, especially during the low incentive period. In contrast, the treatment effect in TG4, the 'opt-out' group, increases markedly in the final week of the low incentive period (when the price increase notification was delivered) and peaks during the week commencing 19 November. However, this was short-lived; about five weeks after the notification the consumption of both treatment groups is back to the level of the control group.

The postal notification sent to participants about the increase in payment rates landed w/c 5 November. Consumption of both treatment groups declines this week (TG3 consumption was 2.1% lower than the control group, TG4 was 5.5% lower), even though the rate increase did not take effect until 12 November. It's likely the receipt of the notification increased engagement and translated into a decrease in consumption, even though the price increase did not take effect until the following week. This was most pronounced in the opt-out group.

Figure 29: Estimated treatment effects of TOU rebate as mean change in consumption in peak-hours, participation rate embedded



The maximum estimated load reduction for both treatment groups was observed during the week commencing 19 November 2018 – the second week of the high incentive period – with mean effect sizes as follows:

- **TG3 maximum reduction of 2.6%, or -17 Wh/h**
- **TG4 maximum reduction of 7.1% -44 Wh/h**

Both TG3 and TG4 had overall reductions in consumption (kWh) across both incentive phases. The weekly average peak kWh savings for all of TG3 and TG4 (including both participants and non-participants) are presented in Table 8 below. This provides additional evidence that the banded price trial produced overall lower consumption in both treatment groups and across both incentive levels.

Table 8: Average weekly peak consumption savings

Intervention Group	Weekly peak savings during low incentive period (kWh)	Weekly peak savings during high incentive period (kWh)
TG3 (opt-in)	-0.69	-0.43
TG4 (opt-out)	-1.04	-2.56

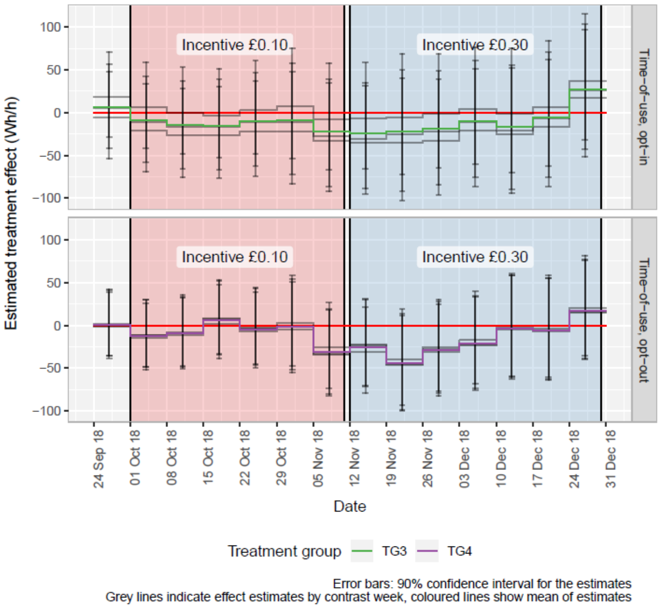
Participants only

The estimated treatment effects for only the participants that accepted the banded-pricing are shown in Figure 30 and presented as Wh reductions per hour. The pink highlight shows the period of low incentive payment (£0.10/hour) and the blue highlight indicates the high incentive payment period (£0.30/hour). The grey lines represent different reference weeks used in the difference-in-difference analysis; the green and purple lines show the average effect.

The consumption of the opt-in group (green line) is more consistently below that of the control group, while the opt-out group's (purple line) consumption is similar to the control group during the low incentive period but reduces markedly after notification of the mid-trial price increase in w/c 5 November. The effect of the price increase on the opt-in group is much smaller than the opt-out group.

This suggests that participants in the opt-in group start out more engaged and aware of their energy consumption; an increase in price does not radically change their habits. This means there is very little price elasticity displayed by the opt-in group, TG3. However, the opt-out group, TG4, shows more price elasticity as they are better able to respond to the mid-trial price increase.

Figure 30: Estimated treatment effects of TOU rebate as mean change in consumption in peak-hours, participants only



The maximum estimated load reduction for TG3 occurred in w/c 12 November 2018 and for TG4 in w/c19 November 2018, with mean effect sizes as follows:

- **TG3 maximum reduction of -4.2% or -24 Wh/h**
- **TG4 maximum reduction of -7.1% or -44 Wh/h**

7.3.2.2 Household characteristics

Analysis examined the relationship of household characteristics to the magnitude of treatment effect in each group and in each trial period. The results show the following effects by sub-group:

- Household size (people) - one and two-person households show the strongest observed response, followed by households with four or more occupants. Three-person households exhibit the smallest response to the intervention.[49]
- Dwelling size (bedrooms) - for both treatment groups, households occupying larger dwellings (3 and 4+ bedrooms) show the greatest treatment effect.
- Primary heating fuel - in both treatment groups, the strongest response was observed in households heated by 'other' fuels (not gas or electricity), followed by households primarily heated electrically. On average, the smallest effects were observed in gas-heated households.

However, due to the small sample sizes within these sub-groups, the results are indicative only. Very large confidence intervals surround the estimated effects. For full details, see SDRC 2.3.[50]

7.3.2.3 Vulnerable customer analysis

Analysis was conducted to determine if significant differences in treatment effect existed between vulnerable and non-vulnerable customers. For both groups, there is no statistically significant difference in treatment effect between vulnerable and non-vulnerable customers.

For full details on analysis performed and how vulnerability was defined, see SDRC 2.3.[51]

49 There were a smaller number of 4+ households, therefore we have less confidence in the results of this category.
50 Available at https://www.ssen.co.uk/save/
51 Available at https://www.ssen.co.uk/save/

8

ENERGY IMPACTS

8.1 Trial Period 1 impact

Overall, the analysis shows that membership of one of the treatment groups does not predict significant differences in consumption over the trial period, meaning that the engagement techniques did not have a statistically significant effect on consumption.

The event day did result in lower consumption for both event groups when compared to the control group. TG2 had a reduction of 3.6% while TG3 had a reduction of 3.4%. The greatest difference was in the 18:00 to 20:00 period, suggesting that if any treatment effect is present, it is largest in this period. As with the overall trends, the confidence intervals overlap with the control group and therefore these results are not statistically significant.

However, there is still evidence of shifted consumption, as TG3 used more electricity than the control during the peak period the day before the event and both TG2 and TG3 used more electricity immediately after the event. While these results are not statistically significant, the increase in consumption outside of the event time does provide evidence that load shifting has occurred.

This shows that engagement or education alone is unlikely to result in reductions in electricity consumption during the peak period. This was true for the group that received both the email and postal engagement as well the group that only received postal messaging.

Event days are more promising, as both treatment groups were able to reduce their consumption during this time. The event day reductions were almost identical across both treatment groups, possibly indicating that price signals have little effect. At this level (£10), price signals were not an effective motivator. TP2 tested additional delivery methods and price signals to further investigate how these may influence customer behaviour.

Evidence from the Time Use Diaries also shows that participants were significantly more likely to be out of the house during the peak period than the control group. This also reinforces the hypothesis that participant groups are actively working to reduce their consumption during the event.

This suggests that for some participants, the easiest way to reduce their consumption is simply by staying out of the house. Future programmes or trials should investigate this further. Offering discounted activities or restaurant meals on days where the network is stressed may be an effective way to reduce peak electricity use in an area. For example, a DNO could partner with a local cinema to offer discounted movie tickets for specific days or times to encourage customers to stay out of the house during the peak period. This may be especially useful if deployed through community engagement groups, such as the Community Energy Coaching method of the SAVE project (for more information, see SDRC 8.8[52]).

8.2 Trial Period 2 impact

The maximum reduction for TG3 occurred during the week of Event 4 (7.0%) and the maximum reduction for TG4 occurred during the week of Event 1 (3.8% W). However, none of these results were statistically significant.

The longitudinal analysis shows the results of the engagement campaign had no statistically significant impact on overall energy consumption. TG3 actually increased its consumption (relative to the control group) in the first half of the trial; the overall decrease in consumption of TG4 was small and not statistically significant.

In the second half of the trial, consumption of both groups reduces in January, suggesting that the weekly emails are useful in reminding participants to reduce their consumption, although these results are not statistically significant. Consumption relative to the control increased for both TG3 and TG4 in February, perhaps suggesting fatigue with the messaging. The rate at which participants unsubscribed for the SAVE mailing list was higher in TP2 than in TP1, which also provides evidence for some level of fatigue. However, these effects are not statistically significant.

There is a fine balance to be struck to ensure that regular reminders do not become too frequent and lead to fatigue or backlash.

52 Available at https://www.ssen.co.uk/save/

Reductions during the events were greater in TG3 (who were offered price signals) for two of the four events. This suggests that financial incentives do not necessarily provide increased participation.[53] SDRC 1 stated, "financial incentives can be effective but potentially need to be relatively large and impacts are often not sustainable over time; non-financial incentives should also be considered." The additional cost of incentives may not reflect good value for money for DNOs; when asking customers for one-off reductions (such as the events trialled here), a sincere 'ask' may be more effective than a financial offer.

8.3 Trial Period 3 impact

8.3.1 Event day interventions

None of the event days tested in this trial period had significant results, and some even resulted in higher consumption when compared to the control group. The event with the greatest reduction was Event 3. The notification for this event was delivered by post and with Energy Savings Trust branding and resulted in a reduction of 2.9% when compared to the control group. Both events delivered by text message resulted in higher peak consumption than the control group.

The average reductions of these events were lower than events from TP1 and TP2, suggesting that delivering education materials along with event day type 'asks' may result in higher reductions.

8.3.2 Banded price incentives

Under the lower incentive, the per household reduction was higher in the opt-in group (TG3) than the opt-out group (TG4). During the higher incentive period, overall group reductions and per household reductions were higher in the opt-out group than the opt-in group. The opt-in group seemed to be less motivated by money—their reductions were broadly consistent over the whole trial period. The reductions of the opt-out group, however, increased markedly after receiving the offer of higher incentive. However, this impact is short lived, as by the end of the trial the peak energy use of both groups was similar to the control group.

