WESTERN POWER DISTRIBUTION

INNOVATION

NEXT GENERATION NETWORKS

SUNSHINE TARIFF

THE CUSTOMER RESPONSE

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Contents

Glossary

Abbreviation	Term
BEIS	Department for Business Energy and Industrial Strategy
DG	Distributed generation
DSR	Demand side response
EAC	Estimated annual consumption
HEUS	Household Electricity Usage Study
HH	Half hourly
kW	Kilowatts
kWh	Kilowatt hours
PV	Photovoltaic
WPD	Western Power Distribution
WREN	Wadebridge Renewable Energy Network

Executive Summary

The Sunshine Tariff trial sought to develop and test the feasibility of an 'offset connection agreement', which would enable generation customers to connect to the grid on the basis that they can change the pattern of local demand on the network to offset the power generated.

This report sets out both the quantitative and qualitative findings from the trial. The quantitative findings are descriptive and do not attempt to provide statistical association or correlation due to the small sample size. The qualitative analysis provides insight into the underlying attitudes of the participants to the study.

The quantitative data indicates that participants on the Sunshine Tariff shifted between 9 and 10 percent of their demand into the Sunshine Tariff period compared to the control. The average consumption shifted into the Sunshine Tariff period compared with the control group was approximately 150 kWh over the Sunshine Tariff period from April to September. In order to offset the generation from a 250 kW solar farm, this finding suggests that approximately 650 Sunshine Tariff customers would be required.[1] This would be approximately 20% of the homes in Wadebridge.

The households with automation technology were able to shift 13 percent (1.49 kWh in absolute figures) of their consumption into the 10:00-16:00 period compared to 5 percent (same as control group in absolute figures) for those without automation. The qualitative findings correlated with this. Overall, automated control technology was perceived to be helpful in shifting electricity consumption to the middle of the day and the customers with automation were more likely to sign up to a time of use tariff again in the future.

The findings from the households with automation technology suggest that 360 customers would be required to offset a 250 kW solar farm. Therefore, the concept of an offset connection will become more viable as automated control technology becomes more widespread and households have a greater flexible load, for example from electric vehicles and other forms of energy storage.

Other comparisons within the dataset indicated that:

[1] Based on an 11.1 percent load factor and the export of 40 percent of the total annual consumption in the 10:00-16:00 period between April and September.

- The retired/unemployed group were able to shift seven percent more demand to the middle of the day than the employed/self-employed, potentially due to being at home more during the day
- The high energy users were able to shift a greater proportion of their consumption into the Sunshine Tariff hours (18 percent) than the low and medium energy users. This is most likely due to having a larger flexible load, such as hot water immersion or an electric vehicle
- Although the sites with PV imported less power than those without PV, they tended to shift one percent more of their consumption into the 10:00-16:00 period than households without PV. The interviews and survey revealed that some customers with PV had already established habits of using more power during the middle of the day and therefore didn't find it challenging to shift their consumption
- Wadebridge Renewable Energy Network (WREN) members shifted up to three percent less of their overall consumption than non-members. This is most likely due to a lower proportion of WREN members in subgroup B, which generally had higher loads and automation technology.

When customers were asked about how they changed their behaviour, their perception of how much they shifted was greater than the smart meter data indicated. This may be due to a lack of understanding of how much electricity appliances use. For example, it may require considerable effort to use a washing machine in the middle of the day instead of the evening, but the impact is relatively small.

Overall, customers reported a positive experience of taking part in the trial and when asked if customers would switch to a time of use tariff again in the future, nearly three quarters said they would.

1 Project background

1.1 Project scope

This project sought to develop and trial the feasibility of an 'offset connection agreement', which would enable generation customers to connect to the grid on the basis that they can change the pattern of local demand on the network to offset the power generated.

The trial also sought to better understand what mix of low tariff, behavioural signals and technology options are the most effective in shifting demand. As well as the scale, longevity and reliability of the demand side response (DSR).

1.2 The trial

The Sunshine Tariff trial took place in Wadebridge, Cornwall, and used an incentive to achieve a DSR from domestic customers. The trial period was between April and August 2016. During this time, a time of use tariff incentivised a demand response between 10:00-16:00 and the change in load against a baseline was measured.

The proposed method for controlling load was to engage around 240 homes with four levels of intervention as follows:

1. Manual interventions (≈60 homes)

   Customer directly turns on appliances based on the reward of a reduced tariff at a pre- arranged time of day.

2. Manual interventions with feedback (≈60 homes)

   As above but with regular feedback from the local community energy cooperative – Wadebridge Renewable Energy Network (WREN) – on money saved and kW shifted, with both benchmarked against others in the trial.

3. Automated hot water controller (≈60 homes)

   A controller pre-set to bring on electrical water heating at the time of reduced price, either by means of a timer, or by remote switching.

4. Automated load switching (≈60 homes)
   Tempus Energy (the supplier) to identify the flexible loads in the customers' premises and add the ability for remote switching to it.

In addition to the trial subgroups there was a fifth, additional group which acted as a trial control:

1. Control group (≈60 homes)

The control comprised customers that reside just outside of the trial catchment area, but wanted to be involved in the trial. They received a smart meter and were put on a flat rate tariff of 13.4p/kWh. As there is no financial incentive for control-group customers to shift their demand, their consumption during the trial was used as a comparison to the other subgroups.

1.3 Numbers of trial participants and grouping

The target number of households was 240 plus a control group. However, recruitment proved challenging with 89 households attempting to sign up and a final number on the Sunshine Tariff being 46 (plus 15 in the control group). Considerable learning was gained from the recruitment and switching process, which is set out in the 'Sunshine Tariff: Customer recruitment learning report'.

Table 1 Number of participants on the project (subgroups 1-4)

	Total number of homes
Subgroup 1	14
Subgroup 2	20
Subgroup 3	10
Subgroup 4	2
Control	15
Total	**61**

For the purposes of analysis, subgroups 1 and 2 were combined into a single group of customers with no automation technology (subgroup A), and subgroups 3 and 4 were combined to form a group with some automation (subgroup B). This was done for three reasons:

1. The additional intervention that subgroup 2 had over subgroup 1 (feedback from the local energy cooperative) did not take place due to data retrieval problems with the meters. This meant that the participants in subgroup 2 experienced exactly the same trial conditions as subgroup 1.
2. Subgroup 4 only had two customers, making it difficult to draw any conclusions from their consumption behaviour. Therefore, they were combined with subgroup 3, which also had some automation technology with the immersion timers.
3. Allocating the sample population to just two subgroups and the control improved the confidence level in the subgroup demand analysis.

Subsequent analysis of the subgroups now refers simply to 'subgroup A' for those with no automation and 'subgroup B' for those with automation, with the following proportion of sites that 'export energy':

Table 2 Number of participants on the project (subgroups A and B)

	Total number of homes
Subgroup A	34
Subgroup B	12
Control	15
Total	**61**

Given the sample size, statistical association or correlation cannot be inferred from the data. Therefore this report focusses on descriptive analysis of the quantitative data, followed by qualitative analysis to provide insight into the underlying attitudes of the participants to the study.

2 Data collection process

2.1 Quantitative data collection process

In order to allow participants to be correctly billed and to establish how the Sunshine Tariff trial would affect customers' demand profiles, each participant received a smart meter that logged their electricity import (and export if they owned any generation assets). These meters were expected to log electricity demand data in minute intervals from the point at which they were installed, providing an accurate picture of customers daily demand profile.

Tempus Energy installed a new model of meter, which had unique features and benefits such as being able to communicate in real time, compared to other meter providers that only send data consumed during half hour or wider time periods. This meter was deliberately chosen for the Sunshine Tariff project as the more granular data would have helped with the analysis of customer behaviour.

However, there were telecommunication problems that the meter supplier was unable to resolve, which resulted in difficulty retrieving the data from the meters. Therefore, data was manually downloaded directly from some of the smart meters at the end of the trial, which provided half hourly data, rather than minute-by-minute.

2.2 Quantitative data analysis methodology

2.2.1 Collating a comparable data set

The problems with the smart meters resulted in having a range of data sets depending on whether data were transmitted by the smart meter or manually downloaded. The data streams were:

- Minute-by-minute data for some properties, as transmitted by smart meters
- Half hourly (HH) import data, as downloaded by WREN staff at the end of the trial period
- HH export data, as downloaded by WREN staff at the end of the trial period

The table below illustrates the data landscape that was available for analysis.

Table 3 Quantitative data generated by the project

		Type of data available			Total data available (either minute-by-minute or HH, to the nearest month)						
Unique ID	Subgroup	Quality of minute data received	HH Import	HH Export	Mar	Apr	May	Jun	Jul	Aug	Sep
ST03	1 (A)	7%	✓	✓	M	M			M	M	M
ST09	1 (A)	48%	x	x		M		M	M	M	M
ST15	1 (A)	0%	✓	✓							
ST12	1 (A)	52%	x	x		M		M	M	M	M
ST14	1 (A)	93%	✓	x	M	M					
ST17	1 (A)	44%	✓	x	M	M					
ST49	1 (A)	31%	x	x	M	M		M			
ST50	1 (A)	0%	✓	x							
ST61	1 (A)	0%	✓	x							
ST63	1 (A)	0%	✓	✓							
ST65	1 (A)	0%	✓	x							
ST66	1 (A)	0%	✓	x							
ST67	1 (A)	0%	✓	✓							
ST74	1 (A)	0%	✓	x							
ST05	2 (A)	61%	✓	✓		M	M	M	M	M	M
ST08	2 (A)	0%	✓	x							
ST10	2 (A)	18%	x	x	M	M				M	
ST11	2 (A)	0%	✓	x							
ST16	2 (A)	62%	x	x	M	M	M	M	M		
ST22	2 (A)	46%	✓	✓	M	M			M		
ST25	2 (A)	5%	✓	x					M		
ST28	2 (A)	8%	✓	✓	M	M		M	M		
ST33	2 (A)	63%	✓	x	M		M				
ST34	2 (A)	28%	✓	x	M	M			M	M	M
ST39	2 (A)	58%	✓	x	M	M					
ST45	2 (A)	20%	x	x	M	M			M	M	
ST47	2 (A)	0%	✓	x							
ST56	2 (A)	0%	✓	x							
ST57	2 (A)	0%	✓	x							
ST60	2 (A)	0%	✓	x							
ST68	2 (A)	0%	✓	x							
ST70	2 (A)	0%	✓	x							
ST06	3 (B)	0%	✓	x							
ST20	3 (B)	0%	✓	x							
ST23	3 (B)	0%	✓	x							
ST24	3 (B)	0%	✓	x							
ST30	3 (B)	0%	✓	x							
ST35	3 (B)	57%	✓	x	M		M				
ST54	3 (B)	0%	✓	x							
ST69	3 (B)	0%	✓	x							
ST01	4 (B)	34%	x	x	M	M		M	M		
ST02	4 (B)	45%	x	x	M	M	M	M	M	M	M
ST04	Control	0%	✓	✓							
ST21	Control	0%	✓	x							
ST31	Control	0%	✓	x							
ST42	Control	0%	✓	✓							
ST43	Control	0%	✓	x							
ST52	Control	0%	✓	x							
ST53	Control	0%	✓	x							
		Type of data available			Total data available (either minute-by-minute or HH, to the nearest month)						

Unique ID	Subgroup	Quality of minute data received	HH Import	HH Export	Mar	Apr	May	Jun	Jul	Aug	Sep
ST55	Control	0%	✓	✓							
ST59	Control	0%	✓	✓							
ST72	Control	0%	✓	x							
ST73	Control	0%	✓	x							

M	Minute data available
	HH data available

For all of the data streams above, not every minute or half hour time period generated data. In some cases, hours, days or weeks' worth of data was missing from the data sets. However, the timestamps in the spreadsheet did not account for missing data, simply jumping from one reading to the next. Therefore, in order to compare data streams, a certain amount of data processing had to be undertaken. The process is outlined in the figure below.

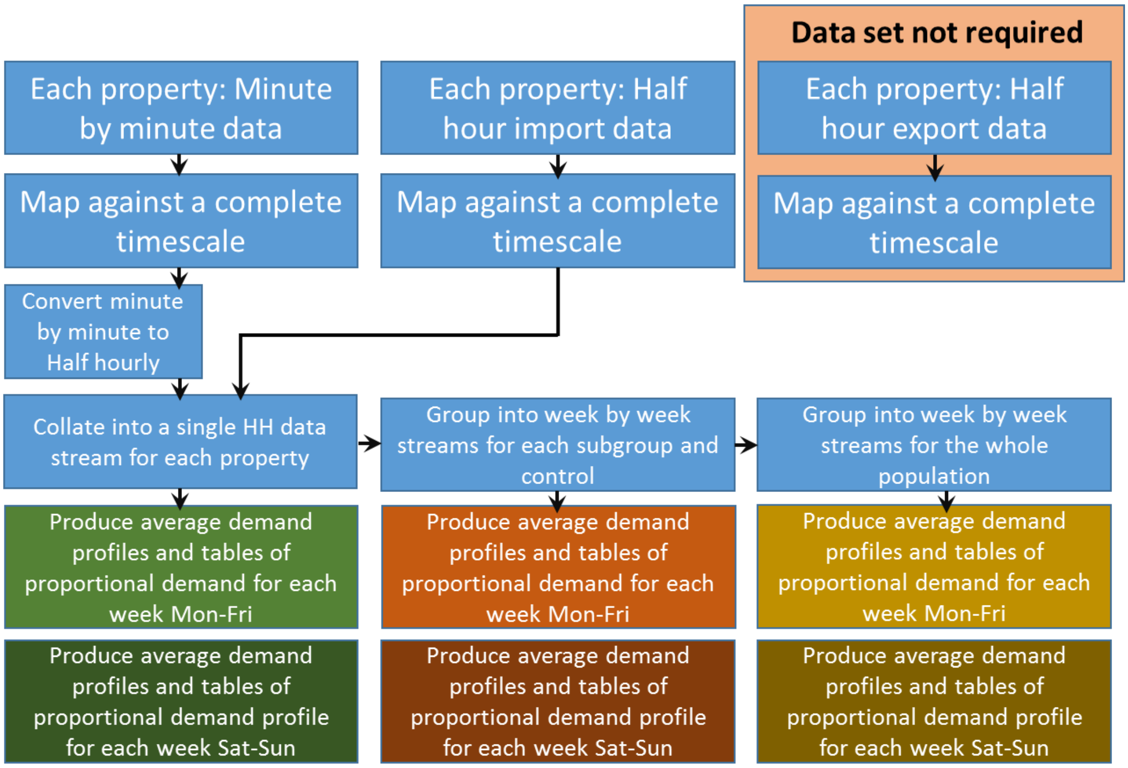

Figure 1 Quantitative data handling process

2.2.2 Export data

Properties that also have onsite solar PV produced two half-hourly data sets: one for imported electricity and one for exported electricity. Due to the high proportion of properties on the trial with solar PV (35 percent of homes), some analysis was conducted in two streams: one that included sites with export potential; and another where those sites with export potential were excluded. This was to see if there was a difference between the imported power during the sunshine hours of the houses with and without solar PV. See section 3.3.5 for more information.

2.2.3 Use of weekday and weekend day averages

In order to establish whether there was any trend in demand shift from any of the subgroups, each home participating in the trial had its demand data averaged over two time periods: weekdays and weekends. Averaging the profiles in this way permits trends in behaviour to be identified. The split between weekdays and weekends enabled us to test the expectation that weekend demand profiles were likely to be different to those profiles exhibited during the week.

Furthermore, the data streams from each home were averaged across each week according to their subgroups.

These averaged profiles formed the basic dataset from which the comparative analysis was undertaken.

2.3 Qualitative data collection process

In addition to the quantitative findings, significant learning can be gained from assessing customers' experiences of the time of use tariff through qualitative research.

A better understanding of what motivates households to change their behaviour enables industry to develop services/tariffs that are more likely to be attractive to customers and to deliver the desired DSR.

After the trial period had finished, customers were invited to complete an online survey. Out of 46 customers, 34 responded. The survey was anonymous, but enabled customers to leave contact information if they were happy to be contacted with follow up questions.

Structured interviews were then held over the phone with 10 customers to talk in more depth about how they found the experience of having a time of use tariff. This group was self-selecting and therefore may have been more engaged in the trial overall compared to a customer that did not respond to the online survey.

Another online survey was sent out to the WREN members that chose not to sign up to the Sunshine Tariff, of which 51 of the 450 households responded.

3 Quantitative analysis

3.1 Verification of the baseline

As there were very few smart meters installed prior to the start of the Sunshine Tariff trial, a study was conducted to establish a demand profile baseline for the trial area. The purpose of this baseline was to establish a standard weekend and weekday 'typical demand curve' for the Wadebridge area, against which the control and trial data could be compared. The methodology for this is set out in the appendix.

Baseline data was provided by Ovo Energy for Cornwall for spring and summer 2015, which was scaled using an Estimated Annual Consumption (EAC) figure for the Wadebridge area, and the standard daily demand profiles published by Elexon.[2] Pre-trial smart meter was also obtained from a small number of trial participants, as well as smart meter data for the control group throughout the trial period. Each will be examined in turn.

3.1.1 Pre-trial data

Smart meter data was available for 15 households before the trial start date. All of the data available before 1 April was in the minute-by-minute format and did not necessarily cover the same time periods. In addition, as mentioned in section 2.2 above, the smart meters did not consistently transmit a reading for every minute of that time period. The table below shows the time periods that the meters were active prior to the trial, and the proportion of the data that was transmitted during that period.