This suggests that self-selecting (opt-in) households are relatively engaged with energy consumption already, and likely to have consistently lower energy consumption than the control group. The opt-out group is likely more representative of the general population and their attitudes and practices towards energy consumption. The opt-out group responded well to the mid-trial price increase, which suggests both that they are more motivated by higher financial incentives and that occasional engagement can increase the treatment effect.

The maximum treatment effect for both groups occurs during the second week of the high-incentive period, and slowly reduces over the rest of the trial. By the end the trial, both groups have higher consumption than the control group. It's likely that over time, both groups experienced some level of fatigue with the trial (or simply forget about it). This also reinforced findings from SDRC 1, which notes that financial incentives often do not produce sustainable changes over time.

8.4 Comparison to other LCNI projects

Both UK Power Network's Low Carbon London (LCL) and Northern Powergrid's Customer-Led Network Revolution (CLNR) investigated how smart solutions and demand side management could act as alternatives to traditional network reinforcement, much like SAVE. This section presents high-level findings from both to compare with the results of the SAVE trial.

8.4.1 Low Carbon London Dynamic Time of Use Tariff

The Low Carbon London project[54] investigated how a dynamic time of use tariff (DTOU) can shift consumption patterns and lower peak consumption. It explored how this could be deployed through DUoS (Distribution Use of System) directly to customers by partnering with an energy supplier. Since changes in DUoS may or may not be passed to the customer, we focus on the results of the trial where LCL partnered with a supplier. The LCL approach was a tariff, and so participants may have been worried about high bills if they switched tariff plans, although the trial did protect participants from any losses.

The DTOU tariff had three price levels: high, default and low. Customers in LCL were notified of price events and schedules a day ahead rather than using fixed time schedules.

53 SDRC 1 and Gyamfi et al. 2013. Residential peak electricity demand response—Highlights of some behavioural issues. Renewable and Sustainable Energy Reviews 25, 71–77. https://doi.org/10.1016/j.rser.2013.04.006

54 UK Power Networks. 2014. Residential Demand Side Response for Outage Management and as an Alternative to Network Reinforcement. http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20A1%20-%20Residential%20Demand%20Side%20Response%20for%20outage%20management%20and%20as%20an%20alternative%20to%20network%20reinforcement.pdf

The LCL project worked with an energy supplier to recruit participants into the DTOU trial. Similar to the SAVE banded price incentives deployed with TG3, this was an opt-in approach. Like SAVE, LCL also used post and phone communications to recruit customers. The update rate of LCL was 24%, while the updated of the SAVE banded price incentives was 38%.

The LCL project offered significant incentives to customers to persuade them to switch to this tariff, an average of £143 per customer. This is unlikely to be possible in a BAU scenario, and so real-world recruitment rates may be lower than 24%.

All SAVE interventions were incentive-only, and so may explain the higher update rate. The prices were set so that the price impact of a customer with a 'typical' demand profile would be neutral, although obviously not all customers will follow typical consumption patterns.

The LCL project simulated constraint management events, where a period of high price was surrounded by periods of low price, to stimulate a high level of response. These are similar to the 'event days' employed by the SAVE project. These events had an average response of 50W per household, while the average response from SAVE events was 11W per household. The tariff also utilised its high and low levels to encourage customers to shift load to times when energy was abundant and inexpensive, such as periods of high wind power. This results in an average peak demand reduction of approximately 9%. However, the report does not indicate if these results are statistically significant or not. There is also the possibility that the LCL trial had higher than usual reductions due to self-selection biases. Customers that are unable or unwilling to change their habits are unlikely to agree to this trial.

High tariff periods were variable and did not always coincide with the typical peak period (winter weekdays 16:00-20:00).

A survey conducted with participants suggested most customers shifted load from laundry and cleaning appliances, such as a dishwasher, tumble dryer or washing machine.

8.4.2 Customer-led Network Revolution

The Customer-led Network Revolution project[55,56] looked at a number of low carbon technologies and their impact on load profiles as well as non-traditional solutions to network reinforcement. The project included: solar PV, electric vehicles, heat pumps, micro-CHP, smart appliances and static time of use tariffs (STOU).

The CLNR project worked with British Gas to recruit participants into the STOU trial. Similar to the SAVE banded price incentives deployed with TG3, this was an opt-in approach. Customers were paid £100 for their participation. Despite this being a tariff change, customers were assured that they would not lose money in the trial and the project compensated those that had higher energy bills. Approximately 39% of the participants had higher bills on the STOU tariff; of these the median increase was £18.40.

The TOU tariffs deployed in CLRN were similar to the SAVE banded pricing in that they specifically targeted then evening peak (16:00-20:00), although there were three price periods. The price periods were 'day' (07:00-16:00), 'evening' (16:00-20:00) and 'night' (20:00-07:00). 'Day' and 'night' were below standard rates while the 'evening' period was significantly higher than standard rate.

The CLNR project had an average week day peak reduction of about 8% for participating households. The difference in total energy consumption (kWh) in the peak period was about 6% lower for participating households. Both differences were statistically significant at the 95% confidence level. No significant effects were found on weekends. However, it should be noted that there were demographic differences between the treatment group and the control. There is also the possibility that this trial had higher than usual reductions due to self-selection biases. Customers that are unable or unwilling to change their habits are unlikely to agree to this trial.

However, during the half-hour with the greatest demand of the year, there was no statistically significant difference between the treatment and the control group.

Like LCL, participants in the CLNR project reported that laundry and dishwashing were the household chores most easy to shift outside of the peak period.

55 Bulkeley, H., et.al. 2015. High Level Summary of Learning: Domestic Smart Meter Customers on Time of Use Tariffs. http://www.networkrevolution.co.uk/wp-content/uploads/2015/01/CLNR-L243-High-Level-Summary-of-Learning-Domestic-Smart-Meter-Customers-on-Time-of-Use-Tariffs.pdf

56 Whitaker, G., et.al. 2013. Insight Report: Domestic Time of Use Tariff. http://www.networkrevolution.co.uk/wp-content/uploads/2015/01/CLNR-L093-Insight-Report-Domestic-Time-of-Use-Tariff-Recovered.pdf

8.4.3 Energywise

The Energywise project[57] tested various forms of demand reduction thorough energy efficient equipment and demand side response (DSR) with vulnerable customers. Participants were recruited by postal and face-to-face communication and were randomly allocated to either the treatment group or control group (like SAVE).

The first Energywise trial installed a smart meter and energy efficient equipment (LED lighting, eco-kettles and 'standby saver' power strips) in participants' homes.

The second trial encouraged participants to shift their consumption to outside the peak period, through either:

- Pre-payment customers were offered 'Bonus Time', a non-punitive dynamic peak rebate tariff. Customers were credited ten units of energy back for every one unit they saved during Bonus Time periods. Participants were notified of the Bonus Time period the day before via text message.
- Credit customers were offered 'HomeEnergy FreeTime', a non-punitive static time of use tariff where customers could choose free energy on either Saturday or Sunday between 9am and 5pm.

Customers had to opt-in to the second trial and switch their tariff, although they were encouraged to do so by phone calls and in-person visits. The second trial had a recruitment rate of 86%. This is higher than SAVE's opt-in rate for TP3 (38%), however SAVE did not utilise in-person visits and so can be expected to be lower. Future deployment of similar schemes will need to balance the cost of in-person recruitment with the (likely) higher acceptance rate.

In the first trial, participants reduced their peak consumption by about 5.2%, or 23W.

The second trial's 'Bonus Time' scheme resulted in an average shift of 7 Wh per event, or a peak reduction of 1.5%. The second trial's 'HomeEnergy FreeTime' scheme achieved a 2.2% reduction in event peak use and an increase of 22% in weekend peak use. These reductions are slightly lower than the reductions seen from SAVE's event days and banded price incentives.

The Project Closedown Report states that the change in overall energy consumption (kWh) from the first trial was statistically significant[58], however it is unclear if the other results are statistically significant.

8.5 Network impacts

The increasing penetration of low carbon technologies and distributed energy resources connected in the Medium Voltage and Low Voltage network are expected to create great challenges related to voltage problems and thermal overload of the system. In addition, the penetration of technologies such as heat pumps and electric vehicles (EVs), create further uncertainty for the DNOs which impacts long-term operational planning and investments in grid reinforcement. Therefore, overall energy reduction and peak reduction can assist in a number of network issues and processes including voltage problems and instability, deferral or avoidance of grid reinforcement, grid losses, maintenance planning, system overload and peak management, unplanned faults and events.

8.5.1 Overview

Event days show promise as a potential network management tool for DNOs and should be investigated further. Successful events produced reductions between 2% and 7%. Additional evidence of shifted consumption (higher consumption than the control group before or after events) and survey data showing participants were more likely than the control group to be out of the house during an event confirm that participants are actively working to reduce their energy use when requested.

The SAVE project tested a range of event types through a variety of messaging channels (email, text, post) to address a variety of DNO needs.

Table 9: Cost per event by messaging channel (no incentive)

Messaging channel	Maximum reduction (%)	Cost per household
Postal (based on a A5 card)	-5.5%	£0.66
Email	-7.0%	£0.18
Text	No reductions seen	£0.25

Network planners design the network for peak power flows, hence electrical plant must be rated to manage the peak load whether this occurs on a daily, weekly or seasonal basis. Therefore, network upgrades can be triggered by a peak demand event occurring only a very small number of times per year. The ability to reduce peak demand by means other than replacing electrical infrastructure such as transformers, switchgear, cables or overhead lines can support the deferral of significant capex and hence result in cost savings.

57 UK Power Networks. 2018. Vulnerable Customers and Energy Efficiency Close Down Report. https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2019/05/Energywise-Closedown-Report.pdf

58 Energywise used 0.75 statistical power.

If the typical distribution substation size is 500 kVA, the estimated savings of up to 7% on a typical substation could result in up to 35 kW savings at peak loading.

8.5.2 Thermal constraint reduction

The ability to reduce peak demand by a small amount could be used under different scenarios to defer investment based on annual load growth approaching close to the substation capacity. The expectation is that a 7% reduction may be able to defer an infrastructure upgrade in the short or medium-term. However recent trends with increases in customer energy efficiency measures have actually seen electrical demand reducing and hence it may be possible to defer an investment on a longer-term basis.

Conversely, the predicted uptake in electric vehicles and heat pumps is likely to see sharp rises in peak demand over the coming years of RIIO-ED1 and into ED2. The estimated typical maximum reduction of 35 kW per substation, while small, could support the connection of 5 additional electric vehicles or up to 5 heat pump installations. It is unlikely that this would be used as a permanent solution, however it is a low cost means of supporting connection of low carbon technologies that could be utilised for a short period of time or in conjunction with other measures (such as smart charging of EVs). SAVE could also influence homeowners to charge their EVs during non-peak time, which can provide additional benefits. It should also be noted that this technique could be deployed in a more efficient manner than traditional upgrades with less disruption to the customer and a lower risk of safety related incidents from traditional site works.

8.5.3 Actively managing power flows

As DNOs move from a passive network approach to a more active role under a Distribution System Operator (DSO) model, the ability to control power flows will become increasingly important. This could be on a close to real time basis or on a longer term if appropriate monitoring and forecasting techniques are in place.

Each trial period tested at least one 'short' event, of 4 hours or less and occurring on one day only. DNOs could use events to address short-term critical peaks in their network that may lead to thermal overload, such as those resulting from short planned maintenance, 'television pickup' during breaks[59], daylight-savings or extreme cold. This approach would work best on a well monitored and predictable network, where potential issues can be seen in advance and are unlikely to be frequent or long lasting. These short-term events had a maximum reduction of 7%.

If the peak can be anticipated a few days in advance, DNOs could notify customers of the request by post, which is easily deployable in a business-as-usual scenario. Postal notifications can also reach a wider audience, as generally DNOs do not at present have mobile phone numbers or email addresses for all their customers.

Postal notification could be used mainly to reduce consumption during planned maintenance events that are expected to last for a few hours. In this case, the DNOs could still meet their (n-1) obligations by reducing peak load. In case of planned maintenance, the DNO may inform their customers about the date and time of the maintenance ahead of the actual event, so that consumers are aware of the actions that they need to take.

Short events through email notification could be used in post-fault situation, when the DNO needs a reduction in the demand following a network fault. Consumers' response to post-fault instruction needs to be quick (and therefore email notification is suggested) and the DNO will need to ensure reliability of customer response[60]. Successful short events could be also appropriate for restoration support, when following a loss of supply the DNO can instruct sites to lower demand until the supply is re-established.

TP2 and TP3 also tested longer events (between 2 and 5 days), which could be used to address network issues lasting longer than a single day, such as a network fault or other maintenance situations where customers have been back fed for example and hence the substation leading is higher than under normal circumstances.

The final trial period, TP3, tested a banded price incentive somewhat similar to a ToU rebate, where customers were paid to keep their consumption below a target during peak hours. This approach could be utilised by DNOs on networks where peaks are harder to predict in advance or where the network is constantly near capacity. Banded pricing may also facilitate long-term planning and optimisation performance of assets. For example, by consistently keeping the consumption below peak levels, the lifetime of grid components can be extended.

Banded pricing could mitigate voltage control issues which are caused by the increased penetration of distributed energy sources; voltage problems occur, for instance, when solar PV systems generate significant amounts of electricity and demand is low. Banded pricing can shift load consumption to times where distributed generation is high, which will facilitate voltage control.

59 Newton, Paul. 2014. Keeping it cool throughout the World Cup. https://utilityweek.co.uk/keeping-it-cool-throughout-the-world-cup/

60 SSEN has produced an operational report advising on reliability and practical implementation of SAVE's results, specifically within the Network Investment Tool. This also notes impact on planning standards and business procedures to be considered in the rollout of SAVE's outputs. This report can be viewed in the appendices of SDRC 7.3/8.5- Network Model and Pricing Model.

Finally, energy saving and peak reduction methods can be applicable to networks issues that need coordination between the Electricity System Operator (ESO) and the DNOs. The ESO faces constraints in some areas of the network because of growth in low carbon technologies and distributed energy resources connecting to the distribution network, such as thermal constraints and voltage management issues. These constraints can lead to operational issues and limit the connection of more low carbon technologies. If peak reduction at DNO level and energy saving actions are coordinated between the ESO and DNOs (in a similar way to the Power Potential trials[61]), the operation of both the distribution and transmission networks can be kept within operational limits. This coordination will need to use reliable load management and therefore the banded price incentive and short term postal notifications may be suitable.

With the anticipated introduction of ToU tariffs through the GB wide smart meter rollout, the learning captured as part of the TP3 trials will help to inform DNOs of the benefits that price signals can have on peak demand reduction. This is an area that would benefit from some further investigation to define a suitable price point to be able to shift demand from the peak time and compare to the cost of traditional network infrastructure upgrades.

8.5.4 Network losses reduction

The ability to reduce peak power flows or move demand and hence flatten the profile reduces the network losses. This occurs as losses are primarily lost through heat and follow Ohm's law:

Power = Current^2 * Resistance

As the losses relate to the square of the current, the greatest losses occur at times of peak demand on the network. Therefore, a flatter demand profile that delivers the same amount of energy to the customer (in kWh) will result in a reduction in network losses.

Network operators are mandated to operate an efficient network through regulation and also through a losses incentive scheme, however do not specifically pay for technical or non-technical losses. Network losses are passed through to the suppliers and ultimately paid for by the customer. Hence a reduction in the network losses can provide a direct benefit to the customer through lower bills.

8.5.5 Summary

None of these reductions were statistically significant, and in some instances the peak consumption of the treatment groups were higher than the control groups. However, these should not be discounted completely, as treatment groups were able to reduce their consumption in a majority of cases, and there was other anecdotal evidence that confirms participants are reducing their peak load (such as staying out of the house during events or higher consumption before and after the events that indicates shifting). DNOs should consider investigating further and with larger sample sizes to increase confidence.

The event days specifically were very inexpensive to run, with an average cost of less than £1 per household (plus any incentives). Because of their low costs, they are a low-risk solution to deploy, especially without financial incentives. DNOs could further test event days in constraint managed zones or other areas that are at or near capacity to provide additional evidence on their effectiveness.

It is expected that the customer demand reductions trialled under SAVE will be able to be rolled out as BaU in conjunction with supporting measures such as EV 'smart charging' and will require the implementation of ToU tariffs to make a meaningful contribution to peak demand reduction (how this may take shape is explored in section 9 below). If these supporting measures are in place it is anticipated that the use of customer engagement in demand reduction could be a cost-effective alternative to traditional network upgrades.

61 Power Potential, NationalGrid ECO, https://www.nationalgrideso.com/innovation/projects/power-potential

9

CONSIDERATIONS FOR COMMERCIAL DEPLOYMENT

This section provides high-level considerations for the commercial deployment by DNOs of the 'event days' and 'banded pricing' solutions developed in SAVE.

9.1 Context

As described in Sections 3.3, 4.3 and 5.1 above, the 'event days' solution explored the willingness and ability of trial participants to reduce their consumption on a specific day (or days) in response to an extraordinary event, such as equipment failure(s), exceptionally high electricity use, or maintenance works. In exchange for reducing load as requested, some participants received a financial incentive such as a high-street voucher or were entered into a prize draw.

The 'banded pricing' solution, as set out in Section 5.3 above, provided participants with a financial incentive to keep consumption below a tailored target level (baseline) during peak hours. The solution is designed as a dynamic pricing method similar to the tariff banding for half-hourly metered customers in the common distribution charging methodology (CDCM) but differs in that the incentive is not applied in a variable charge (p/kWh) but as a set amount for every hour (e.g. £0.10/hour) a household was able to keep its energy consumption below the target.

Both the 'event days' and 'banded pricing' solutions have been, for the purpose of the SAVE trials, delivered as an 'explicit' demand-side flexibility service. Explicit flexibility services involve customers invited to explicitly provide a specific, defined flexibility service. Although explicit flexibility services for DNOs are currently still in a nascent state, the ESO commonly contract explicit flexibility to ensure supply adequacy (e.g. strategic reserves), for constraint management (e.g. voltage control) and for balancing purposes (e.g. frequency response). It can be argued that both 'event days' and 'banded pricing' can also be delivered as 'implicit' flexibility services, in which an existing contractual relationship is designed to incentivise a certain behaviour. Examples of 'implicit' flexibility include time of use (ToU) tariffs in electricity supply, but also the distribution tariff banding for half-hourly metered customers.

This section considers the deployment of 'event days' and 'banded pricing' through an implicit mechanism, as an incentive embedded in distribution charges (see Section 9.3); as well as in an explicit mechanism, where (a proxy for) the solution is procured in a local flexibility market (Section 9.4). Section 9.6 provides considerations on the feasibility of different payment mechanisms tailored to different types of flexibility solutions.

9.2 Previous projects

Section 8.4 makes a reference to work undertaken on demand side response solutions in the Low Carbon London and Customer-led Network Revolution projects by UKPN and Northern Powergrid, respectively. Here we explore in more depth the commercial findings of those projects.

9.2.1 Low Carbon London

LCL explored two possible DTOU options, both implicit mechanisms, and identified some minimum requirements for these options to work:[62]

- To introduce a DTOU tariff in DUoS charges, designed to encourage load shifting during peak hours. In the absence of a direct relationship between individual customers and the DNO, this option requires that the relevant energy supplier must be required to pass through the DTOU tariff to customers directly, since otherwise customers are not exposed to the incentive. This also assumes that the relevant customer is on a smart meter and their consumption can be verified in near real time, at least half hourly, to confirm its performance against the variable distribution tariff.