[2] The Ovo data was obtained as a monthly average that included weekdays and weekends. The Elexon profiles are available in average weekday and weekend, and seasonally throughout the year.

Table 4 List of households with pre-trial data available

Households with pre-trial data	Subgroup	Time period reporting data (pre 1 April)	Complete data
ST003	1	21/03/2016 20:00 - 31/03/2016 22:00	10%
ST014	1	21/03/2016 17:00 - 31/03/2016 23:30	97%
ST017	1	31/03/2016 13:30 - 31/03/2016 23:30	53%
ST049	1	30/03/2016 12:00 - 31/03/2016 23:30	64%
ST010	2	31/03/2016 10:00 - 31/03/2016 23:30	64%
ST016	2	21/03/2016 15:30 - 31/03/2016 23:30	96%
ST022	2	22/03/2016 13:30 - 31/03/2016 23:30	98%
ST028	2	30/03/2016 11:30 - 31/03/2016 18:00	6%
ST033	2	31/03/2016 09:30 - 31/03/2016 23:30	66%
ST034	2	29/03/2016 17:30 - 31/03/2016 23:30	68%
ST039	2	30/03/2016 11:00 - 31/03/2016 23:30	59%
ST045	2	30/03/2016 13:00 - 31/03/2016 23:30	52%
ST035	3	30/03/2016 15:30 - 31/03/2016 23:30	57%
ST001	4	28/03/2016 13:30 - 31/03/2016 23:30	51%
ST002	4	23/03/2016 15:30 - 31/03/2016 23:30	85%

For each of the 15 households that transmitted pre-trial data, only eight had a data quality of 60% or higher, and of these only five had data that covered more than one day (highlighted in green).

As discussed in section 2.2, all of the pre-trial data from these five meters was converted into half-hourly data. Figure and Figure illustrate the resulting demand profiles in comparison with the control group data. It is also compared with baseline data obtained from Ovo customers in Cornwall in the summer of 2015.

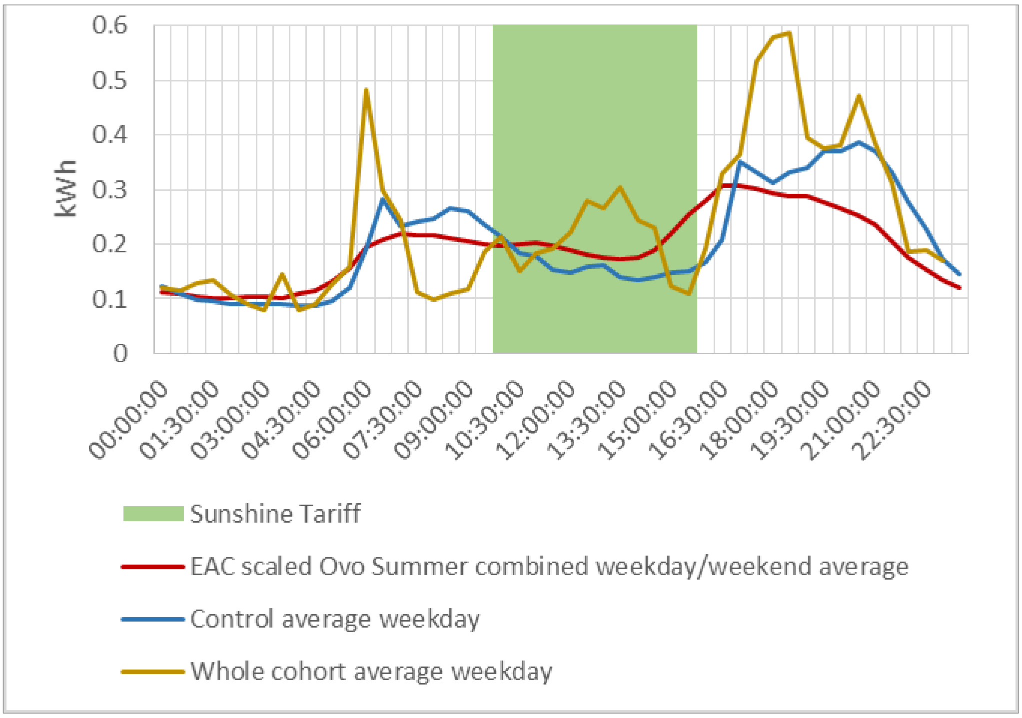

Figure 2 Average weekday demand profile for households with pre-trial data, compared to the control and Ovo baseline

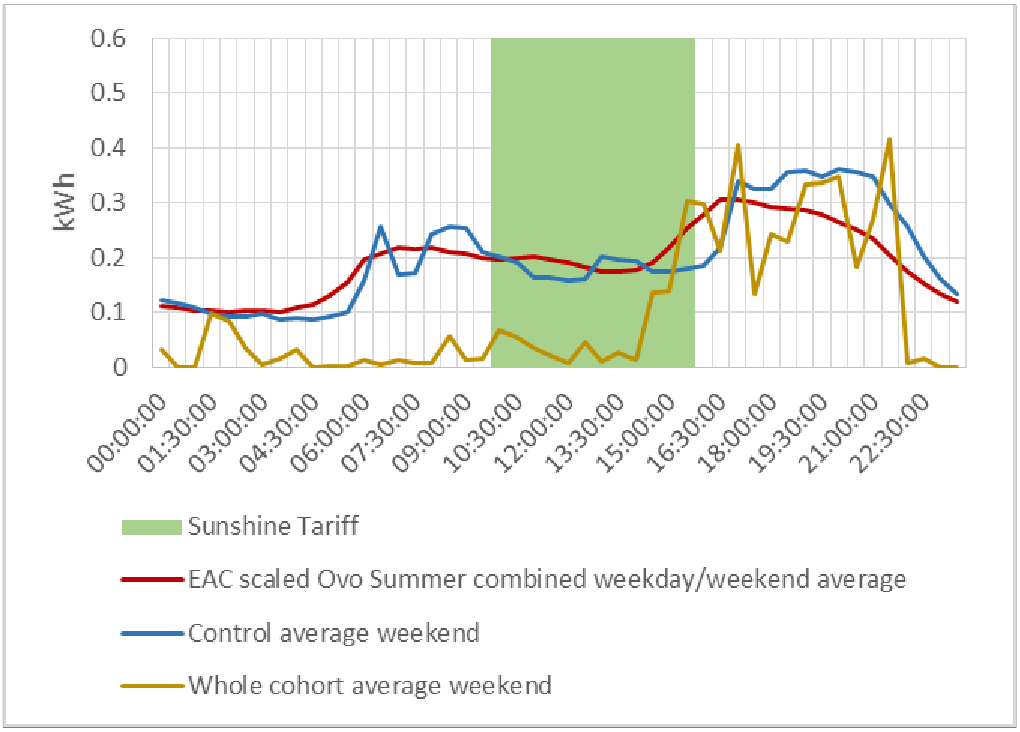

Figure 3 Average weekend demand profile for households with pre-trial data, compared to control and Ovo baseline

As can be seen in the charts above, the small numbers of households involved result in profiles that exhibit sharp peaks and troughs due to participants switching load on and off. Because of this, the pre-trial data does not give a fair reflection of an average consumption over the time period, although it does still offer useful information about the magnitude of daily demand.

3.1.2 The control group

The data gathered from the control group can be compared to both the Ovo and Elexon baselines:

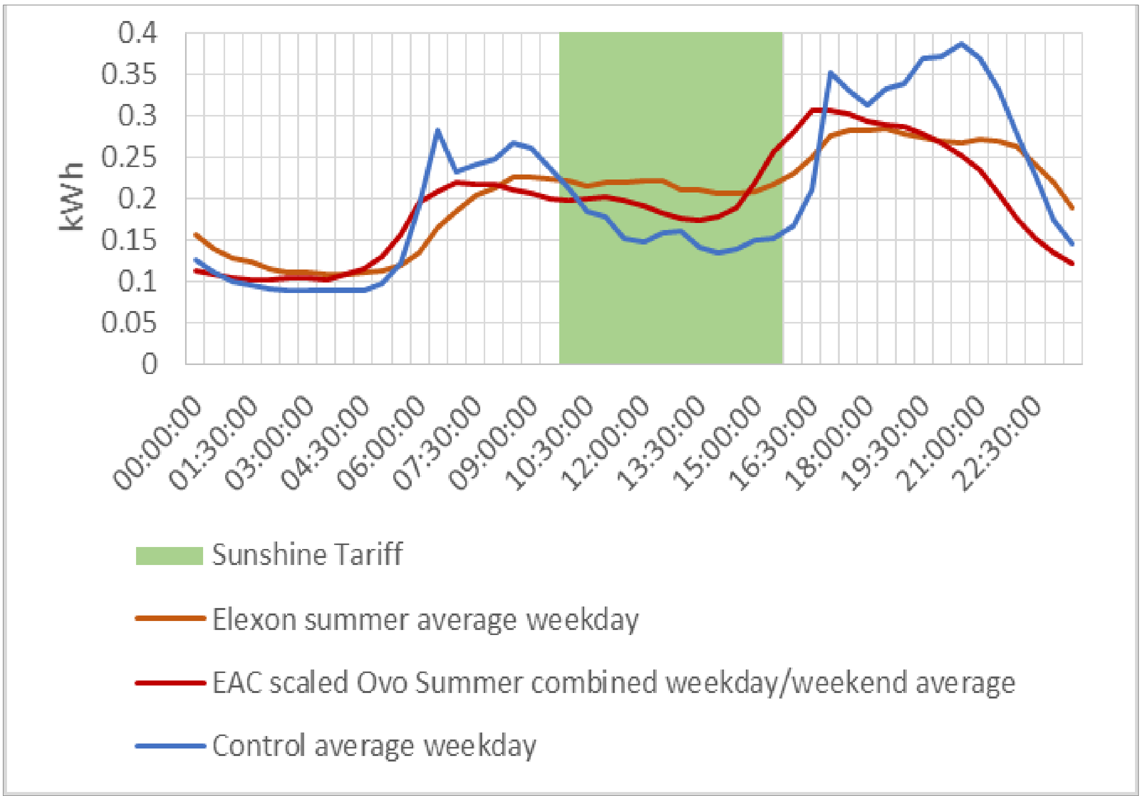

Figure 4 Comparison of baseline demand profiles to the average control (weekday)

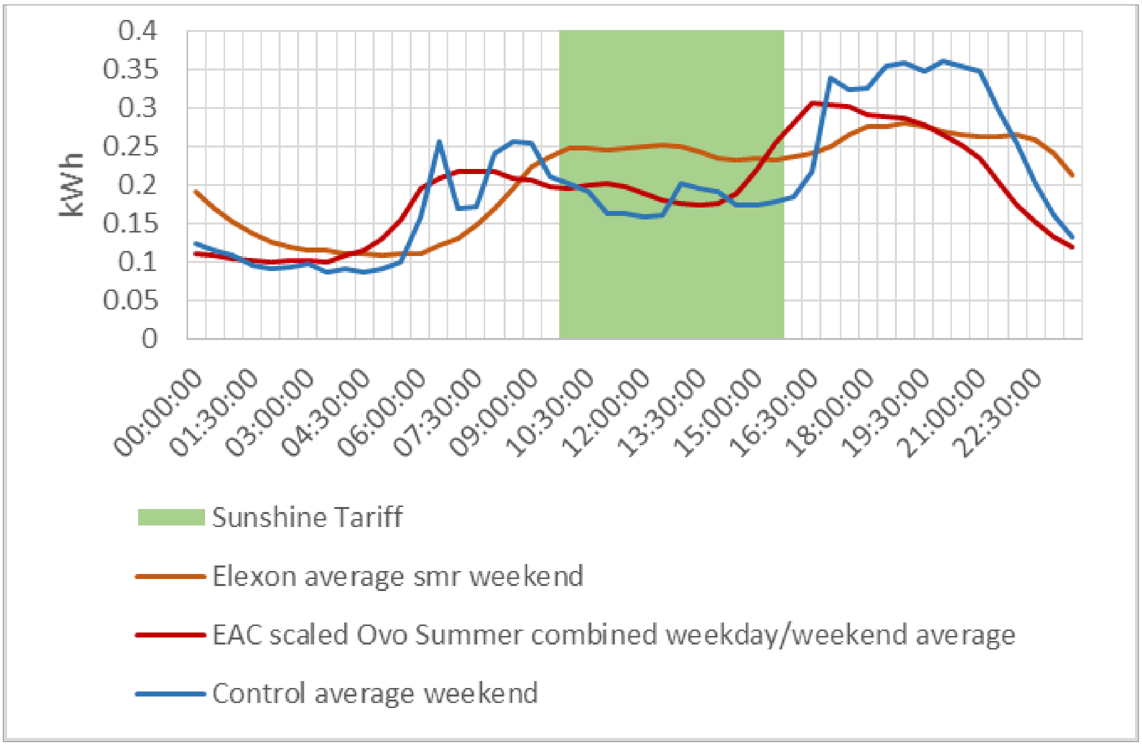

Figure 5 Comparison of baseline demand profiles to the average control (weekend)

As can be seen from the figures above, the control average daily demands have some correlation with those generated from the Ovo 2015 data and the standard Elexon curves. The most notable observation is that the smaller datasets exhibit a more ‘peaky’ profile, with higher peaks and lower troughs. This is an expected feature of the data, and indicates that a comparison of the Sunshine Tariff trial profiles with the control average profile should be accompanied with a comparison with another baseline data set.

Further analysis was undertaken to examine the proportion of daily demand that is consumed inside and outside of Sunshine Tariff hours. The following table looks at the proportions of both the Ovo and Elexon baselines, and the control data, for average weekdays and weekend days.

Table 5 Proportion of baseline average daily demand in and out of the Sunshine Tariff time period

Weekday averages (%)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	33%	25%	42%
Elexon Summer average	31%	26%	43%
Control average	32%	20%	48%
Weekend averages (%)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	33%	25%	42%
Elexon Summer average	29%	29%	42%
Control average	30%	22%	47%

The absolute values for these percentages are shown in the table below.

Table 6 Average daily absolute demands (kWh), in and out of the Sunshine Tariff period

Weekday averages (kWh)	00:00 – 10:00	10:00 – 16:00	16:00 – 00:00
Ovo 2015 baseline data	3.02	2.36	3.88
Elexon Summer average	3.02	2.57	4.14
Control average	3.14	1.91	4.70
Weekend averages (kWh)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	3.02	2.36	3.88
Elexon Summer average	2.91	2.92	4.15
Control average	2.91	2.16	4.57

As can be seen from the tables above, the average control data exhibit a significantly lower demand during 10:00-16:00 and a correspondingly higher demand from 16:00-00:00. This is most likely due to the high penetration of onsite solar PV, which amounts to 33 percent of the control group. A similar percentage of groups A and B have solar PV, which suggests that the control group data provides a useful comparable baseline.

3.1.3 Baseline conclusions

When ascertaining whether the Sunshine Tariff trial stimulated a shift in demand, the control group data provides the most useful comparison. The Ovo baseline data has also been included in the analysis for reference purposes. The Ovo average profile has been deemed a more accurate representation of the demand in the Wadebridge area compared to the Elexon data. The drawback of using the Ovo data is that the profile has been averaged across both weekdays and weekends, which will have an impact on the day time demand averages.

3.2 Impact of the Sunshine Tariff on electricity consumption behaviour

This section looks at the overall impact of the tariff on electricity consumption behaviour for the whole cohort, followed by comparisons between the following groups to look for any trends in behaviour change:

- Households with and without automation technology
- WREN members and non-members
- Retired/unemployed and employed/self-employed
- Large, medium and small energy users.

The following charts and tables compare the whole cohort average weekday and weekend day's demand during Sunshine Tariff trial against the control and baseline data.