- To enter into a commercial arrangement with energy suppliers, who would develop a dedicated ToU tariff targeted at customers physically located to provide a response to a particular network constraint. LCL notes that the DNO would still need to "coordinate tariff programmes across all of the suppliers with customers in that network area" and highlights some complexity in the relation between the supplier and the DNO to administer and control the arrangement. A key observation is that the "DNO might be just one of a number of market participants that call upon the same dynamic tariff." This observation is effectively an early interpretation of a flexibility market mechanism, in which a supplier or aggregator enters into an explicit agreement with a DNO to provide flexibility services, based on a pool of (aggregated) customers.

62 UK Power Networks. 2014. Residential Demand Side Response for Outage Management and as an Alternative to Network Reinforcement, p2.

9.2.2 Customer-led Network Revolution (CLNR)

CLNR considered a variety of technologies to provide non-traditional solutions to network reinforcement under a static time of use tariff. The CLNR closedown report notes the limitations of a residential ToU implemented by a DNO and notes the potential role for energy suppliers:

"The reduction in peak demand seen in this trial would not be significant enough in itself to assist in network planning. However, ToU could be used as part of a solution and could help if introduced by another party such an energy supplier."[63]

The project also noted that, for any DNO mechanism to deliver value, such a mechanism might need to target domestic customers in specific geographical or network areas, although the CLNR project itself did not explore this in detail.[64]

CLNR generated similar insights from the trials focusing on I&C customers, noting that, at the time of writing in 2015, only about 5% of half-hourly metered (I&C) customers were actually exposed to the time bands included in the common distribution charging methodology (CDCM). The report suggests that suppliers did not, at the time, create visibility of distribution time bands to customers on the grounds that customers wanted simplicity.[65]

9.2.3 Key findings

The LCL and CLNR projects explored a similar territory and yielded a number of common findings, including:

- Potential limitations of implicit mechanisms, like ToU tariffs, when administered directly by DNOs; and
- The finding that for any incentive to be effective, customers need to be fully and clearly exposed to it; and
- The potential role for third parties, like energy suppliers, to facilitate effective demand response mechanisms for DNOs.

Both projects, LCL most concretely, suggest a course in which a DNO enters into an (explicit) agreement with a third party (such as an energy suppliers) as the most efficient route for DNOs to access flexibility services.

9.3 Implicit mechanisms

As suggested above, both 'event days' and 'banded pricing' solutions can be thought of as implicit mechanisms. By definition, an implicit mechanism involves a temporal price variation that connected customers can choose to adapt to, or not.

Time of use tariffs, such as the 'Red', 'Amber' and 'Green' bands, generally ensure a higher price for using the network during peak hours as compared to off-peak hours. Customers that adapt 'economically' to such a scheme will end up with a lower bill than customers who do not adapt accordingly, all else being equal. The price differences between time periods are indeed incentives (or disincentives), and it is important to observe that distribution network charges, including any incentives (such as ToU tariffs) therein, must be cost-reflective to ensure an economically efficient outcome. This means that, whether or not an implicit incentive is 'one-sided' (i.e. reward only) or 'two-sided' (i.e. penalty and reward), the underlying cost to the DNO is the same, and therefore the opportunity cost for a customer from not diverting load to a lower time band would have to be equivalent to a penalty in the same amount.

Consider two identical consumers, both using 100 units over a fixed period, say one day or one week. Let us assume that the initial consumption profile is identical and flat for consumers, but they are subsequently exposed to a higher price in one half of the period as compared to the other half, such that the time-weighted average price across the period does not change. Customer A manages to reduce consumption during the high price half while increasing consumption in the second half, whereas customer B simply ignores the price signal. As a consequence, A will experience a reduction in average unit cost, while B will see an unchanged average cost. A's cost saving is the reward to A for adapting to the banded price.

An 'event day' approach uses 'external' events rather than time of day as trigger for a price variation. Such events could involve, among others, weather-related circumstances, equipment failure, or (un)planned maintenance. The event would trigger a defined period of tariff change (decrease), to be communicated in advance to relevant connected customers, who could adapt demand in response to the incentive. However, given the non-standard nature of the 'events' triggering the requirement for flexibility, we consider this requirement is most effectively procured through an explicit mechanism.

63 Northern PowerGrid, 2015, CUSTOMER-LED NETWORK REVOLUTION PROJECT CLOSEDOWN REPORT, p13.
64 Northern Powergrid, 2015, Developing the smarter grid:the role of domestic and small and medium enterprise customers, p65.
65 Northern PowerGrid, 2015, CUSTOMER-LED NETWORK REVOLUTION PROJECT CLOSEDOWN REPORT, p13.

There are some common features of implicit approaches. These are related to both the overall cost of addressing a network issue in this manner (as an alternative to traditional grid reinforcements) as well as to how the DNO compares the relevant alternatives:

- If the DNO has to offer identical tariff schemes across its entire network, it ends up paying for a lot of demand response that is not necessarily helpful towards the initial issue the banded pricing was supposed to solve in the first place. As a result, even if the DNO realises a net saving against a costly investment, an implicit mechanism may stimulate larger or wider reaching changes than actually needed, including load changes in areas where they are not intended or not desired, and the DNO might 'pay' more than it absolutely needs to.

- Upon initial launch, the DNO cannot know for certain how many consumers react on the incentives, or how large the volume of changes will be. As the incentive mechanisms matures, however, the volume response can be forecasted with a reasonable accuracy.

- If the incentive prices are applied only occasionally or for a short period only (e.g. event-based), end-users may have limited ability to anticipate the incentive and only a short period to benefit. The SAVE trials show limited impact of the addition of price incentives on event days (as opposed data alone), as often the non-incentive group had greater reductions than the group offered an incentive.

- International experience and findings from SDRC 1 indicate that any incentive must be quite significant even to achieve a small volume impact, unless the incentive is accessed through an automated response via smart equipment. The results from SAVE Trial period 3 broadly corroborate this finding, with Figure 29 showing a generally higher response when incentive levels were higher (especially with the opt-out group, TG4).

- Infrequent and/or short-lived incentives are not very likely to trigger investments in smarter homes, and so are most likely to solicit greater impact in places where smart solutions have already been implemented.

9.4 Explicit mechanisms

This section provides an analysis of how the SAVE solutions Event days/Critical Peak Pricing and the Banded Pricing can be traded as explicit products on local flexibility markets, in order to service the DNO. In order to develop SAVE solutions as tradeable products on a flexibility market, it is important to consider both the product and the market it will be traded on.

This section will start by assessing the types of platforms on which products can be traded, which shows the directions that can be taken by a DNO to procure explicit services. This is followed by an assessment of the potential timescales and product types that can be traded, to provide a full overview of the possibilities. The SAVE solutions are then mapped to the possible products in order to assess the most suitable product type of Event Days and Banded Pricing, before providing some general considerations that will be applicable to this type of product. The section ends with some notes on how a fair market can be set up, that avoids conflicts of interest.

9.4.1 Market specifications and product design

Currently, two types of flexibility markets exist that are, or could be, suitable for DSO products:

- **Single buyer platform**: A platform developed for a DNO or a Transmission System Operator (TSO) (principal) and its products specifically, where the principal is the only buyer. The perceived advantage of this type of platform is that integration of the DNO's or TSO's specific requirements (e.g. flexibility location) are already reflected in the design of the platform. The downside is that the platform itself fails to create any additional value for the sellers (agents) and does not facilitate standardisation and transparency in the market and therefore may undermine efficient decision-making. Even if the principal is the only buyer on his platform, it is not the only buyer in the market. When faced with single buyer platforms, sellers will need to undertake additional effort to identify and compare different routes to market (other platforms), different product specifications, and different contract forms, among others. This will push up the cost to provide services, and therefore will not lead to the most economic outcome for DNOs.

- **Multi-buyer platform**: Utilization of a platform that is shared by multiple flexibility buyers apart from the DNO, such as other DNOs, the TSO and BRPs. Such a platform can either be developed from square one, but considering the TSO and BRPs already have platforms where flexibility is traded (BRP market platforms for energy trade and the TSO ancillary services platforms), the most likely route is an extension or integration of existing platforms. This might increase the difficulty of getting DNO-specific product integrated, but would facilitate transparency and standardisation, as well as providing additional flexibility supply and more competitive pricing. It also contributes to healthy investment conditions for flexibility service providers, and increases the chances of a liquid market to provide the services DNOs require.

As can be noted in these two market platform types, the markets on which the actual trade takes place can differ. Three market times can be distinguished, each with a different timescale at which the trade takes place:

- **Day-ahead:** The initial purchase and sale of blocks of energy based on expected demand and supply, traded up to the gate closure time (GTC) – typically at 12:00 (CET) the day before delivery.
- **Intraday:** Trading based on unexpected deviations from expected demand and supply after GTC, can typically be traded up to 5 minutes before delivery.
- **Real-time (Balancing):** Real-time matching of supply and demand. At these timescales, no actual trading takes place, as the real-time difference between demand and supply means there is no need for a countertrade to keep the system balanced. Instead, flexibility is dispatched to balance out existing surpluses or shortages.

The short-term nature of these markets means that they are more suitable to cater to short-term or ad-hoc flexibility services, like event days, than long-term recurring services, such as banded pricing. Section 9.4.2 explores this further. Of course, it is also possible for DNOs to enter into long-term flexibility service agreements, to secure services longer in advance.

In general, the combination of the market platform and the type of market also determines the types of product that can be traded on each market, as well as how the flexibility provider is remunerated. Three types of products and associated payment structures are used in the market:

- **Capacity (£/MW):** Flexibility providers contracted for keeping capacity available for usage by the flexibility buyer during an agreed upon period of time. There is no additional remuneration for the energy used during this period; instead, if there is a net delivery of energy it will be settled in the normal energy settlement process. Examples include: Enhanced Frequency Response (EFR) in the UK, and Frequency Containment Reserve (FCR) in continental Europe
- **Energy (£/MWh):** Flexibility providers are paid for a trade of energy. Typical examples are the purchase and sale of electricity to exploit price movements on the intraday market, or re-dispatching production through congestion management.
- **Combined (£/MW & £/MWh):** A combination of contracts for keeping capacity available and remuneration for energy delivered. Examples: Fast Reserve (FR) and STOR in the UK and contracted Frequency Restoration Reserve (FRR) in continental Europe.
- **Activation (£/MW, can be combined with £/MWh):** Capacity-based products that do not provide payment for having capacity available, but only provide payment once the capacity is activated. Can be combined with remuneration for the energy delivered. Typically, the cost of reserving (keeping available) capacity would be reflect in the activation price – capacity or energy. Example: Emergency power products.