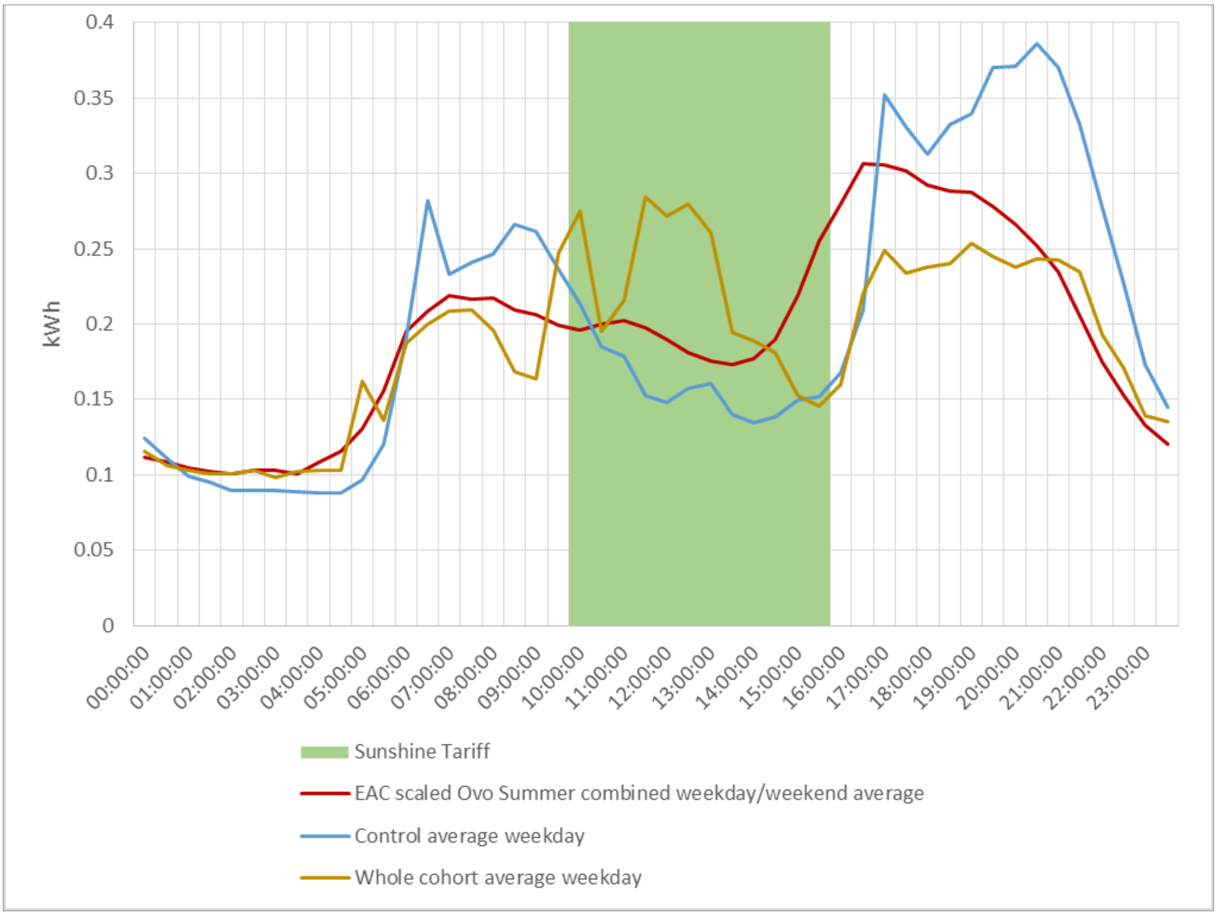

Figure 6 Comparison of the whole cohort average weekday demand during Sunshine Tariff trial against control and baselines

Table 7 Comparison of the whole cohort average, baseline and control daily demand for the average weekday during the Sunshine Tariff trial

Weekday averages (%)	00:00 – 10:00	10:00 – 16:00	16:00 – 00:00
Ovo 2015 baseline data	33%	25%	42%
Control average	32%	20%	48%
Whole cohort average	32%	29%	38%
Weekday averages (kWh)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	3.02	2.36	3.88
Control average	3.14	1.91	4.70
Whole cohort average	2.91	2.65	3.44

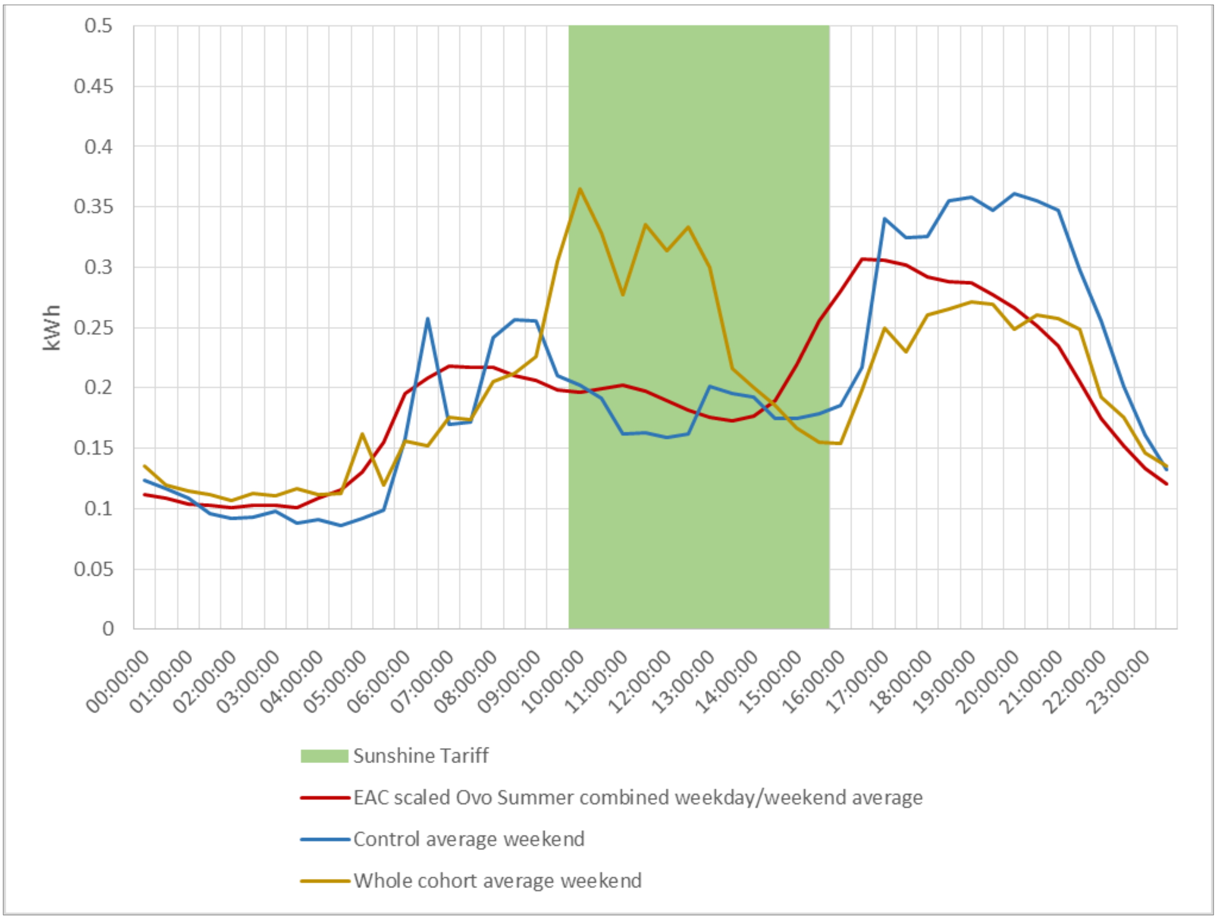

Figure 7 Comparison of the whole cohort average weekend demand during Sunshine Tariff trial, against control and baselines

Table 8 Comparison of the whole cohort average, baseline and control daily demand for the average weekend during the Sunshine Tariff trial

Weekend averages (%)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	33%	25%	42%
Control average	30%	22%	47%
Whole cohort average	31%	32%	36%
Weekend averages (kWh)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	3.02	2.36	3.88
Control average	2.91	2.16	4.57
Whole cohort average	3.04	3.18	3.57

The evidence presented above indicates that participants on the Sunshine Tariff shifted:

- **9% of weekday demand into the Sunshine Tariff period when compared to the control and 4% when compared to the Ovo profile**
- **10% of weekend day demand into the Sunshine Tariff period when compared to the control and 7% when compared to the Ovo profile.**

The average consumption shifted into the Sunshine Tariff period compared with the control group was 0.74 kWh per customer on weekdays and 1.02 kWh per customer on weekend days. Therefore, the average household would have shifted a total of just under 150 kWh over the Sunshine Tariff period from April to September. In order to offset the generation from a 250 kW solar farm, approximately 650 Sunshine Tariff customers would be required.[3]

It is worth noting that the increase in consumption takes place in the first half of the 10:00-16:00 period with a drop off after about 13:00. This was in part due to the hot water timers all coming on at 10:00 and switching off once the target temperature was reached, along with some customers waiting for 10:00 to switch other appliances on, such as the washing machine, which tends to complete its cycle within a few hours.

3.2.1 Comparison of households with and without automation technology

The average weekday and weekend demand profiles for subgroup A (without automation technology) and subgroup B (with automation) were compared to the equivalent baseline and control profiles:

[3] Based on an 11.1 percent load factor and 40 percent of the total annual generation taking place in the 10:00-16:00 period between April and September.

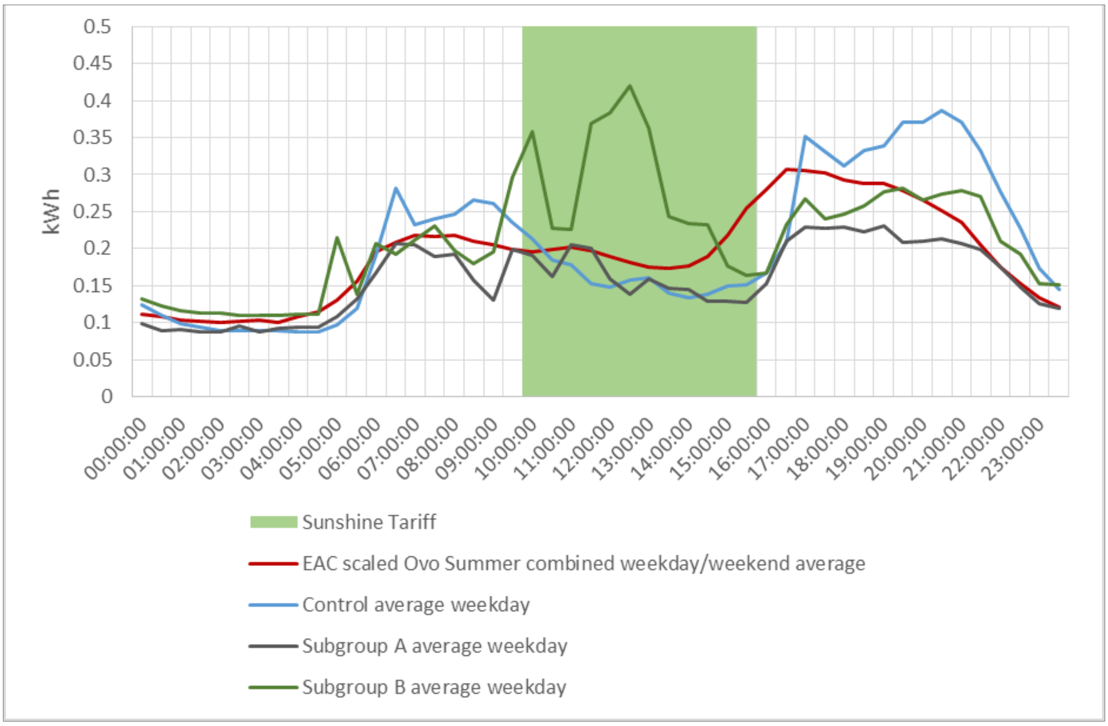

Figure 8 Comparison of demand profile for subgroup A and B against the baseline and control for the average weekday

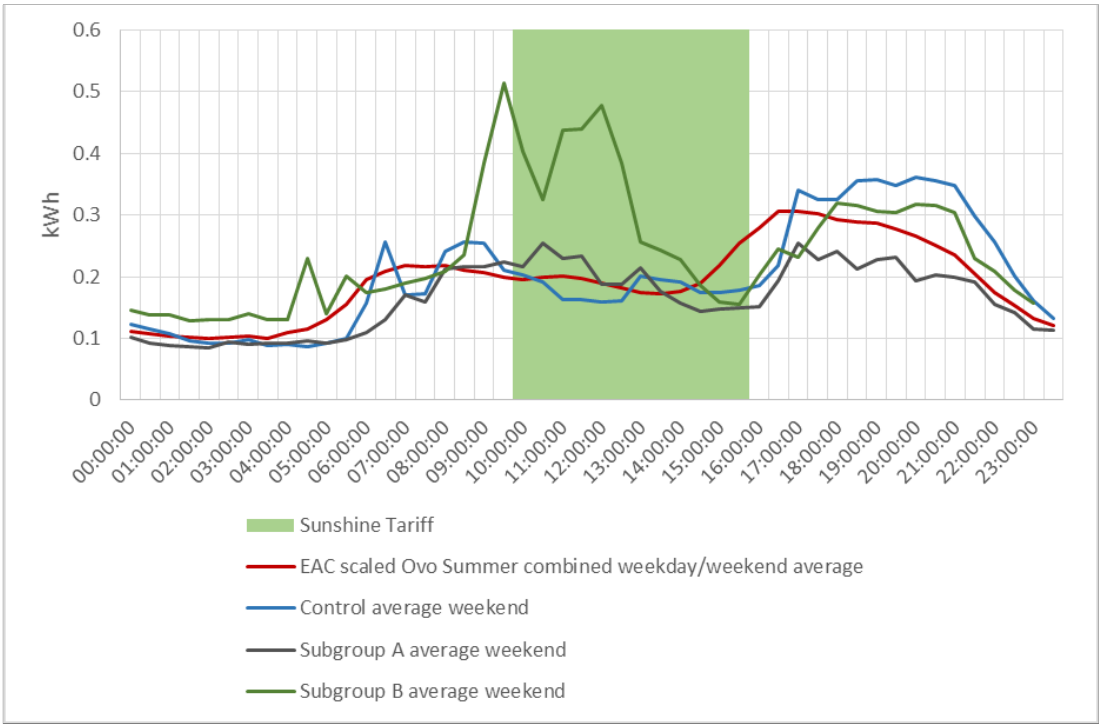

Figure 9 Comparison of demand profile for subgroup A and B against the baseline and control for the average weekend

As can be seen in the charts above:

- The average weekday electricity consumption profile of subgroup A does not appear to greatly differ to that of the Ovo baseline profile
- However, there is a difference in average demand between 10:00-16:00 for subgroup B when compared to the other profiles
- There is more variation in the evening peak (18:00-21:30) between subgroups, the control and the baseline than there is in the morning peak (07:00-09:30)
- For the weekend average profiles, there is a peak demand at 09:30 for subgroup B – just outside of the Sunshine Tariff period.

Although plotting the demand profiles is useful, it is easier to see the level of demand shift through the proportions of daily demand met in the three timeslots, as shown below.

Table 9 Comparison between subgroups, control and baseline for proportional weekday daily demand

Weekday averages (%)	00:00 – 10:00	10:00 – 16:00	16:00 – 00:00
Ovo 2015 baseline data	33%	25%	42%
Control average	32%	20%	48%
Subgroup A	34%	25%	41%
Subgroup B	31%	33%	36%
Weekday averages (kWh)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	3.02	2.36	3.88
Control average	3.14	1.91	4.70
Subgroup A	2.61	1.89	3.11
Subgroup B	3.22	3.40	3.76

The subgroup A average weekday demand is very well correlated to the Ovo profile. However, compared with the control group, subgroup A demonstrates a shift away from the evening peak (a decrease of 7 percent) and into the sunshine hours (an increase of 5 percent). But, the absolute figure of kWh's consumed in the 10.00-16:00 period is slightly lower for subgroup A than the control group, as overall demand is lower.

Subgroup B shows a larger shift of 13 percent more electricity consumed between 10:00-16:00 compared to the control and a shift away from the evening of 12 percent.

Households with automation technology were able to shift eight percent more of their average daily consumption into the 10:00-16:00 period than those without automation and therefore are responsible for a greater proportion of the overall shift.

3.2.2 Comparison of WREN members and non-members

In order to test the hypothesis that those more engaged in energy issues would shift more consumption into the 10:00-16:00 period, a comparison was made between WREN members and non-members. See the charts and table below.