The insights regarding market platforms, timescales and product types can be combined to provide the basic outline of possible products in which flexibility can be offered. This is outlined in Table 10.

Table 10: Mapping of flexibility market timescales and product types

Timescale	Product type
Day-ahead	Energy
Intraday	Energy/Capacity
Real-time	Capacity/Combined/Activation

Flexibility services with a long-term timescale can involve all product types.

9.4.2 SAVE-based market products

In order to translate the SAVE solutions into products, the SAVE solutions need to be mapped to the product possibilities based on their intended purpose.

9.4.2.1 Event days/Critical Peak Pricing

Event Days or Critical Peak Pricing refers to demand response for specific, unforeseen circumstances. A DNO could consider the following payment structure(s), depending on their appetite for risk:

- Depending on the DNOs expectations of the frequency and potential impact of events, it can consider entering into a long-term capacity-based agreement with providers to ensure some capacity is under contract to respond in case of an event. However, this would require a DNO to have an expectation of the potential location of events, to ensure contracted providers can actually respond to resolve the issue. It might be particularly challenging for DNOs to contract the right providers (residential households) in sufficient numbers at LV level.
- Payment for delivery or activation under such a contract could very well be energy based, in which case we are talking about a combined product.
- In addition to capacity-based agreements, a DNO could seek to procure short-term services for which the remuneration is energy based. This would solicit an ad-hoc response in the absence of capacity-based services contracted in the relevant network area.

- As an insurance option in case 'standard' capacity and energy products do not resolve the event, a DNO could consider contracting an Activation-based service, which would carry a higher price, but which would only be incurred if and when the other routes fail to deliver.

A DNO might consider having a combination of flexibility contracts in place, depending on the nature and likelihood of events, the ability to anticipate their location, and the potential financial impact of such events being resolved through traditional curtailment or going unresolved. A DNO would of course also have to ensure it has access to the relevant market platform to procure the product that provides the most effective and economic answer to its needs.

9.4.2.2 Banded pricing

The Banded Pricing solution is not triggered by a specific event, but is an enduring arrangement to solicit demand response during daily/recurring peak periods. Procured as an explicit flexibility service, this could involve a day-ahead repeat procurement of an energy-based product from connected customers. The benefit would be that an explicit mechanism would allow the DNO to target its procurement specifically at customers in certain network areas (with a high peak load), more precisely than what an implicit mechanism in distribution tariffs might currently allow. The downside is that explicit mechanisms for individual customers would be more expensive than an implicit mechanism in distribution network charges (if administered effectively), since the transaction cost (from repeat procurement and contracting of an explicit mechanism) would be higher.

Depending on the level of response a DNO is looking for, and whether the daily procurement of energy-based products demonstrates sufficient liquidity and is economic, a DNO could consider procuring a bespoke, long-term capacity-based or combined product to obtain further assurance that the required response can be met.

9.4.2.3 General considerations

In addition to the type of product, there are also some more general considerations that need to be taken into account by the DNO in designing a flexibility product. Examples of these are:

- Energy neutrality of flexibility transactions;
- Baseline design; and
- Product specifications.

Energy neutrality is an issue, as the DNO is a regulated entity that is not allowed to take an active position in energy markets (wholesale or retail). It can therefore not simply purchase flexibility on the market and create an imbalance for a supplier or wholesaler. This condition can be met by putting requirements in place for flexibility providers to ensure the energy neutrality of the services they provide, to a DNO or otherwise, and it suggest that professional energy companies, such as suppliers or aggregators, would be the logical counterparts for DNOs in the provision of explicit flexibility services.

A further consideration is baseline design. Flexibility is typically not provided by dedicated assets, but by assets that have the capacity to increase or decrease their supply or demand from their regular operating mode. These regular operating modes often have supply or demand profiles that are unpredictable and can vary from minute to minute. In order to determine the amount of flexibility that was provided, and to verify that this matches the amount purchased, a *baseline* is necessary that determines what the asset would have done if no flexibility was provided. There are several ways to approach this, and the approach should be tailored to the type of assets and the type of service provided.

A final consideration is the inclusion of specific product specifications. Not every asset will be able to provide the same type of flexibility and tailoring the specifications the assets need to adhere to is vital for the selection of suitable assets. A number of potential specifications are outlined in Table 11.

Table 11: Potential specifications for a flexibility product

Specification	Explanation
Response time	Timeframe within which the flexibility should start to dispatch
Duration	How long the flexibility should be able to be delivered
Ramp	Timeframe within which the flexibility should be at full capacity
Minimum bid size	Minimum capacity the (aggregated) flexibility source should be able to deliver
Communication	Requirements regarding communication protocols and frequencies
Availability	Percentage of dispatches the flexibility should be available

9.4.3 Avoiding conflicts of interest

When purchasing flexibility, a regulated party such as the DNO should avoid real or perceived conflicts of interest. The design of the flexibility market should facilitate the most economic outcome of an effective, competitive market process. Effective market design must comply with a number of principles to ensure this test is met with confidence:

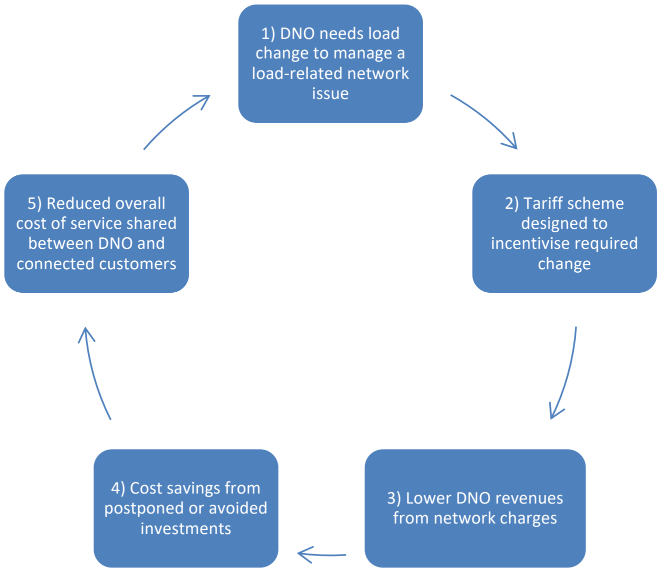
- **Non-discrimination** in market access to facilitate market liquidity. This includes equal access rights as well as low entry barriers (such as prequalification requirements).
- **Transparency**, meaning that the market provides full visibility of (standardised) processes, transactions and market outcomes. This includes clear and available documentation and reporting.
- **Homogenous (or: standardised)** products, to lower transaction costs, facilitate comparability and eliminate potential ambiguity over product or provider preferences.

A multi-buyer flexibility market platform, as discussed in section 9.4.1 and operated by a neutral third party, would reduce the risk of non-compliance with these principles, and provide the best way to mitigate potential conflicts of interest.

9.5 DNO Flexibility Procurement Decision-making Process

For a DNO explicitly purchasing a defined service based on its own specifications, the basic economic structure is relatively straightforward, at least from a 'revenue stream perspective'. The DNO pays and the service provider delivers, both according to contract, and so long as the service is delivered as agreed, the DNO solves its problem, and the provider is remunerated. The economics of an implicit approach are different, but corresponds roughly to the same dynamic, although there are significant differences in the details. The diagram below highlights the key steps in this process.

Figure 31: DNO Flexibility Procurement Decision-making Process



- The process assumes a DNO is looking for alternative solutions to reduce network load during peak times, instead of increasing network capacity via traditional investments.
- The DNO initiates an effort to incentivise its customers to solve the issue. Whether this is handing out LED lights or adjusting (through energy suppliers) distribution network charges is an important detail, but with little impact on the underlying economic principles. In ensuring economic efficiency, the fundamental challenge for the DNO is to design the scheme so that the 'right' customers react to the incentive and that the overall reaction matches the minimum requirement to solve the issue.
- Depending on the nature of the effort, the immediate impact on DNO revenue can be large or negligible. Time-of-use network tariffs can indeed be implemented in a revenue neutral manner, whereas supporting customer initiatives can involve a large transfer payment from the DNO to specific end-users.
- If the right customers react sufficiently, the issue that started the whole chain is addressed and resolved.
- If so, the DNO has succeeded and managed to deliver a net reduction in the overall cost of running the distribution network. The net benefit would be shared between the DNO and its connected customers in the form of lower connection and use of system charges in the future.

The process above is a repeatable process that DNOs would have to undertake every time they are considering alternative solutions to network reinforcement. The key underlying principle, that the DNO is incentivised through regulation to look for the most economical way of operating its network, would also incentivise DNOs to look for the most economic ways of procuring such alternative solutions, including through implicit and explicit mechanisms.

9.6 DNO Facilitation of EDR and DSR Solutions

The SAVE project has trialled both electricity demand reduction (EDR) and demand side response (DSR) solutions to provide services to DNOs, for instance to manage network constraints. A key consideration, as also observed in the LCL project, is that in order for flexibility services to have value for a DNO, they must be available in the place where the DNO needs them (i.e. in or near the congested network area). Hence, it is in a DNO's interest that EDR and DSR solutions are in place with customers in the right locations. Particularly for residential customers, the availability of these solutions is not a given.

Depending on the type of solution, the investment required in EDR or DSR solutions may prove too high a barrier for some types of customers, especially if the costs are recovered (from providing services to DNOs) over a longer period. EDR solutions in principle require a one-off capital investment to replace energy inefficient assets with more energy efficient assets to (permanently) reduce the consumption level at a specific site. Sophisticated DSR solutions may also require a sizeable upfront capital investment in communications and control equipment, as well as (unlike EDR) potentially incurring operational cost when being deployed. The question is how such investment hurdles might be overcome to ensure DNOs have access to EDR and DSR in the right places, and whether or not the DNO has a role to play in overcoming such barriers.

It is worth noting that some GB DNOs currently explore the facilitation of customer energy efficiency behaviour in a number of ways, including customer coaching or engagement and (through trials) the free provision of LED lights to certain customers. Through these activities, DNOs incur cost to stimulate energy efficient behaviour, and sometimes even take over the required capital investment from customers to deliver an energy efficiency outcome. It is not unreasonable for DNOs to undertake these activities and incur associated costs so long as it is economically efficient compared to alternative solutions (such as network reinforcement), and the costs may be socialised among a DNO's connected customer base. Similarly, a DNO could also support customer investment in EDR or DSR solutions by providing financing (i.e. a loan) for such investments, to be paid back over time (including, in theory, through a discount on distribution charges). However, any support provided by DNOs would be subject to tests akin to EU State Aid requirements to ensure that any support does not involve an undue transfer of wealth and that the DNO is not unduly advantaging specific parties or individuals. To the extent such arrangements target specific customers, the criteria must be transparent (so that anybody can see what is going on) and objective. Localisation in the network will normally be an objective criterion, while type of customer or relation to the DNO will normally be subjective.

A fundamental question is whether or not DNOs are uniquely, or comparatively better, placed to provide this support, if it is required, than other parties. Certainly, banks and other financial institutions are well placed to provide efficient financing to customers where this is required, especially where the investment generates future returns to customers in the form of energy bill savings and possibly a commercial return from providing flexibility services. Energy Service Companies (ESCOs) also provide financing solutions for energy efficiency and renewable energy projects. It is not clear that a DNO would have added value here, especially since DNOs do not currently have a direct financial relationship with most end-users (since it is the energy supplier who passes on distribution charges to customers). Moreover, it's worth observing that a DNO providing commercial financing services would have to comply with all relevant regulation applicable to financial services providers, as well as registered with the Financial Conduct Authority (FCA) and the Prudential Regulation Authority (PRA), bringing new costs and requirements outside of a DNO's core business. On the other hand, if the relevant measure can solve an issue that anyway is a concern for the DNO, e.g. a congested network element(s), the fundamental question turns into how the DNO best can implement this measure. If the best measure is (for example) a subsidised loan to targeted customers, it can be more efficient for the DNO to ask a bank to administer loans to these customers rather than starting a virtual bank themselves.

Putting this question into the context of implicit and explicit flexibility services for DNOs, it provides support for the idea that DNOs would most effectively procure flexibility services via explicit mechanisms on a competitive market from a third party, such as an energy supplier or an aggregator. This would avoid any unnecessary complications and would provide the most economic outcome. An efficient and transparent flexibility market enables price discovery of flexibility services, meaning that flexibility providers discover where DNOs require flexibility as well as what they are willing to pay, allowing flexibility providers to undertake efficient investment in flexibility (EDR and DSR) to ensure solutions at customer sites are available where and when they are required.

Finally, it must also be noted that implicit mechanisms, such as tailored network charges, tend to preclude alternative uses of the flexibility in question. With explicit mechanisms, the connected customers can better evaluate which problem to solve (i.e. where to provide flexibility services) and to which extent multiple issues can be solved using the same resource.

9.7 Social Constraint Managed Zones

SSEN is evolving their Constrained Managed Zones (CMZs) into Social Constrained Managed Zones (SCMZs). An SCMZ looks to remove barriers to entry in flexibility markets for non-conventional means of demand response, such as energy efficiency or critical peak pricing. This includes measures like the SAVE trial that encourage behaviour change from domestic customers. The results of SAVE will provide insight by:

- Providing evidence to third parties in 'best practice' engagement and messaging techniques and how to create a cost-effective domestic demand response (DDR) tender application.
- Providing evidence to DNOs and third parties on the level of demand reduction that can be procured through behavioural mechanisms.
- Providing evidence to DNOs around the expected longevity of behavioural interventions to ensure targeting at the correct network scenarios.
- Using the SAVE project's statistical rigour to provide DNO planning teams with the resources needed to understand likelihood of achieving given levels of demand response and hence carry out the appropriate analysis to maintain security of supply. This could be determining the network's capacity to run over thermal limits for a limited time or back-up options for immediate response where DDR does not deliver.

The SAVE trials discussed below are also utilised by SAVE's Network Investment Tool (NIT) to provide DNOs direct insight into the level of DDR they could expect across different areas of their network based on customer demographics. DNOs can use this tool to:

- Determine value of engaging customers with given DDR methods
- Show methods that are likely to be most effective
- Predict likely tender responses to running an SCMZ tender in a given area of network

Full details on the Network Investment Tool are available in SDRC 8.2.

9.8 Summary of Findings

This section has considered the commercial deployment by DNOs of the 'event days' and 'banded pricing' solutions through 'implicit' and 'explicit' mechanisms. The following summarises our findings:

- The 'event days' solution involves the procurement of flexibility in response to events that may be unpredictable in terms of impact and (frequency of) occurrence, making the solution suitable for procurement under explicit mechanisms.
- The 'time banding' solution embodies the very definition of an implicit mechanism, where an incentive is embedded in an existing contractual relationship.
- The LCL and CLNR projects have previously explored the deployment of ToU tariffs by DNOs, finding that they are limited when administered directly by DNOs and highlighted a role for 3rd parties, like suppliers, to ensure customers are exposed to a ToU incentive. These findings point to the benefit of explicit mechanisms between a DNO and flexibility providers, like suppliers or aggregators.
- In considering the procurement of flexibility through an implicit mechanism, and ensure this is economically efficient, DNOs must design the mechanism so that the 'right' customers react to the incentive and that the overall reaction matches the minimum requirement to solve the issue. With such a mechanism in place, DNOs face a repeated consideration if the mechanism is fit for purpose and will truly provide the most economic solution compared to the next best alternative.

- Explicit mechanisms enable a DNO to procure flexibility services from targeted customers, tailored to a specific problem or requirement, but with standardised product requirements and contractual arrangements. This allows a DNO to procure flexibility commensurate with their willingness to pay and risk preferences. Procurement of explicit flexibility services on an open and competitive market ensures economic efficiency.

- Potential conflicts of interest can be mitigated by the design of effective markets that are transparent, non-discriminatory and on which homogenous (standardised) products are traded.

- A well-designed market for explicit flexibility would also facilitate effective price discovery of flexibility services, allowing flexibility providers to undertake efficient investment in flexibility solutions, including overcoming any potential investment barriers, and would negate the need (if any) for DNOs to take an active role in facilitating flexibility through the provision of financing.

10

CONCLUSION

The SAVE project trialled a number of behaviour-based interventions over two years with the objective to:

- Gain insight into the drivers of energy efficient behaviour for specific types of customers.
- Identify the most cost-effective channels to engage with different types of customers.
- Gauge the effectiveness of different measures in eliciting energy efficient behaviour with customers.

SAVE used a large scale RCT with a representative sample. RCTs are generally considered the 'gold standard' of trials, and useful in minimising bias and examining the cause and effect relationship of a given intervention. The SAVE sample is representative of the target population, and does not suffer from opt-in biases as its initial recruitment process was not dependent on agreeing to a specific treatment. A non-random sample may lead researchers to conclude that an intervention had an affect when this may not have been the case.

The SAVE project used more robust methods for indicating statistical significance than previous projects, some of which used small samples and many do not report if findings are statistically significant.

This study is of a significantly higher standard than past research on behaviour change and energy efficiency in the UK. Because the SAVE sample was random and representative, the project's results are generalizable to the wider customer base. This is not true of many other recent projects.

The majority of engagement approaches tested in the SAVE project were successful in reducing peak energy use. A summary of the results is shown below in Table 12. Negative values show a reduction compared to the control group (consistent with the trial hypothesis) and positive values show an increase (inconsistent with the trial hypothesis).

Table 12: Summary of reductions by intervention

Event	Delivery Mechanism	Reduction target	Duration	Incentive	TG2	TG3 (£)	TG4
TP1 Event 1	Email	10%	1 day, 4 hours	£10 gift card to all	-3.6%	-3.4%	-
TP2 Event 1	Post	10%	5 days, 4 hours a day	Raffle for £100 gift card	-	-5.5%	-3.8%
TP2 Event 2	Email	10%	5 days, 4 hours a day	Raffle for £100 gift card	-	-0.8%	-1.3%
TP2 Event 3	Email	20%	2 days, 4 hours a day	Raffle for £1,000 gift card	-	+3.0%	+2.4%
TP2 Event 4	Email	10%	1 day, 2 hours	£10 gift card to all	-	-7.0%	-3.0%
TP3 Event 1	Text	None	1 day, 4 hours	None	+2.1%	-	-
TP3 Event 2	Email	None	5 days, 4 hours a day	None	-2.2%	-	-
TP3 Event 3	Post	None	5 days, 4 hours a day	None	-2.9%	-	-
TP3 Event 4	Text	None	1 day, 4 hours	None	+1.1%	-	-
Banded Pricing – whole group	Post	Varied	4 hours, every weekday	£0.10/hour, then £0.30/hour	-	-2.6%	-7.1%
Banded Pricing – participants only	Post	Varied	4 hours, every weekday	£0.10/hour, then £0.30/hour	-	-4.2%	-7.1%

These reductions are generally in line with previous LCNI projects such as LCL, CLNR and Energywise. They are higher than the results from Energywise but slightly lower than LCL and CLNR. However, the self-selection bias is likely to be stronger for LCL and CLNR than SAVE, which was not a tariff-based project and did not impact customer's bills. In the case of the Banded Pricing Trial, the entire treatment group was analysed together regardless of their enrolment in the trial (In addition to analysing only those who participated in the trial). This means participation rates were embedded, leading to lower overall reductions than if only participants were included but more realistic as they represent what could be seen at substation level.