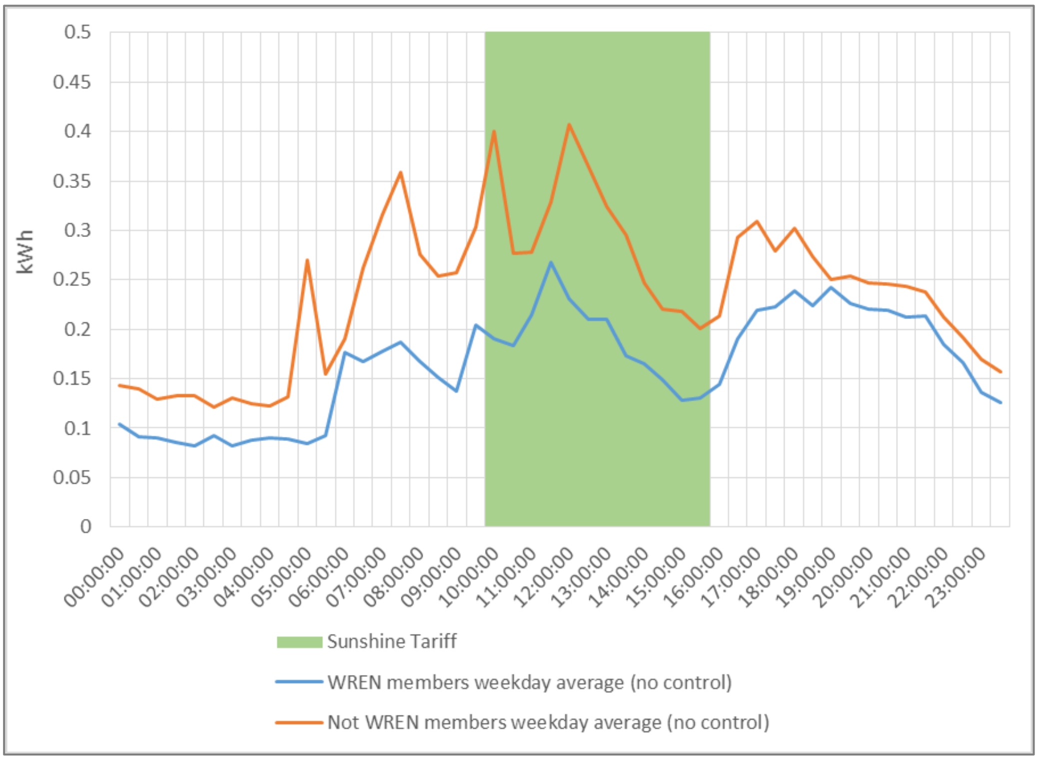

Figure 10 Comparison of demand profile for WREN members and non-members for the average weekday

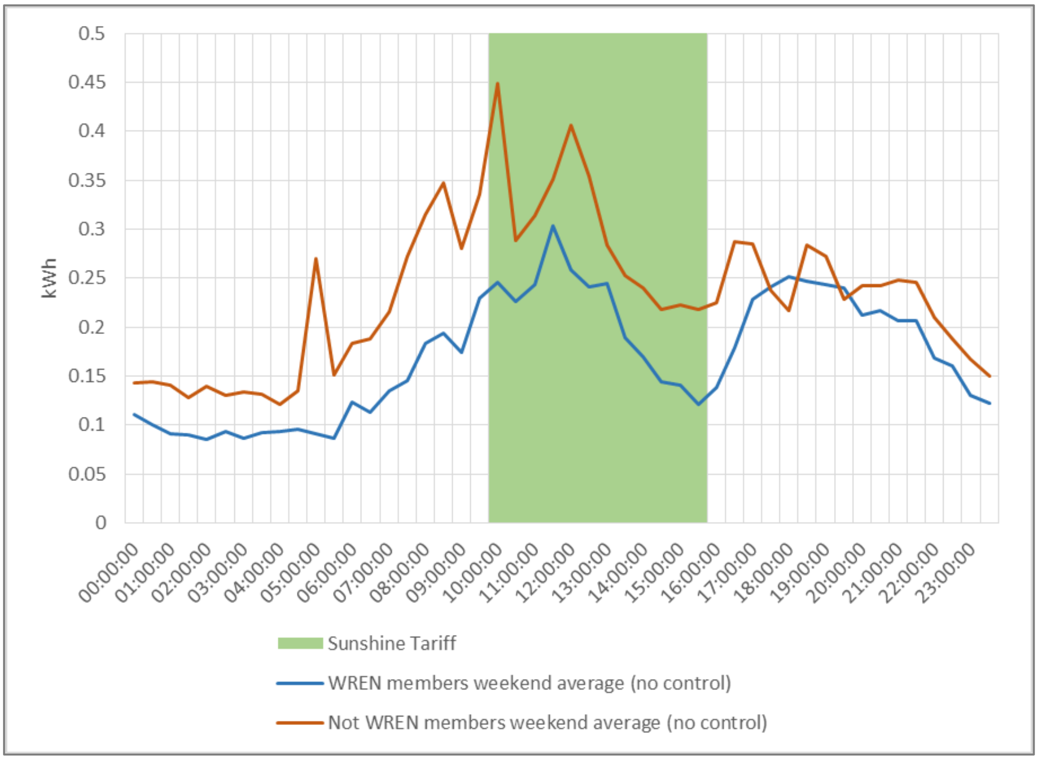

Figure 11 Comparison of demand profile for WREN members and non-members for the average weekend day

Table 10 Proportion of daily demand during sunshine tariff hours of WREN members and non-members

Weekday (%)	WREN members	Non WREN members
00:00-10:00	31%	35%
10:00-16:00	30%	33%
16:00-00:00	39%	32%
Weekend (%)	**WREN members**	**Non WREN members**
00:00-10:00	30%	35%
10:00-16:00	33%	34%
16:00-00:00	38%	31%

The above show that WREN members did not shift more electricity consumption than non-members. Non-members had a higher proportion of subgroup B participants, which would indicate a higher proportion of high load equipment like electricity immersion and/or space heaters. This explains the spike during the day seen in non-members cohort. WREN members had a lower daily demand than non-members, as shown in the table below.

Table 11 Comparison of average daily demand of WREN members and non-members

Average daily demand	WREN members (kWh)	Non WREN members (kWh)
Weekday	7.88	11.39
Weekend	8.13	11.23

This may be due to having installed energy efficiency measures and/or solar PV. 33 percent of the WREN members had solar PV compared to just 8 percent of the non-members.

The assumption that WREN members would be more engaged in energy issues and therefore switch more was proved wrong. There are several reasons why this might be the case. Firstly, more members had solar PV and therefore may have found it harder to increase their import of electricity when they were generating. Secondly, there was a lower proportion of WREN members in subgroup B, which generally had higher load equipment and some automation.

3.2.3 Comparison of retired/unemployed and employed/self-employed

It could be assumed that those households where the main bill payer is either retired or unemployed are more likely to have someone at home during the day than those that are employed. The following charts compare consumption patterns between those that are retired/unemployed with those that are employed/self-employed.

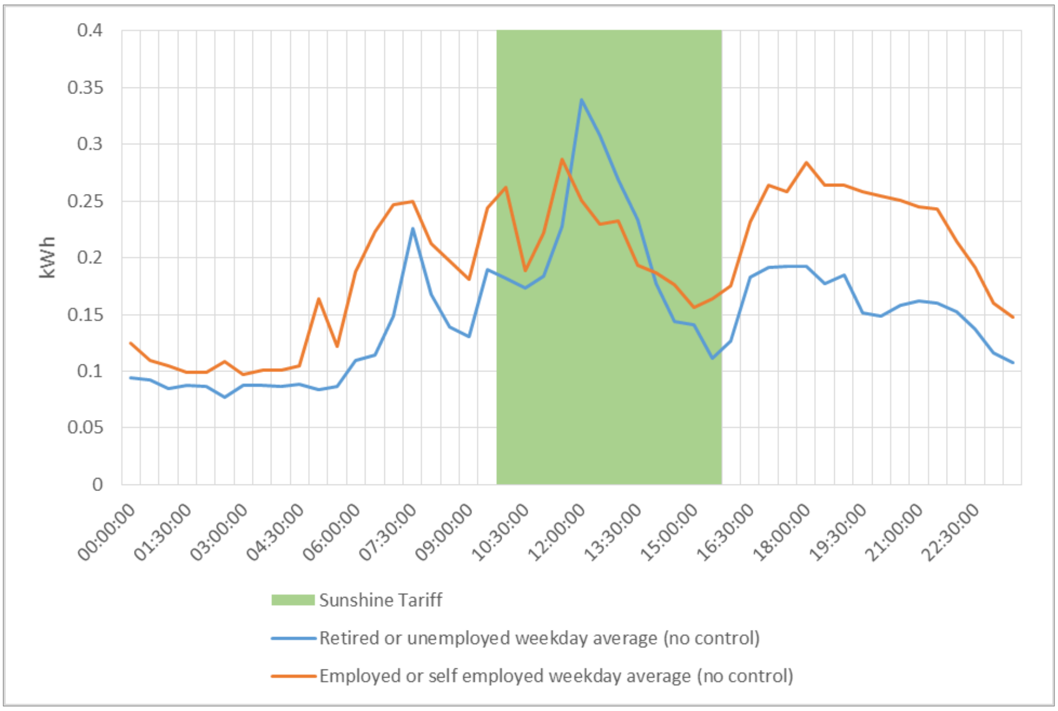

Figure 12 Comparison of demand profile for retired/unemployed and employed/self-employed for the average weekday

Figure 13 Comparison of demand profile for retired/unemployed and employed/self-employed for the average weekend day

Table 12 Proportion of daily demand during sunshine tariff hours of retired/unemployed and employed/self-employed households

Weekday (%)	Retired and unemployed	Self-employed and employed
00:00-10:00	31%	33%
10:00-16:00	36%	29%
16:00-00:00	33%	38%
Weekend (%)	**Retired and unemployed**	**Self-employed and employed**
00:00-10:00	30%	32%
10:00-16:00	39%	32%
16:00-00:00	31%	37%

This suggests that the retired/unemployed group were able to shift seven percent more demand to the middle of the day than the self-employed and employed.

Table 13 Comparison of average daily demand of retired/unemployed and employed/self-employed households

Average daily demand	Retired and unemployed (kWh)	Self-employed and employed (kWh)
Weekday	7.30	9.33
Weekend	7.53	9.59

The average daily demand was lower for the retired/unemployed. Interestingly, average daily demand increases by a similar amount for both groups from the weekday to weekend average, when you might expect a greater jump for the self-employed and employed group.

The retired/unemployed group were able to shift seven percent more demand to the middle of the day than the employed/self-employed. Therefore suggesting that having more flexibility in the daily routine helped with shifting energy consumption.

3.2.4 Comparison of large, medium and small energy users

There was significant variation in the average daily demand of participants on the trial (2.32 kWh up to 22.28 kWh), as shown in the figure below for the 31 participants that shared their annual consumption figures.

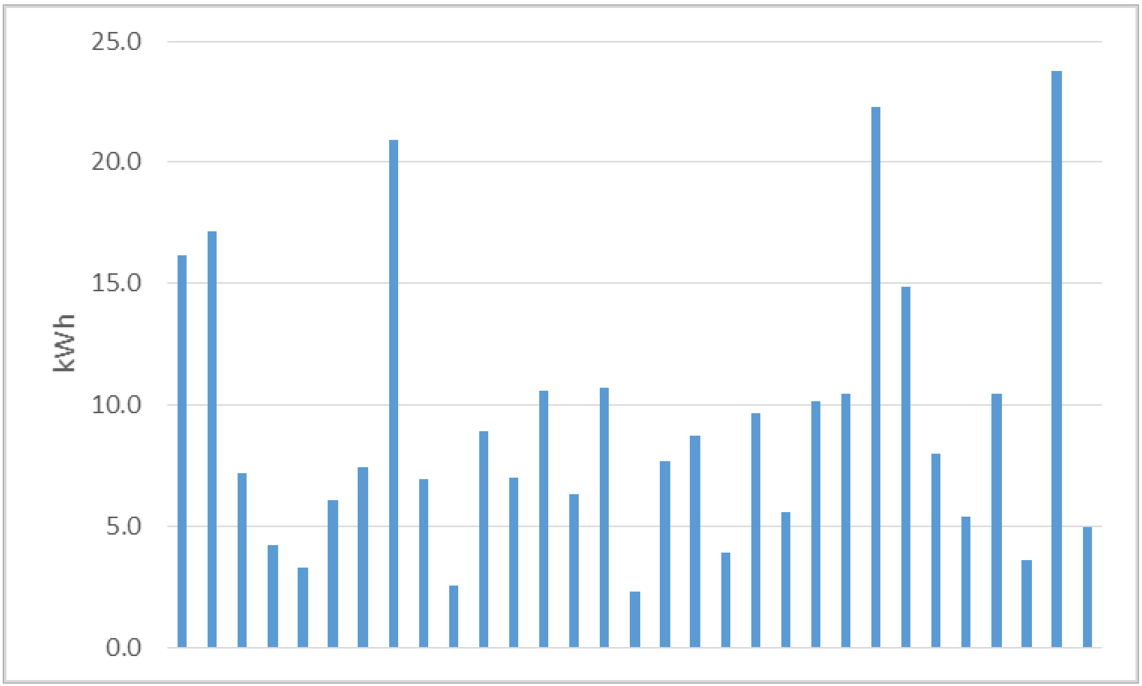

Figure 14 Spread of average weekday daily demand for 31 of the trial participants

The whole cohort was split into high, medium and low demand participants to see if they responded to the tariff incentive in different ways. A summary of participants in each group is shown in the table below.

Table 14 Number of participants in the low, medium and high average daily demand groups

Low (0-6 kWh/day)	Medium (6-12 kWh/day)	High (12+ kWh/day)
Total number: 10	Total number: 15	Total number: 6
Number with PV: 4	Number with PV: 2	Number with PV: 2

The following charts and tables compare the average daily demand profiles for the low, medium and high average daily demand groups.

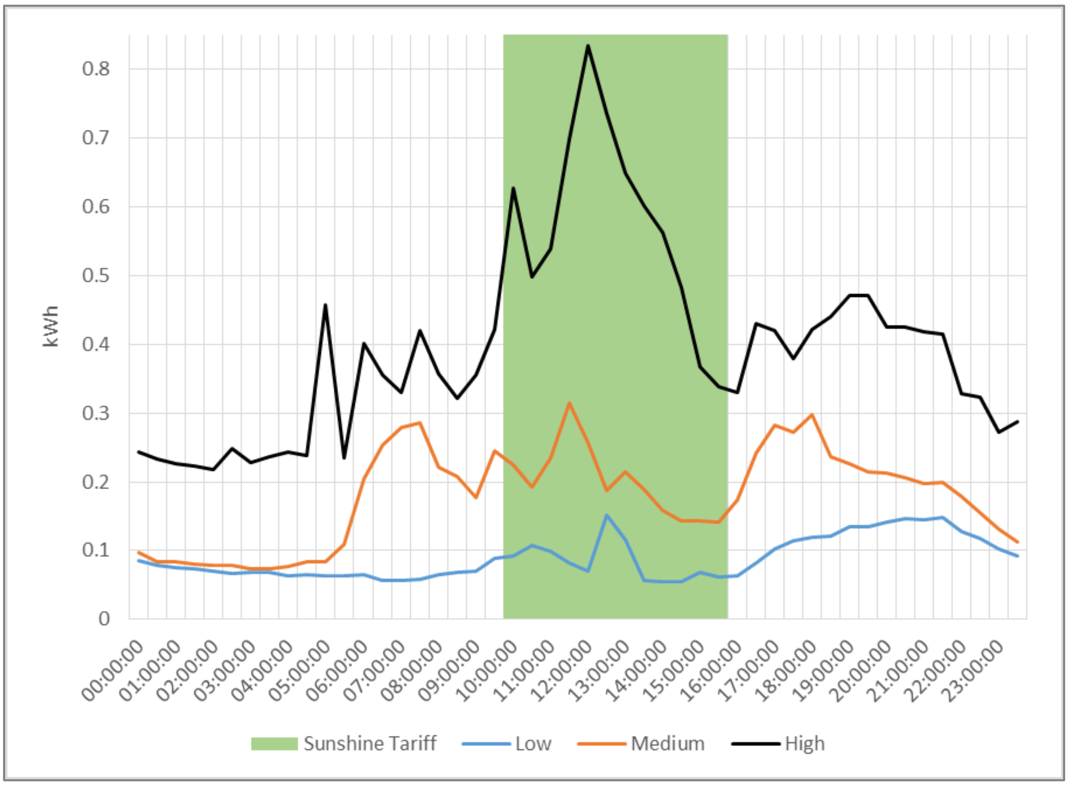

Figure 15 Weekday average daily demand for the low, medium and high average daily demand groups

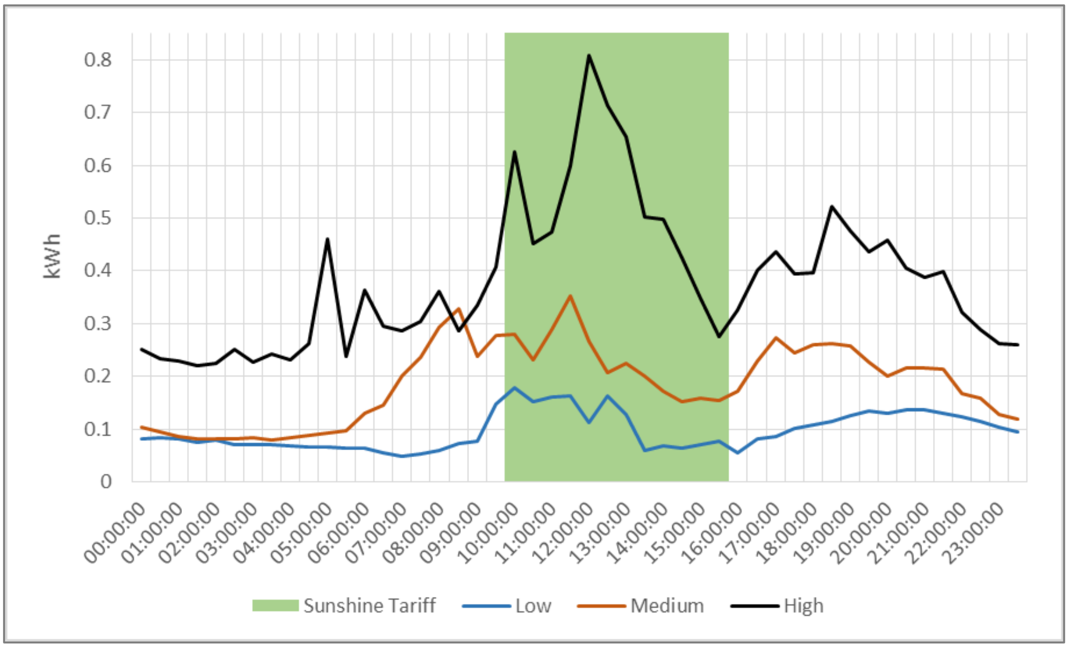

Figure 16 Weekend average daily demand for the low, medium and high average daily demand groups

Table 15 Proportion of daily demand met during sunshine tariff hours for the low, medium and high average daily demand groups

Weekday (%)	Low demand	Medium demand	High demand	Control
00:00 – 10:00	33%	33%	31%	32%
10:00 – 16:00	26%	30%	38%	20%
16:00 – 00:00	41%	37%	31%	48%
Weekend (%)	**Low demand**	**Medium demand**	**High demand**	**Control**
00:00 – 10:00	31.5%	32%	31%	30%
10:00 – 16:00	31.5%	32%	37%	22%
16:00 – 00:00	37%	36%	32%	47%

The high energy users were able to shift a greater proportion of their consumption into the Sunshine Tariff hours than the low and medium energy users. In comparison with the control group, the high demand group used 18 percent more than the control between 10:00-16:00, the medium demand used 10 percent more and the low demand used 6 percent more on an average weekday. This is most likely due to the higher energy users having more flexible load.

The following table sets out the average kWh's that were used in the three time bands, followed by a comparison with the control group.

Table 16 Average daily demands for the low, medium and high average daily demand groups (kWh)

Weekday (kWh)	Low demand	Medium demand	High demand
00:00 – 10:00	1.37	2.88	5.99
10:00 – 16:00	1.08	2.57	7.27
16:00 – 00:00	4.17	8.63	5.84
Weekend (kWh)	**Low demand**	**Medium demand**	**High demand**
00:00 – 10:00	1.45	2.9	5.71
10:00 – 16:00	1.45	2.86	6.70
16:00 – 00:00	1.72	3.17	5.84

3.2.5 Comparison of sites with and without solar PV

All of the subgroups had several participants that had solar PV installations onsite. Out of the 46 sites that formed the trial cohort, 16 had solar PV or just under 35 percent of the trial population, as shown in the table below. This is far higher than the regional average: Devon and Cornwall have an average of around five percent of homes supporting PV installations.[4]

[4] Analysis conducted by Regen SW based on WPD Growth Scenario Report

Table 17 Number of homes with solar PV by subgroup

	Total number of homes	Number of homes with solar PV
Subgroup A	34	12 (35% of the subgroup)
Subgroup B	12	4 (33% of the subgroup)
Control	15	5 (33% of the subgroup)
Total	**61**	**21 (34% of the total)**

The presence of onsite solar PV reduces the overall import to the property and may also indicate that the bill-payer at that property has a keener interest in energy consumption. The figure below compares the average profiles of the whole cohort with the cohort without solar PV.

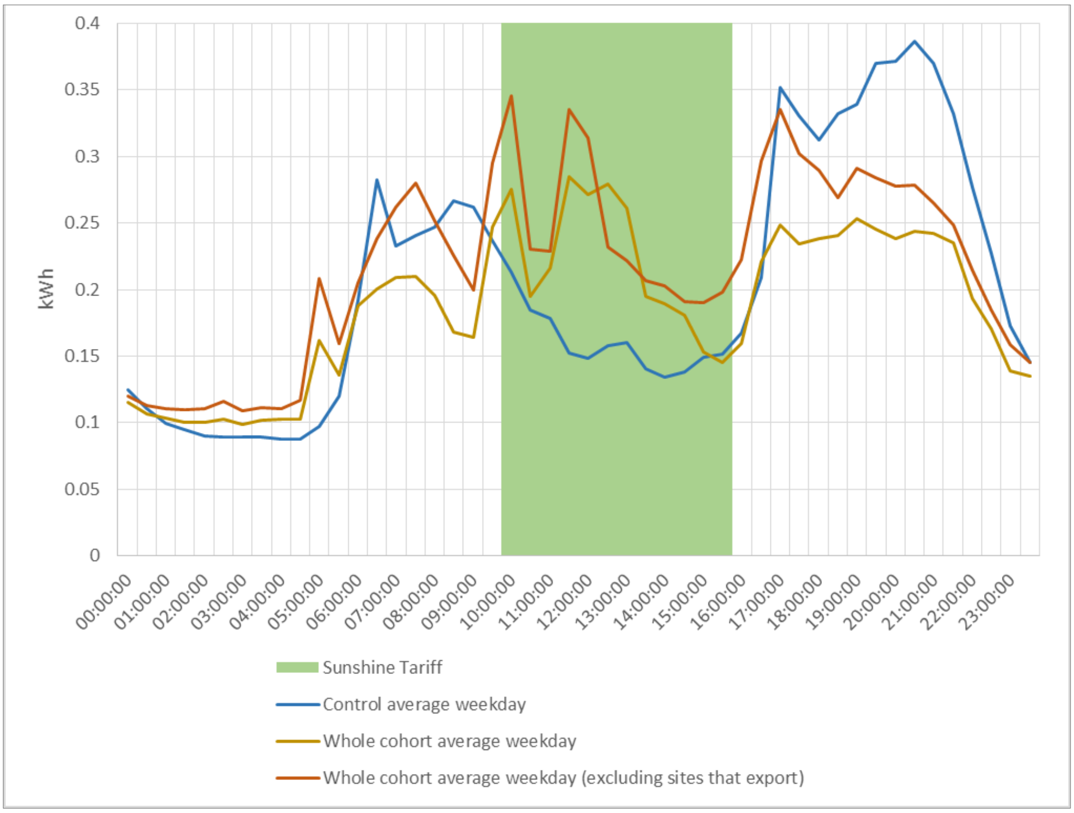

Figure 17 Comparison of the whole cohort average weekday demand during the Sunshine Tariff both including and excluding sites with solar PV

The chart indicates that the sites without PV use more power during the 10:00-16:00 period. However, the proportion of total daily consumption used in this period is less than when the sites with PV are included (by one percent), as shown in the table below.

Table 18 Comparison of daily demand for the whole cohort both including and excluding sites with solar PV

Weekday averages (%)	00:00 – 10:00	10:00 – 16:00	16:00 – 00:00
Ovo 2015 baseline data	33%	25%	42%
Control average (**excluding** PV)	30%	27%	43%
Whole cohort average (**excluding** PV)	33%	28%	39%
Control average (**including** PV)	32%	20%	48%
Whole cohort average (**including** PV)	32%	29%	38%
Weekend averages (%)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	33%	25%	42%
Control average (**excluding** PV)	30%	27%	43%
Whole cohort average (**excluding** PV)	33%	28%	39%
Control average (**including** PV)	30%	22%	47%
Whole cohort average (**including** PV)	31%	32%	36%
Weekday averages (kWh)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	3.02	2.36	3.88
Control average (**excluding** PV)	2.74	2.40	3.89
Whole cohort average (**excluding** PV)	3.45	2.90	4.07
Control average (**including** PV)	3.13	1.91	4.70
Whole cohort average (**including** PV)	2.91	2.65	3.44
Weekend averages (kWh)	**00:00 – 10:00**	**10:00 – 16:00**	**16:00 – 00:00**
Ovo 2015 baseline data	3.02	2.36	3.88
Control average (**excluding** PV)	2.71	2.50	4.07
Whole cohort average (**excluding** PV)	3.76	3.49	4.16
Control average (**including** PV)	29.1	2.16	4.57
Whole cohort average (**including** PV)	3.04	3.18	3.57

When sites with PV are excluded from the control group average, the proportion of electricity used in the different time bands is closer to the Ovo baseline data. This provides a useful comparison for the cohort average excluding PV, which shows only a one percent increase against the control average excluding PV.

This indicates that the sites with PV tended to shift a greater proportion of their consumption into the 10:00-16:00 period when compared with the sites without PV.

3.3 Change in consumption patterns over time

One of the questions asked of the project was how participants' ability to shift demand changed over time, whether in response to project interventions or otherwise. In order to establish the evidence, the proportion of each participant's daily demand for the Sunshine Tariff period (10:00-16:00) was examined.

This was achieved by averaging the demand over every week and weekend for each participant and looking at what percentage of the daily demand was consumed between 10:00-16:00, for each week throughout the trial. This could then be compared to the equivalent consumptions extracted from the Elexon and Ovo baselines (26% and 25% respectively) and the control.

If participants were gradually improving their ability to shift demand into the Sunshine Tariff period, this should show as an increasing trend in the figure below. Conversely, if participants were enthusiastic about shifting demand in the early weeks of the project but subsequently reverted back to previous demand habits, this should show in the figure as a decreasing trend. The average weekday demands for the 10:00-16:00 period for the Ovo baseline profile is shown for reference.[5]

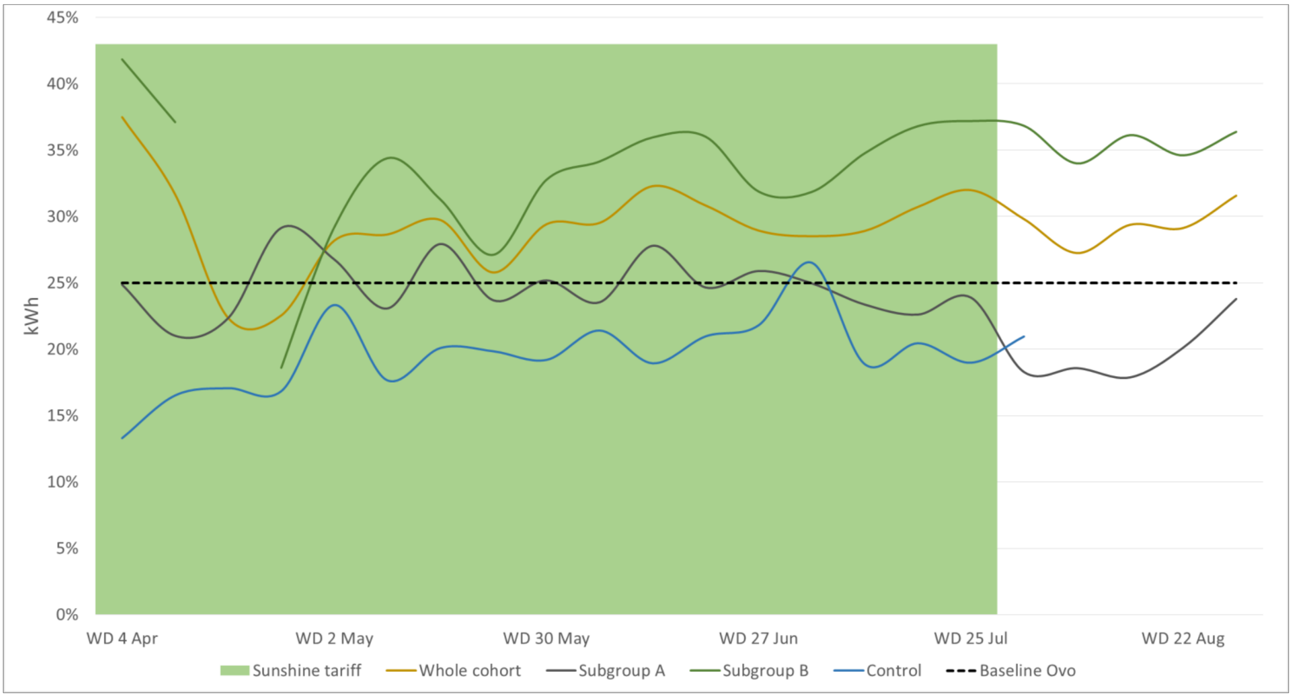

Figure 18 Percentage of weekday demand consumed between 10:00 - 16:00 for the whole cohort and each subgroup

There are greater fluctuations in the data for subgroup B in the first two months than expected, as the majority of the subgroup had timers for their hot water immersion set to come on at the same time each day. This suggests that they were either overriding the timers or shifting other flexible loads. However, the last two months appear to be more stable and consistently higher than the control.

There is a decrease in the proportion of electricity used between 10:00-16:00 for subgroup A during the last month of the trial period (July). This is likely due to reverting

[5] As these figures are averages for a particular season, they keep the same value throughout the Sunshine Tariff period.

back to previous demand habits over time. This is in contrast to subgroup B that maintains consistently high electricity use during the sunshine period in the last two months, suggesting that the automation technology supported a more consistent approach.

3.4 Analysis of demand during peak time

We have seen from previous analysis that most of the shift, if it occurs, is away from the evening period into the Sunshine Tariff period. The following table compares the average weekday evening demand for the control, subgroups A and B, and other groupings of the households.

Table 19 Comparison of average weekday evening demand (between 17:00-19:00)

		Average weekday demand 17:00-19:00			
Subgroup	Average weekday daily demand (kWh)	kWh	Difference from Control (kWh)	% of daily demand	Difference from Control (%)
Baseline	9.25	1.19	-0.13	13%	1%
Control	9.74	1.32	-	14%	-
Subgroup A	7.61	0.91	-0.41	12%	2%
Subgroup B	10.38	1.01	-0.31	10%	4%
Retired and unemployed	7.30	0.753	-0.567	10%	4%
Employed and self employed	9.33	1.070	-0.25	11%	3%
WREN members	7.88	0.95	-0.37	12%	2%
Non- WREN members	11.39	1.16	-0.16	10%	4%
Low demand	4.17	0.408	-0.912	10%	4%
Medium Demand	8.62	1.04	-0.28	12%	2%
High demand	19.10	1.75	+0.43	9%	5%

Most of the shift is from the evening period into the Sunshine Tariff period. There is a percentage reduction in peak evening demand compared with the control group in all the different groupings above.

The high demand subgroup has the highest shift of demand away from the evening peak period, with just nine percent of daily demand consumed during this time – a five percent reduction against the control group.

4 Qualitative analysis

In addition to the quantitative findings, significant learning can be gained from assessing customers' experiences of the time of use tariff through qualitative research.

A better understanding of what motivates households to change their behaviour enables industry to develop services/tariffs that are more likely to be attractive to customers and to deliver the desired DSR. Further information on the recruitment and switching of customers can be found in the 'Customer recruitment learning report'.

4.1 Switching behaviour

4.1.1 Sunshine Tariff customers

Customers were asked why they chose to switch onto the Sunshine Tariff. The most frequently cited response was to support WREN, closely followed by wanting to take part in an innovation trial. Just over 70 percent signed up to get cheaper electricity, which was lower than expected as the marketing material focused on potential cost savings.

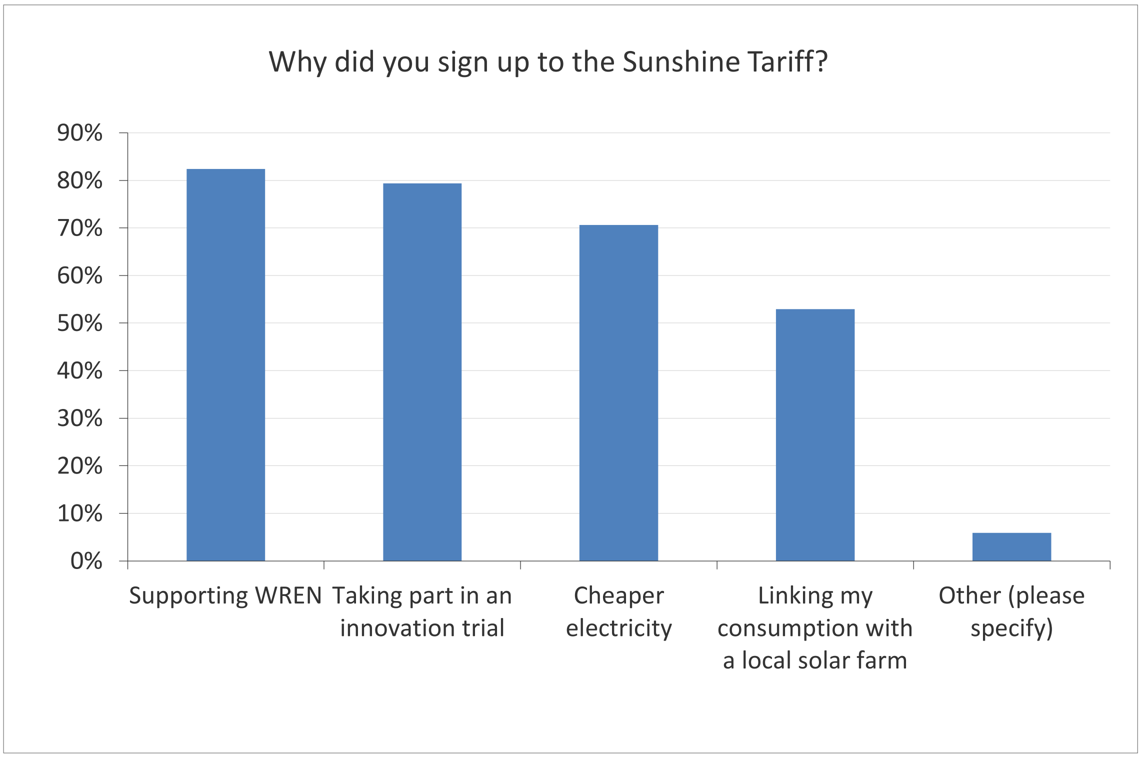

Figure 19 Reasons why customers chose to switch onto the Sunshine Tariff

The two 'other' responses were that they wanted to better understand their energy consumption patterns.

Peoples' motivations for signing up to the tariff can help explain the results. If all customers were motivated by linking their consumption with a local solar farm or to use as much power as possible within the cheap period, there may have been a more significant shift in consumption patterns. However, **people were more motivated by supporting WREN and taking part in a trial, which would not necessarily drive them to shift their consumption patterns**.

4.1.2 Non Sunshine Tariff customers

In order to find out why households chose not to sign up, we sent out a survey to WREN's membership, of which 51 households responded.

After hearing about the Sunshine Tariff, over half sought further information about the tariff before making a decision. The reasons given for not signing up are provided in the figure below.