Enrolment rates from other LCNI projects where highly variable, ranging from 24% to 86%, with higher enrolment from projects that used in-person recruitment visits. SAVE's enrolment rate for the (opt-in) Banded Pricing Trial was 38%, roughly in line with expectations from these projects.

In addition to the electricity reductions found by the SAVE project, there was additional evidence that treatment groups responded to the treatment, especially in the case of event days. On many event days, treatment groups tended to use more electricity before and after the event while having lower consumption during the event.

10.1 Recommendations

In implementing any similar interventions in the future, DNOs should incorporate lessons learned from these interventions, specifically considering the following in their design:

- Customers often need some prompting to save energy; treatment effects are generally highest after an email or postcard that reminds them about the 'ask'.
- While education materials alone do not provide significant reductions in peak energy use, events trialled during education campaigns (as in TP1 and TP2) produce greater peak reductions than events trialled without educational materials (TP3).
- Messaging, if too frequent, may lead to fatigue and disengagement .
- Postal communications are the most consistently effective communication method when communicating one-off reduction 'asks', with all postal events resulting in reductions. However, these are also the most expensive and require longer lead times. Postal communication will reach more customers than text or email communications and therefore generally leads to greater peak reductions.

- Post should be addressed by name to the occupant instead of 'the householder' or something similarly generic. Unique packaging (such as the bright pink envelopes used in SAVE) will also help the message stand out from junk mail or other circulars.

- Email notifications have mixed effectiveness. The greatest reduction was from an email campaign, however one email event also produced an increase in peak load. However, email engagement is the cheapest of all communication method tested and can be deployed very quickly. Therefore, this is still a useful tool to DNOs.

- Text message notifications did not produce any peak reductions. The results from this trial do not recommend using text as the main communication method.

- The shortest event also had the greatest response. Customers likely find it easier to reduce consumption for a couple hours than multiple days.

- Enticing customers to stay out of the house during critical peak periods may result in even larger peak reductions than asking them to shift or cut consumption. For example, a DNO could partner with local businesses to offer discounted activities (meals, theatre tickets, etc.) for specific days or times to encourage customers to stay out of the house during the peak period.

- If deploying an opt-in banded price trial or TOU scheme, marketing should target a large audience as take-up will likely be less than 40%.

- Those that opt-in to a banded price trial or TOU scheme may be less motivated by money than the general population. They also may result in self-selection bias, as households are unlikely to join the TOU scheme if they cannot or will not adjust their consumption.

- The strongest response was generally observed in households primarily heated by 'other' fuels (although it's very likely these households supplement with electric heat), and by households primarily heated electrically. Households heated with gas generally have the weakest response. This shows that at least some of the reduction seen is from heat sources, and may indicate that households with electric heating have more ability to shift their load.

- There were not significant differences between the group that received an incentive and the group that did not during events. In most events, the incentive group had only slightly higher reductions. During events, price signals are unlikely to represent good value for their additional cost.

- However, for the banded price trials, price signals worked well with the opt-out group when sufficiently high, as seen in the jump in treatment effect after customers were notified of the increase to £0.30/hour. However, these results are unlikely to be sustainable long-term. There is potential in the future for more sustainable results if trials can utilise smart appliances, smart EV charging or automated reductions in addition to engagement.

- Price signals are more effective in an opt-out trial that includes a wide range of customers than in an opt-in trial. The customers opting-in are likely to already be motivated to save energy, while the opt-out trial includes customers that are less motivated; if high enough, the price signal can provide this additional motivation.

- The opt-in group displayed a very inelastic response to the price signals of the banded pricing trial. Their peak consumption stayed relatively constant throughout the trial period, despite the change in payment. The opt-out group, however, responded well to the mid-trial price increase and displayed significantly more elastic behaviour.

In conclusion, the techniques tested in SAVE likely have the potential to provide small reductions to peak electricity use and should be further investigated by DNOs and/or third parties to determine how they can best integrate them into BAU. For instance when designing an (S)CMZ tender (as discussed in section 1.5) the delivery organisation may wish to use this information as both a blue-print for how they run their programme and an indication for the level of demand response and hence value they could ensue from data informed and/or price signal mechanisms.

When adapting the SAVE trials into BAU, SAVE can address various network issues:

- Single day events were able to produce peak reductions of up to 7%, which DNOs could use to address short-term critical peaks in their network that may lead to thermal overload, such as those resulting from short planned maintenance or extreme cold.

- Longer, multi-day events were able to produce peak reductions of up to 5.5%. DNOs could use these to address network issues lasting longer than a single day, such as a network fault or other maintenance situations, for example where customers have been back fed and the substation leading is higher than under normal circumstances.

- Due to its short lead time, email notification is best suited to unplanned issues and could be used in post-fault situation when the DNO needs a reduction in the demand following a network fault. Email could be also appropriate for restoration support, when following a loss of supply the DNO can instruct sites to lower demand until the supply is re-established.

- Postal notification could be used to reduce consumption during planned maintenance events or other issues that can be foreseen in advance. Postal communication is easily deployable in a business-as-usual scenario and can reach a wider audience, as generally DNOs do not have up to date mobile phone numbers or email addresses for all their customers. For DNO's to enact online/telephone engagement they would have to weigh up the cost of obtaining such information (higher Capex, lower Opex) against that of ongoing postal communication (lower Capex, higher Opex).

- A banded pricing or similar TOU approach could be utilised by DNOs on networks where peaks are harder to predict in advance or where the network is constantly near capacity. Banded pricing may also facilitate long-term planning and optimisation performance of assets. For example, by consistently keeping the consumption below peak levels, the lifetime of grid components can be extended.

- Banded pricing could also mitigate voltage control issues caused by the increased penetration of distributed energy sources. For example, when PV systems generate significant amounts of electricity but demand is low, banded pricing could stimulate demand to avoid voltage issues.

- While it is unlikely that SAVE would be used as a permanent solution, it could act as a low cost means of supporting connection of low carbon technologies that could be utilised for a short period of time or in conjunction with other measures (such as smart charging of EVs). Events specifically were very inexpensive to run, with the average cost per household under £1 for all types of events.

11

APPENDICES

11.1 Engagement materials

Full engagement materials are available to download on the SAVE website. A selection of images of the materials are presented below. Note that images have been compressed to limit file size. High resolution versions are available on the SAVE website.

11.1.1 Trial period 1

Below are images of the materials used in the engagement trial with TG3 and TG4.

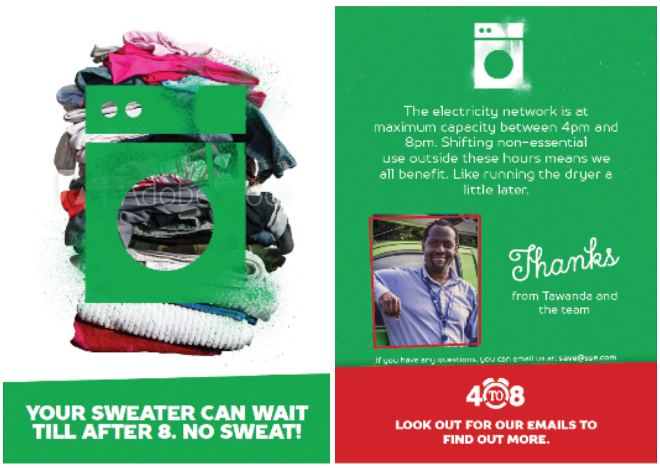
Figure 32: Cover page of TP1 engagement booklet

Figure 33: First page of TP1 engagement booklet

Figure 34: Second page of TP1 engagement booklet

Figure 35: Front and back of TP1 engagement postcard (1)

Figure 36: Front and back of TP1 engagement postcard (2)



11.1.2 Trial period 2

Figure 37: Cover page of TP2 engagement booklet

Figure 38: First page of TP2 engagement booklet

Figure 39: Second page of TP2 engagement booklet

Figure 40: Third page of TP2 engagement booklet

Figure 41: Cover and interior page of TP2 sticky-note pack

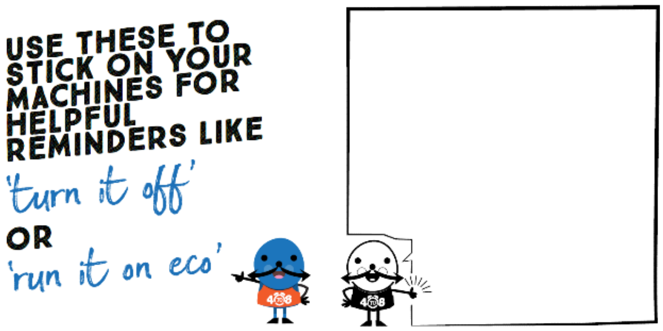


Figure 42: TP2 notebook cover and pencil

11.1.3 Trial period 3

11.1.3.1 Banded pricing trial

Below are images of the materials used in the banded pricing trial with TG3 and TG4.

Figure 43: Front and back cover of TP3 banded pricing trial booklet

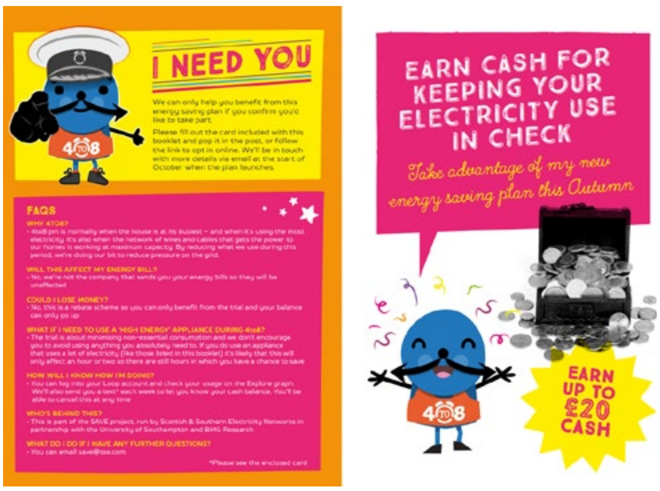


Figure 44: Centre pages of TP3 banded pricing trial booklet

Figure 45: Opt-in postcard used in TP3 banded pricing trial

OPT IN TO THE ENERGY SAVING PLAN

We can only help you benefit from the energy saving plan if you confirm you'd like to take part.