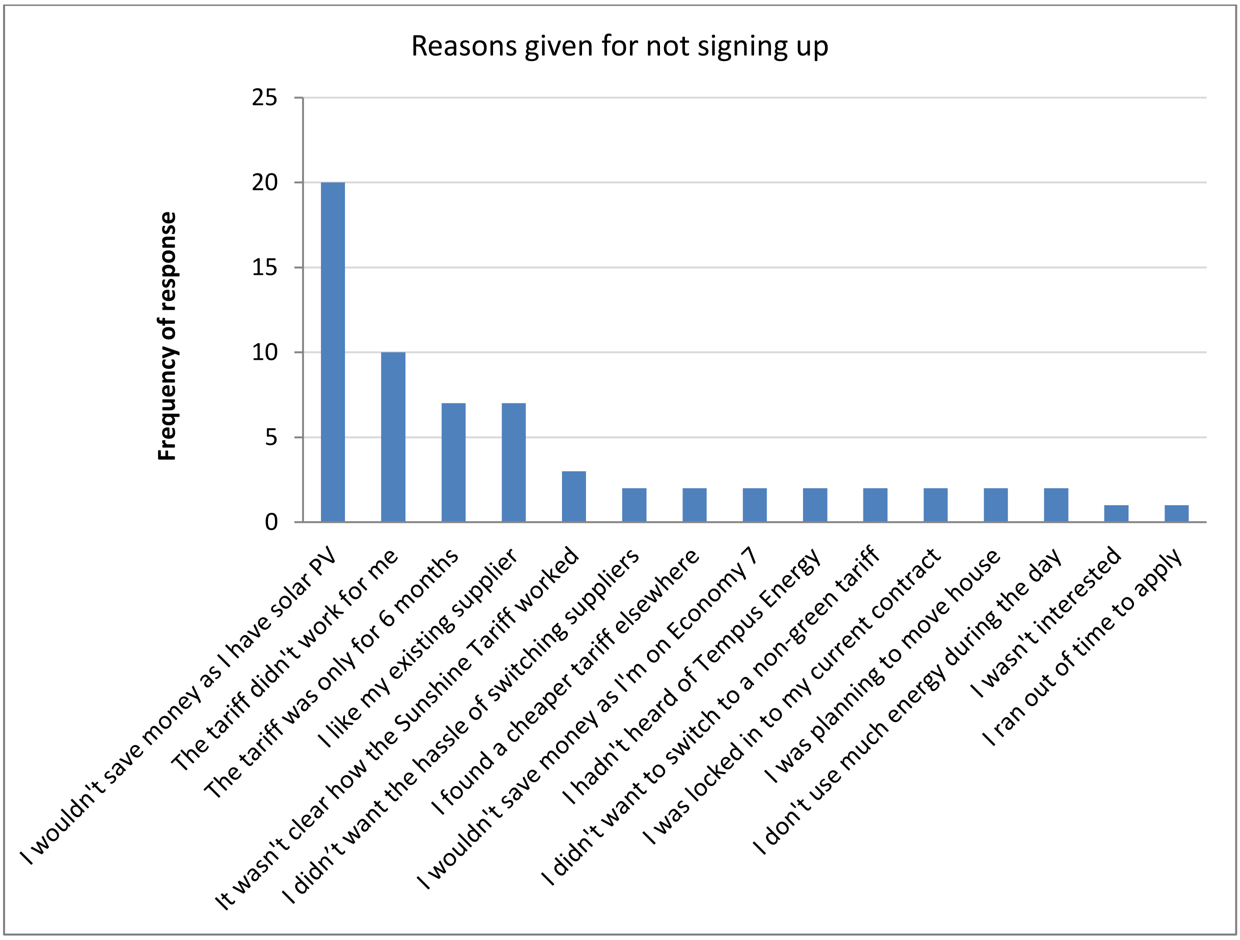

Figure 20 Reasons why WREN members chose not to switch to the Sunshine Tariff

The most commonly cited reasons for not signing up were related to it not making financial sense for the customer, particularly for those that had solar PV. People were also put off by the hassle of switching or didn't want to move away from their current supplier.

4.2 Behaviour change

Customers were asked about how they changed their behaviour, whether shifting consumption was perceived to be easy or challenging and how their behaviour changed over time.

When asked about which appliances they were able to use between 10:00-16:00, the washing machine and dishwasher were the most frequently cited. On average, customers listed three appliances that they were able to time-shift their use, but they ranged from one to seven different appliances per home.

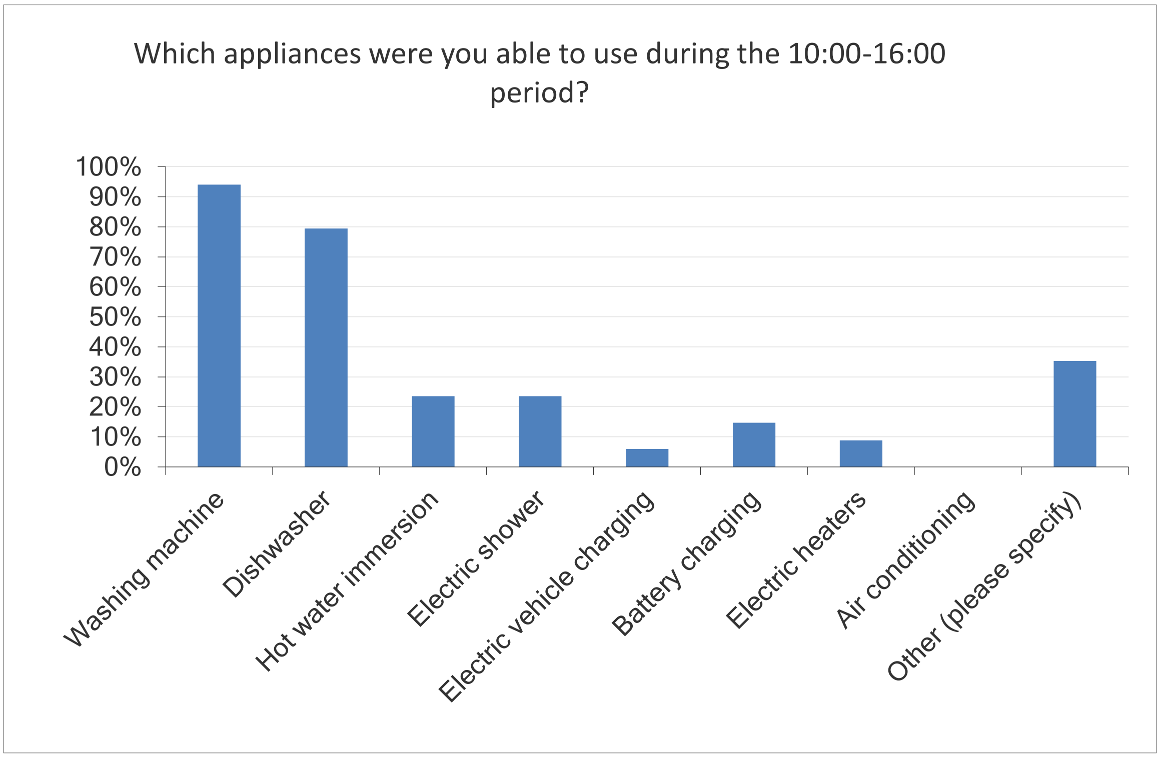

Figure 21 Appliances used during the 10:00-16:00 period

Other appliances listed were:

- Tumble drier (x3)
- Electric oven (x3)
- Vacuum cleaner (x2)
- Kettle
- Iron

- Lighting
- Kiln
- Chargers for portable gadgets
- Computer equipment
- Lawn mower
- Hair dryer
- Electric heating
- Freezer.

The typical power rating or range for each of the appliances is shown in the table below.[6]

Table 20 Appliances and typical power rating or range

Appliance	Power rating
Washing machine	1200-3000W
Dishwasher	1050-1500W
Hot water immersion	3000W
Electric shower	7000-10,500W
EV charging[7]	3300-10,000W
Electric heater	2000-3000W
Tumble drier	2000-3000W
Electric oven	2000-2200W
Vacuum cleaner	500-1200W

The structured interviews revealed that several customers used built in timers on their washing machines and tumble driers to switch them on during the 10:00-16:00 period. None of the customers used air conditioning, which would be a good match for a Sunshine Tariff.

When asked how much customers perceived they were able to shift, over 90 percent stated that they had shifted either ‘a lot’ or ‘a little’. When comparing this finding with the quantitative data that shows an increase in consumption of between three and 10 percent against a baseline, it suggests that customers’ perception of how much they were changing their behaviour differs from their actual behaviour.

[6] https://www.cse.org.uk/advice/advice-and-support/how-much-electricity-am-i-using

[7] http://evobsession.com/electric-car-charging-101-types-of-charging-apps-more/

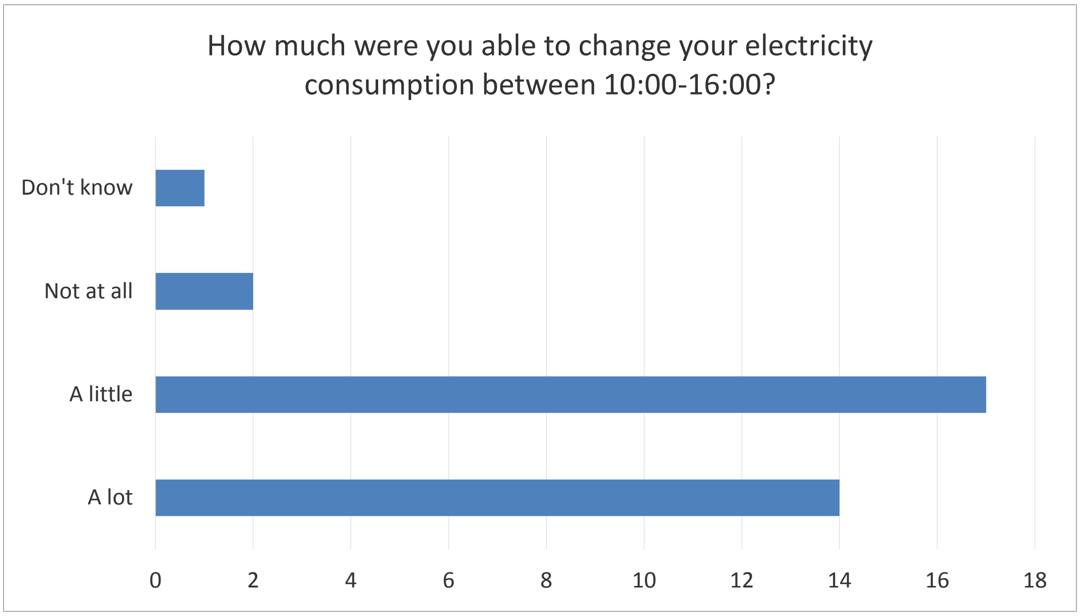

Figure 22 Customer perception of how much they were able to change their consumption

When asked in the interviews whether the feedback from WREN on how much they had shifted reflected how much they thought they had, the majority said yes and that they were pleased with the results. However, this group was self-selected and may have been more engaged in the trial compared to those that chose not to respond.

Customers also stated that it was ‘easy’ to shift their consumption to the 10:00-16:00 period, with only four customers finding it ‘difficult’ or ‘very difficult’. Once again, this differs from the quantitative findings which showed that, on average, customers shifted 10 percent of their consumption compared to the control.

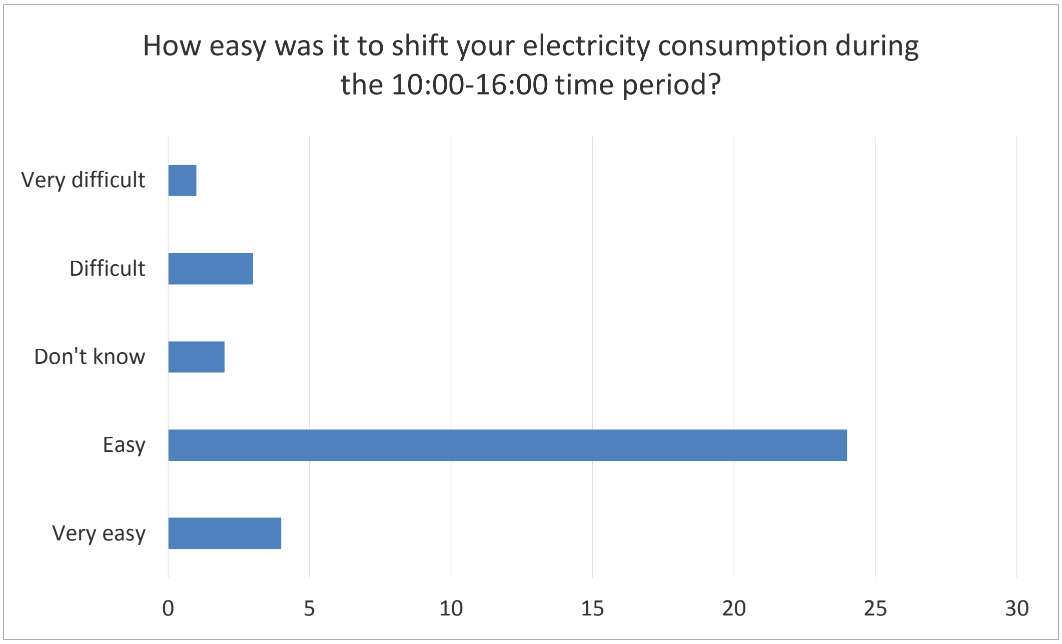

Figure 23 Customer perception of how easy it was to change their consumption behaviour

The customers that were interviewed tended to either be at home during the day or had some automated control, and so either found it easy to wait until after 10:00 to switch appliances on manually or didn't need to think about it if they came on automatically. For those without automation, many established habits like waiting to shower until 10:00 if they didn't need to go out or listening for the change in radio presenter before putting the dishwasher on. Three customers stated that having solar PV helped them to shift consumption as they had already established habits. One customer stated, *"The combination of solar-powered electricity with a cheaper daytime tariff suited me very well"*.

Several customers stated that they found it difficult to influence other household members' behaviour, particularly lodgers. Cooking was another activity that customers found difficult to change, unless they precooked and reheated food for the evening. When asked 'Do you think you could have shifted more?' one customer answered, *"Not whilst having a life, no!"*

Two customers suggested that 09:00-17:00 would have been more convenient. This also came up in the interviews with people stating that the narrow window of 10:00-16:00 was sometimes problematic, especially if an appliance ran beyond 16:00.

When asked about how much effort they made to shift electricity consumption at the beginning and the end of the trial, there was a slight reduction in effort over time, as shown in the figures below. This is reflected in the quantitative data, which also shows a slight reduction in the proportion of electricity used between 10:00-16:00 towards the end of the trial period for subgroup A (see section 3.3).

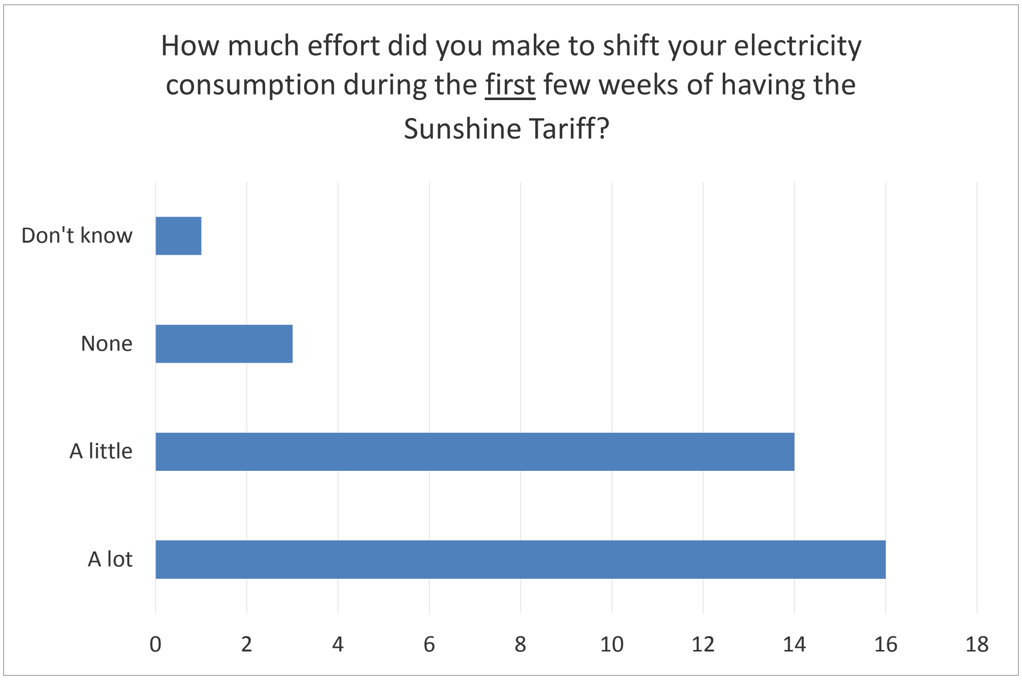

Figure 24 Customer perception of how much effort they made during the first few weeks

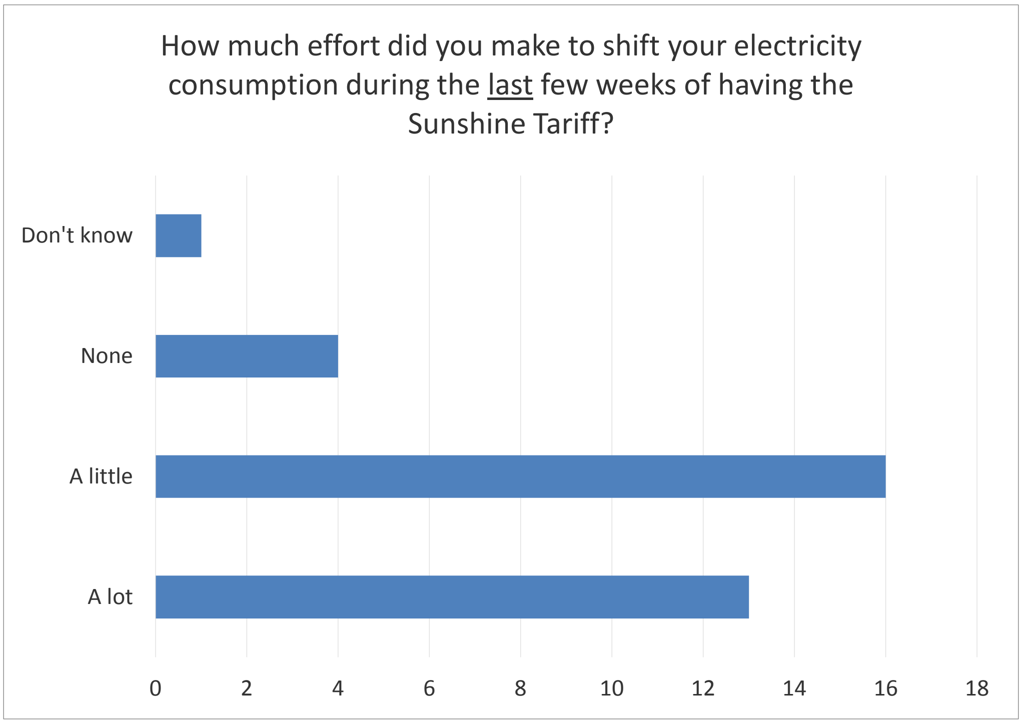

Figure 25 Customer perception of how much effort they made during the last few weeks

When asked in the interviews whether they stuck to their habits throughout the trial period, most stated that they were consistent in their approach. One customer stated that they identified additional activities that they could do in the middle of the day as the trial went on.

In order to gauge how proactive customers were in changing their behaviour, they were asked if they talked with other household members about how they used electricity. Two thirds responded positively, with one third stating "Yes, a lot". This suggests that one potential benefit of greater uptake of time of use tariffs is a greater awareness of energy consumption.

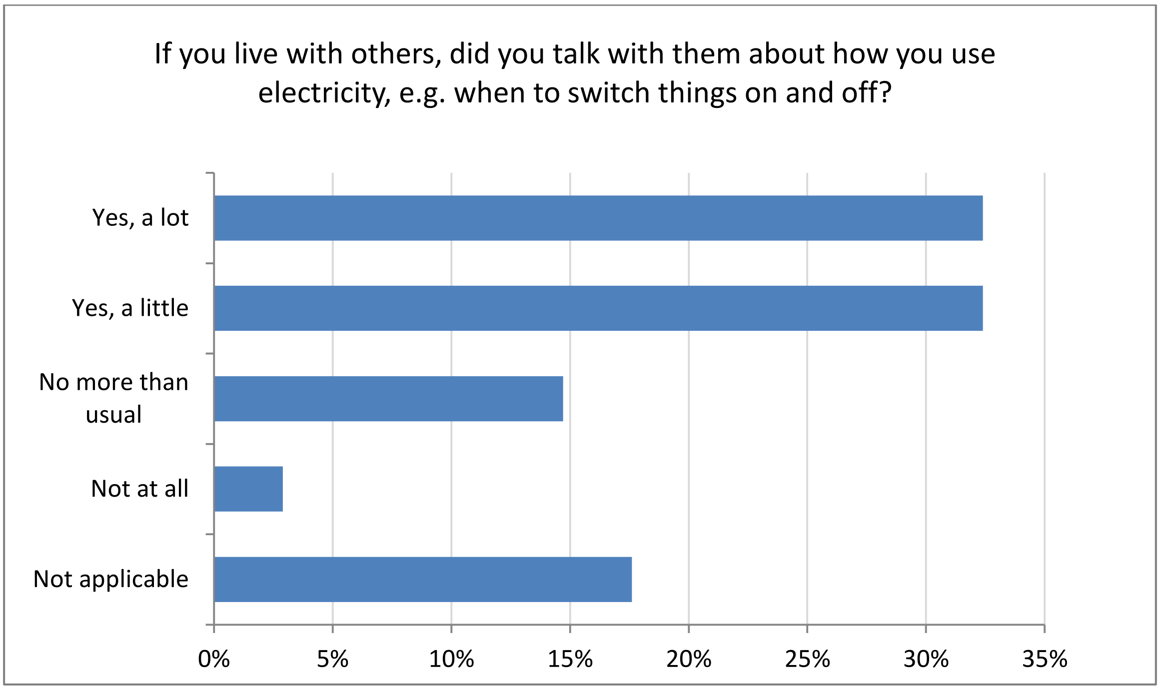

Figure 26 Customer perception of how often they spoke with their housemates about their electricity consumption

Overall, when customers were asked about how they changed their behaviour, their perception of how much they shifted was greater than the actual shift seen in the quantitative data. This may be due to a lack of understanding of how much electricity appliances use. For example, it may require considerable effort to use a washing machine in the middle of the day instead of the evening, but the impact is small.

4.3 Data and monitoring consumption

A common theme in the feedback from customers through both the survey and interviews was their disappointment that the smart meters did not provide real-time data on their electricity consumption. This was due to a connectivity problem with the smart meters. The supplier, Tempus, had an online platform where customers would have been able to monitor their consumption if the data had been available. Over half of customers stated that they would have regularly checked this website.

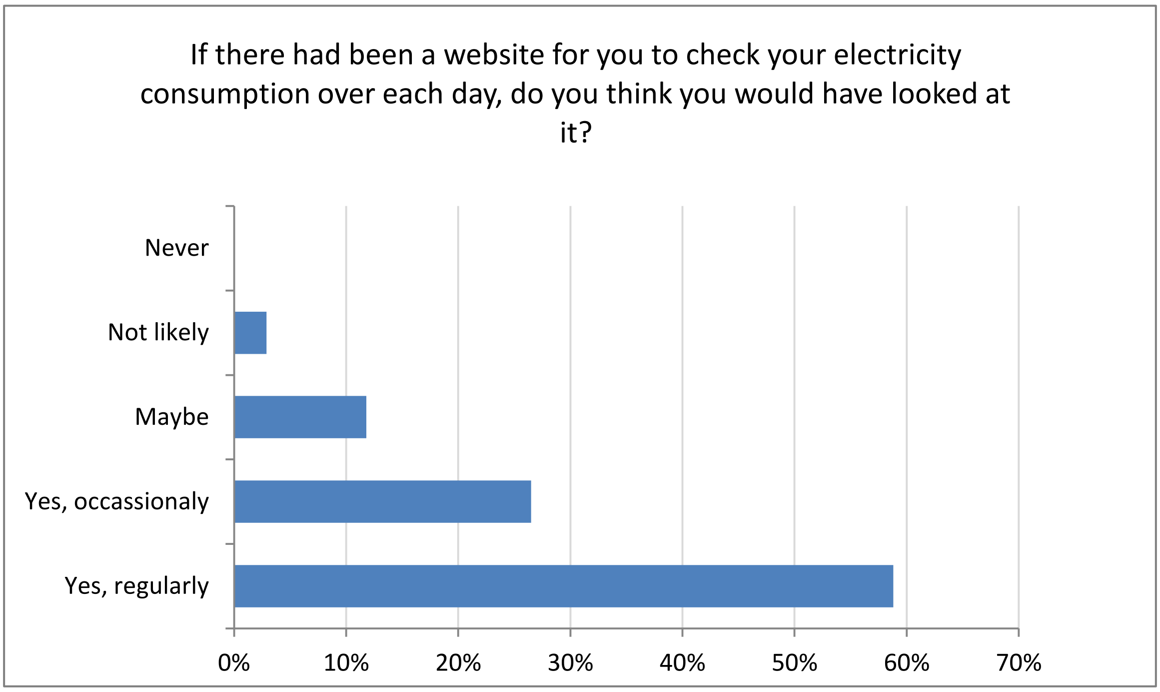

Figure 27 Customer view on whether they would have reviewed their consumption patterns if data had been available

Comments made by customers on this issue include:

"The meter installed is difficult to read and is not likely to change consumer behaviour unless information generated can be accessed easily and conveniently and presented in a format that is useful. It's not the meter that's important, it's the consumer interface."

"Thanks for the opportunity to take part - I'm disappointed I didn't get to learn as much as hoped through not being able to access the real time data but the activity was still worthwhile in growing our awareness about energy usage."

"A smart meter on the kitchen worktop showing ££ used that day would be the most useful to monitor use. I would like to know how much electricity we use and how this compares to average 4 person household. I would like to think we are quite good about trying to save energy....!!"

However, when asked in the interviews if they would have benefitted from having regular reminders (either from WREN or Tempus) about the tariff, all ten customers said no. They all felt committed to the trial and were able to establish habits and stick to them without regular reminders. However, two customers did say that some tips on how to improve performance would have been useful.

It is impossible to know whether making real-time consumption data available to customers would have changed their behaviour during the trial period. However, it is clear that there was a demand from customers to have this information.

4.4 Automation

During the trial, 12 out of the 46 Sunshine Tariff customers had some form of automation technology installed for the trial – subgroup B. Two customers had a range of smart switches with some remote control by the supplier, and the other 10 had pre-set timers on their hot water immersions. Of the 34 customers that responded to the survey, 14 stated that they had some automated control technology. So we can assume that some customers either already had technology installed, most likely timers built into their washing machine or other appliances.

Almost three quarters (73 percent) stated that automated control technology helped them use electricity between 10:00-16:00. This correlates with the quantitative data, which shows that the customers were much more able to shift consumption into the 10:00-16:00 period if they had some automated control technology.

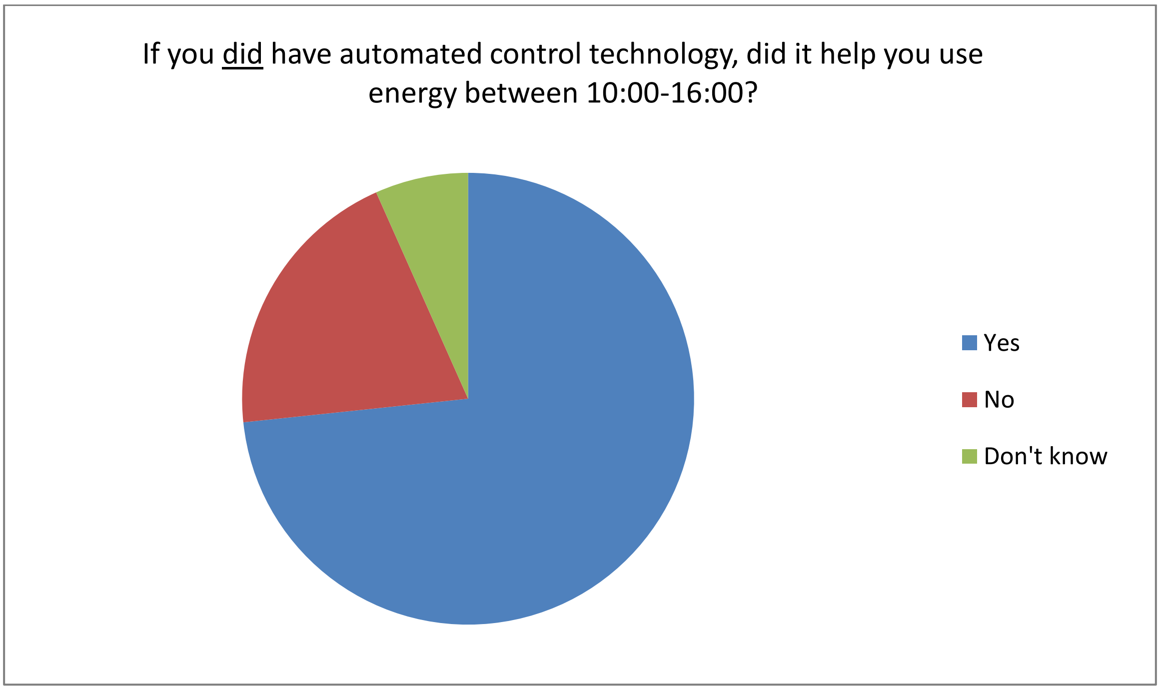

Figure 28 Subgroup B's perception of whether automated control technology helped them

Subgroup A (no automation) were asked if they thought it would have been easier to use energy between 10:00-16:00 if their appliances were switched on automatically, half said yes, quarter said no and quarter didn't know, as shown in the figure below.

For those at home during the day, they stated in the interviews that there was no need for automation. But one customer said that a timer for his storage heaters would have been helpful.

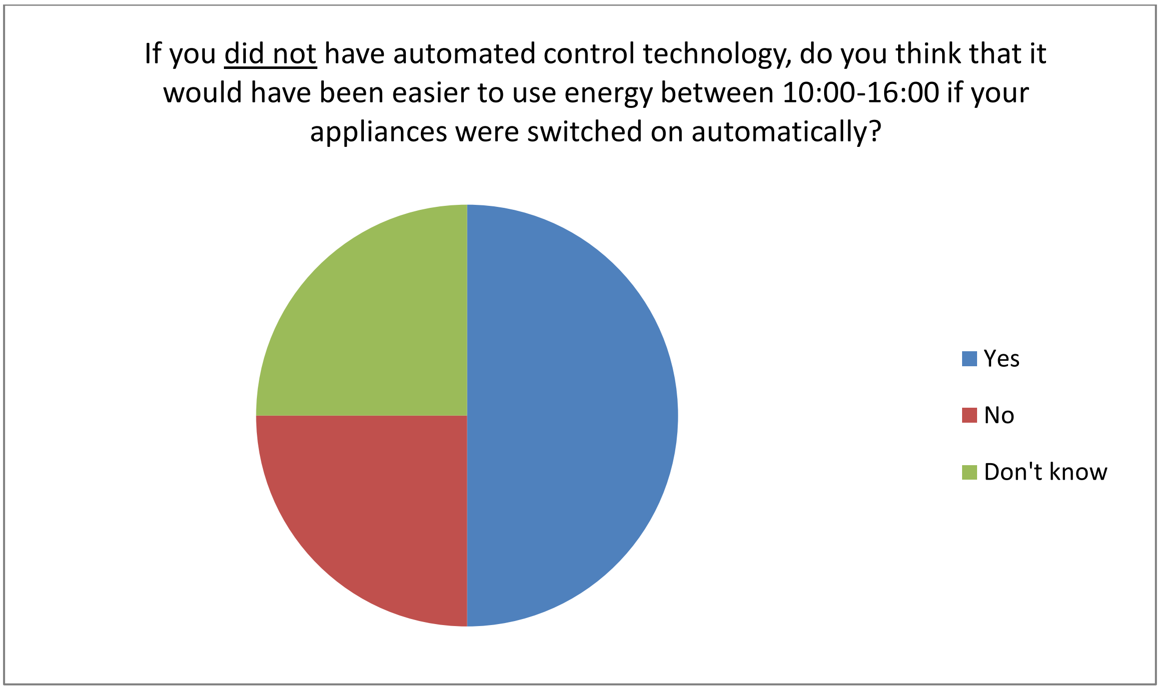

Figure 29 Subgroup A's perception of whether they would have benefitted from having some automated control

When comparing the responses from customers with and without automation technology, those with automation felt they were more able to change their electricity consumption between 10:00-16:00, as shown in the figure below.

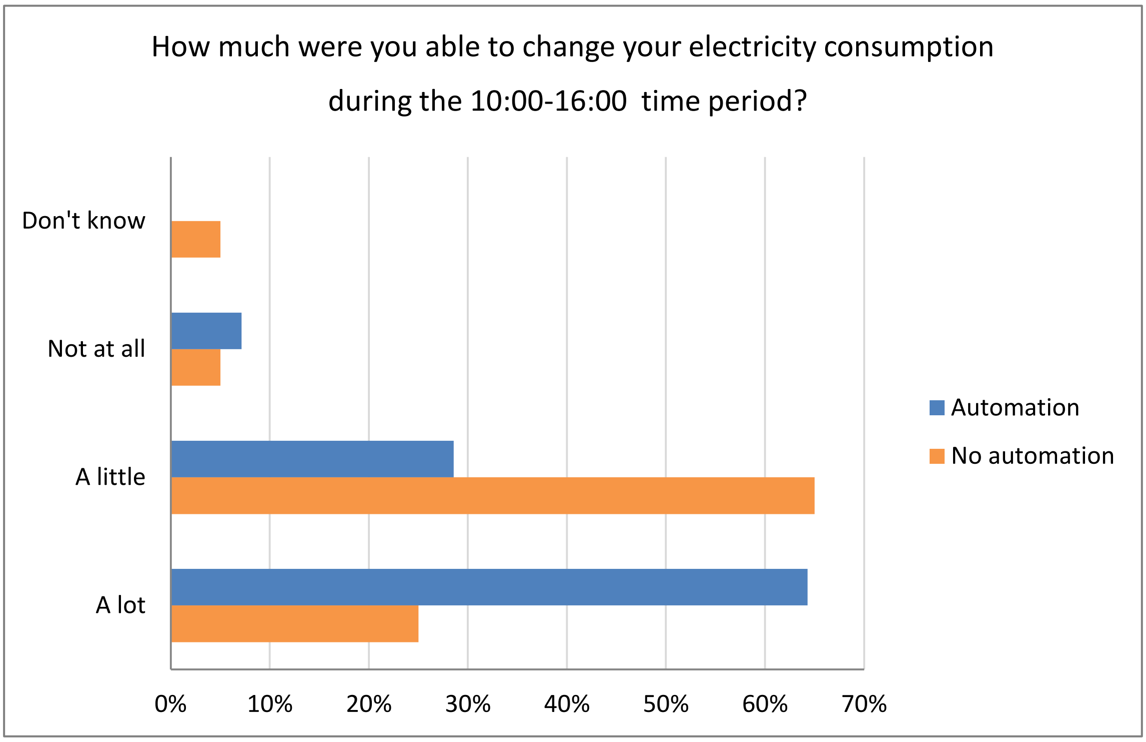

Figure 30 Customer perception of how much they were able to change their behaviour split by those with automation and those without

Overall, automated control technology was perceived to be helpful in shifting electricity consumption to the middle of the day. This correlates with the quantitative findings.