Please tick the box below and post this card back to us. The postage is already paid.

Alternatively, please follow this link to opt in online: www.4to8.co.uk

☐ I confirm I have read the information in the booklet about the energy saving plan and I would like to opt in

If you would like to receive a weekly text update of your balance please add your mobile number here:

Study ID:

You can find out more about what we do with the information we collect by viewing our Privacy Notice: www.bmgresearch.co.uk/privacy

11.2 Detailed analysis and methods

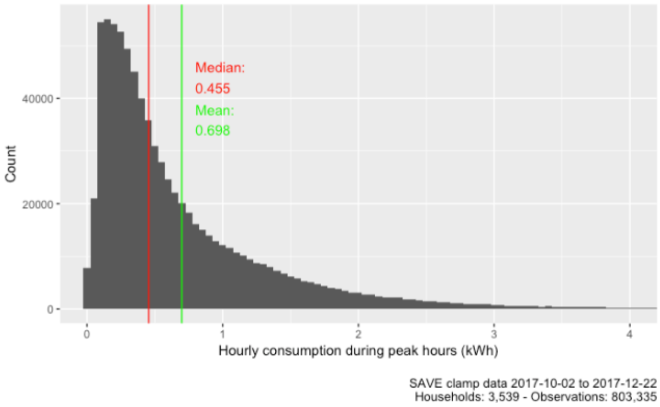
11.2.1 TP3 banded pricing levels

The banded pricing included three custom threshold levels: 0.2 kWh, 0.5 kWh and 1.0 kWh. All participants could not be assigned the same threshold, as a majority would find the target either impossible to meet or they would meet it without adjusting their behaviour. For this reason, multiple targets were developed.

15-minute Loop data from the previous winter (October to December 2017) was aggregated to hourly data and analysed to determine average hourly consumption of SAVE participants during the peak period (16:00-20:00). Hours outside of the peak period were not included. To omit hours with missing data, data was excluded where there were less than 4 observations in any hour. The goal was to group consumption in to three groups: low, medium and high.

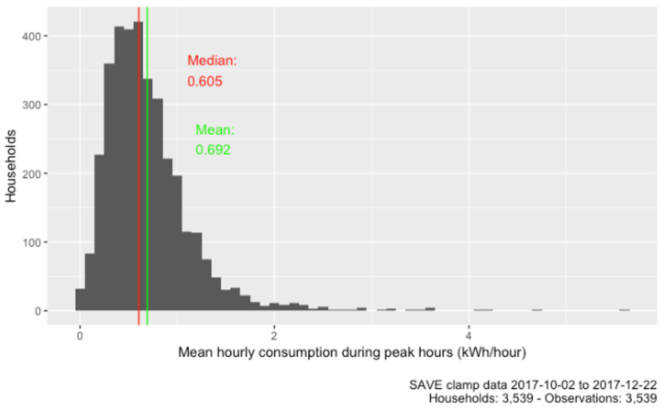
Figure 46 below shows the distribution of hourly consumption for SAVE participants during peak hours. As shown, the distribution skews right, with the majority of data points less than 1.0 kWh. The median hourly consumption was 0.455 kWh and the mean hourly consumption was 0.698 kWh.

Figure 46: Distribution of hourly consumption during peak hours



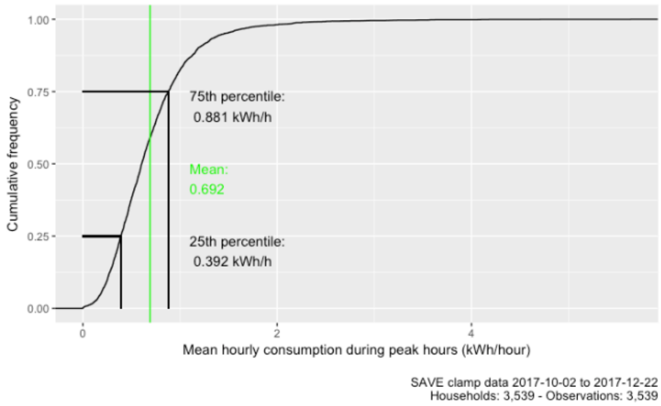
The mean hourly consumption during the peak period was calculated for each household over the whole period (October to December 2017). Any household with less than 10 days or 40 observations was removed from the analysis. Instances of zero consumption were also removed. The distribution of average hourly consumption per household are shown below in Figure 47. Again, the distribution skews right, with a median of 0.605 kWh and a mean of 0.692 kWh.

Figure 47: Distribution of mean household hourly consumption during peak hours



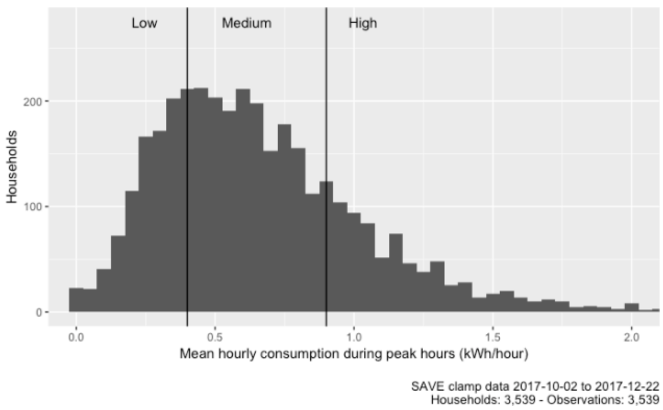
Plotting this data as a cumulative frequency allows for visualization of the quartiles, as shown in Figure 48.

Figure 48: Cumulative frequency plot of mean household hourly consumption during peak hours and visualisation of 25th and 75th percentiles.



Households were then assigned into three initial groups based on these quartiles. The 'low' group included households in the first quartile (below 25th percentile), the 'medium' group included households in the second and third quartiles (between 25th and 75th percentiles), and the 'high' group includes households in the fourth quartile (above 75th percentile). The distribution of households and group membership is shown below in Figure 49.

Figure 49: Distribution of mean household hourly consumption during peak hours with group membership assigned



Once households were assigned to a group, each group's mean hourly (peak) consumption was plotted for comparison (Figure 50) and 24-hour load profiles were developed (Figure 51).

Figure 50: Mean hourly peak consumption by group

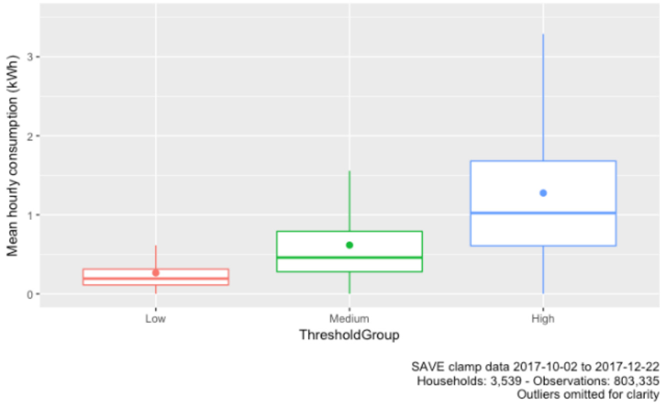
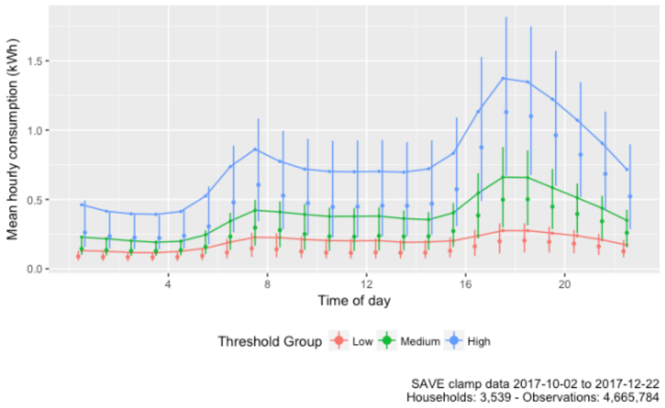


Figure 51: 24-hour load profile by group



Final thresholds were chosen based on the peak load profiles. For each group, the threshold was below the maximum average peak but above the average non-peak consumption (shown in Figure 51) as to be challenging but not impossible. This resulted in thresholds of 0.2 kWh, 0.5 kWh and 1.0 kWh for the low, medium and high groups (respectively).

11.3 Vulnerable customer definitions

SAVE participants completed the questionnaire set out below. Responses that would indicate a vulnerability aspect are listed below each question. If a respondent provided one of these responses to three or more questions they were categorised as a 'vulnerable customer'.

Q2b. What is your age?

65-74

75+

Q2d. What is your working status?

Unemployed

Retired

Permanently sick/disabled

Q2d. What is their [other household members] working status?

Unemployed

Retired

Permanently sick/disabled

Q3.2. Who is your landlord?

Private landlord or letting agency

Q3.8. How do you pay your electricity bills?

Pre-payment meter

Fuel Direct/Third Party Deductions/benefits

Q8.20. Which of the following would you say is the highest level of qualification that you hold?

Have no qualifications

Q8.21. Which of the following would you say is the highest level of qualification the household reference person holds?

Have no qualifications

Q8.26. Do you or anyone else in your home have any long term illness, health problem or disability which limits your daily activities or the work you can do?

Yes

Q8.27. Which of the following matches the total monthly or annual gross income of this household?

Monthly: Under £833 OR Yearly: Under £10,000

Monthly: £834 to £1,042 OR Yearly: £10,000 to £12,500

Monthly: £1,043 to £1,250 OR Yearly: £12,501 to £15,000

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