4.5 Overall experience

When asked if customers would switch to a time of use tariff again in the future, 74 percent said yes and only one customer said no, as shown in the figure below.

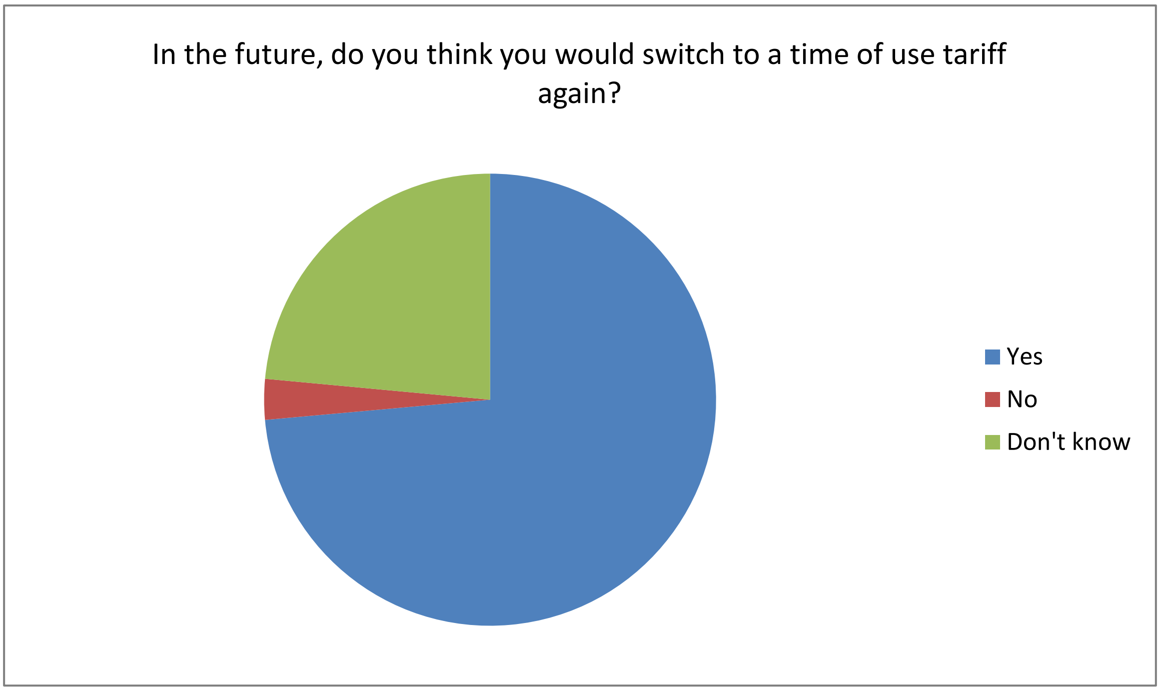

Figure 31 Customer view on whether they would switch to a time of use tariff again

Those with automation technology were more likely to switch to a time of use tariff again compared to those with no automation. This suggests that the overall experience of a time of use tariff is more positive if appliances are switched on automatically.

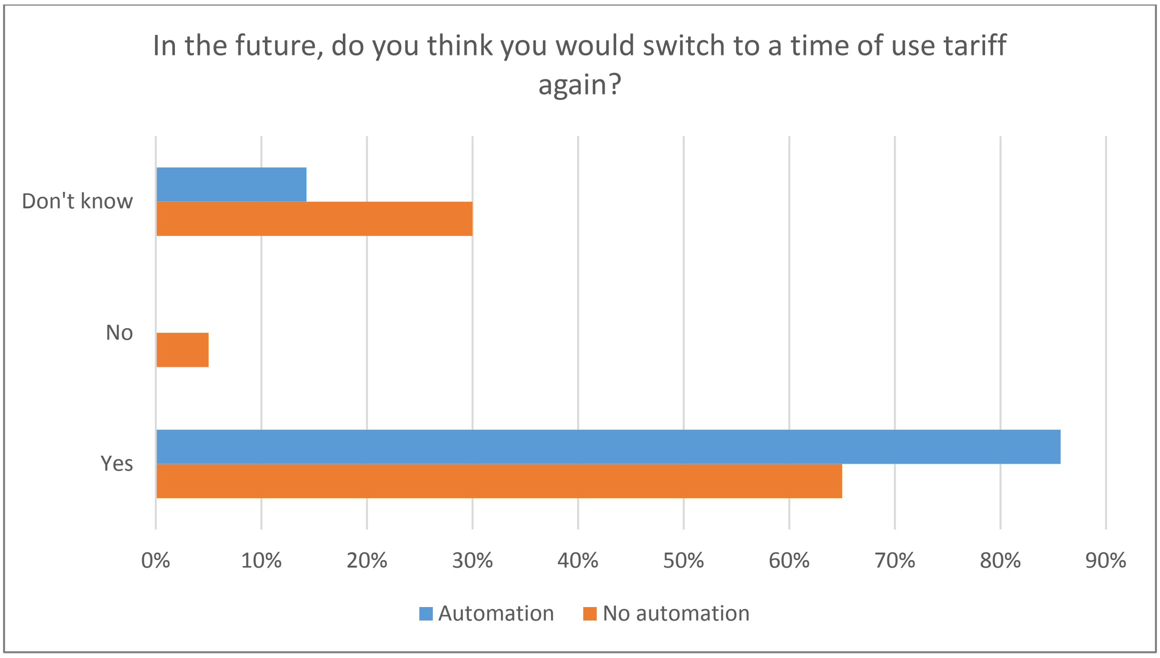

Figure 32 Customer view on whether they would switch to a time of use tariff again, split by those with and without automation technology

Whilst three customers expressed some disappointment that the trial was cut short and that the smart meters did not work, **in general, customers reported a positive experience of taking part in the trial**. Some positive feedback includes:

"I think this was a really good project and it is good to see the community engaged with their energy usage."

"Well done establishing this important work at a time when the policy environment became increasingly hostile."

"It was good but due to various problems the trial was not as long as was hoped, very good nevertheless."

"All the contacts I have made with the supplier and WREN concerning my supply have been very easy to make and very helpful, particularly when the contract was prematurely terminated."

"I was fully committed to the project. Shame it didn't go to plan but I was happy to be part of the trial."

5 Summary of findings

The quantitative data indicates that participants on the Sunshine Tariff shifted between 9 and 10 percent of their demand into the Sunshine Tariff period compared to the control, and between four and seven percent compared to the Ovo baseline data. Most of the shift is from the evening period into the Sunshine Tariff period, with a reduction in the proportion of electricity used in the evening peak of approximately three percent against the control group.

The average consumption shifted into the Sunshine Tariff period compared with the control group was approximately 150 kWh over the Sunshine Tariff period from April to September. In order to offset the generation from a 250 kW solar farm, this finding suggests that approximately 650 Sunshine Tariff customers would be required.[8]

The households with automation technology were able to shift 13 percent of their consumption into the 10:00-16:00 period compared to 5 percent for those without automation. The qualitative findings correlated with this. Overall, automated control technology was perceived to be helpful in shifting electricity consumption to the middle of the day and the customers with automation were more likely to sign up to a time of use tariff again in the future.

The findings from the households with automation technology suggest that 360 customers would be required to offset a 250 kW solar farm. Therefore, the concept of an offset connection will become more viable as automated control technology becomes more widespread and households have a greater flexible load, for example from electric vehicles and other forms of energy storage.

Other comparisons within the dataset indicated that:

- The retired/unemployed group were able to shift seven percent more demand to the middle of the day than the employed/self-employed, potentially due to being at home more during the day
- The high energy users were able to shift a greater proportion of their consumption (18 percent) into the Sunshine Tariff hours than the low and medium energy users. This is most likely due to having a larger flexible load, such as hot water immersion or an electric vehicle

[8] Based on an 11.1 percent load factor and the export of 40 percent of the total annual consumption in the 10:00-16:00 period between April and September.

- Although the sites with PV imported less power than those without PV, they tended to shift one percent more of their consumption into the 10:00-16:00 period than households without PV. The interviews and survey revealed that some customers with PV had already established habits of using more power during the middle of the day and therefore didn't find it challenging to shift their consumption
- Wadebridge Renewable Energy Network (WREN) members shifted up to three percent less consumption than non-members. There are several reasons why this might be the case. Firstly, there was a lower proportion of WREN members in subgroup B, which generally had higher loads and automation technology. Secondly, the customer survey revealed that when signing up, customers were more motivated by supporting WREN than saving money.

When customers were asked about how they changed their behaviour, their perception of how much they shifted was greater than the smart meter data indicated. This may be due to a lack of understanding of how much electricity appliances use. For example, it may require considerable effort to use a washing machine in the middle of the day instead of the evening, but the impact is relatively small.

Overall, customers reported a positive experience of taking part in the trial and when asked if customers would switch to a time of use tariff again in the future, nearly three quarters said they would.

6 Appendix – Methodology for establishing a comparative consumption profile

6.1 Challenges with the development of a baseline

Due to time constraints associated with the project set-up and challenges in providing the necessary smart meters to customers in time, it was not possible to gather baseline data from each participant prior to the trial starting in April 2016. However in order to establish the impact of the trial, a 'baseline' of consumption that would have occurred without the intervention of the trial was developed.

The most robust methodology for generating a baseline would be to collect several years' worth of consumption data for each participant prior to the start of the trial. Having data for several years would enable variances due to annual temperature differences and changes to bill tariffs to be taken into account. Changes to participants' consumption profile could then be directly compared to their typical historic profile.

As this was not possible for the Sunshine Tariff, it was proposed that a methodology was developed to utilise data sets that were available to the project partners, along with the trial control group smart meter data to determine a comparative profile. An alternative solution to the lack of historical data would be to extend the duration of the trial by a year, to enable longer data collection for the control group and a non-trial period (October 2016 – March 2017) of data to be collected for the other sub-groups.

6.2 Methodology for building a comparative profile for data analysis

As outlined above, gathering baseline data directly from the trial participants for a period of time before the trial starts was not possible. Therefore, an alternative method of examining electricity consumption in Wadebridge was developed.

It was proposed that a number of data sources were compared, in order to identify what a typical, average domestic electricity consumption profile was for Wadebridge. The conclusions drawn from the analysis would take into account a level of uncertainty that results from using an average rather than historical, house-specific profile for comparison.

A number of data sets already existed, either from previous trials that used smart meter data or that have been compiled for use in the UK energy market. It was proposed that several datasets were compared to each other to establish how relevant they would be to Wadebridge in the summer of 2016, before establishing a set of profiles to be used as the 'baseline'. This set of average profiles could then be benchmarked against the 'real' data being generated by the control group.

6.2.1 Sources of domestic electricity demand data

Several sources of data were available to project partners and could be used to establish a comparative profile that estimated electricity demand of an average domestic property in Wadebridge for the summer period of 2016:

- Standard Elexon profiles, the industry standard profile describing average electricity consumption patterns in the UK
- Data provided by Ovo Energy, for the average electricity consumed on a half hourly basis from 200 domestic customers in Cornwall, gathered through summer 2015. This data was provided as a single, average domestic profile for each of the summer months (May, June, July, August, September)
- Low Carbon London (LCNF trial) data 2012-2014, measured in kW/HH broken down by month and the Acorn[9] system of subgrouping
- Customer-Led Network Revolution (LCNF trial) data May 2011 – October 2013. This data was available in kW/HH for a range of customers, including profiles for electric vehicle owners and PV system owners
- Estimated Annual Consumption (EAC) data for all Wadebridge households
- Annual consumption data for postcodes in the Sunshine Tariff trial area, published by the Department for Business Energy and Industrial Strategy (BEIS)
- The control group of the Sunshine Tariff, which would provide smart meter data for summer 2016.

Figure 33 outlines how each comparative data source would need to be processed to yield average electricity profiles that were relevant for the year, season and location of the trial.

[9] http://acorn.caci.co.uk/

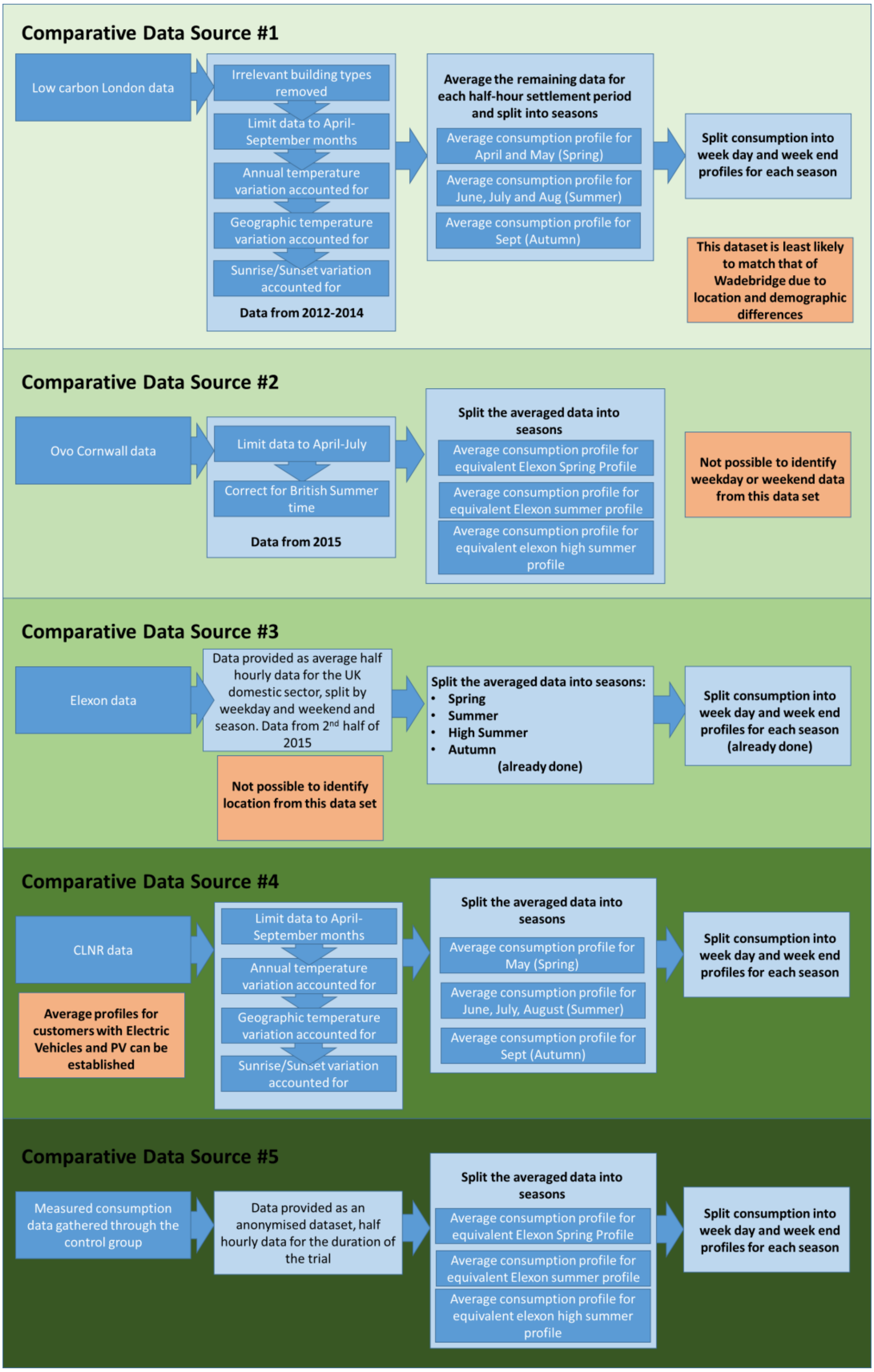

Figure 33 Outline of the data process for each comparative data source

6.2.2 Comparison of available data sets

As described in figure 32, the five sources of comparative data provide a number of profiles:

Table 21 Profiles generated by each data source

Comparative data source	Cornwall	Spring / Summer / Autumn	Weekday / Weekend	Date
Source 1: Low Carbon London data	✘	✓	✓	2012-2014
Source 2: Ovo Data derived from Cornwall smart meters	✓	✓	✘	2015
Source 3: Elexon standard profile (Profile 1, unrestricted domestic)	✘	✓	✓	2015
Source 4: CNLR Data	✘	✓	✓	2011-2015
Source 5: Control group	✓	✓	✓	2016

Not every dataset contained data specific to Cornwall, and not all were split by weekday/weekend. However, by comparing the dataset profile shapes (and ignoring the scale of the profile), the profiles could be compared to data gathered from the control group.

6.2.3 Generation of the comparative profile

The following process would be followed to create a comparative profile.

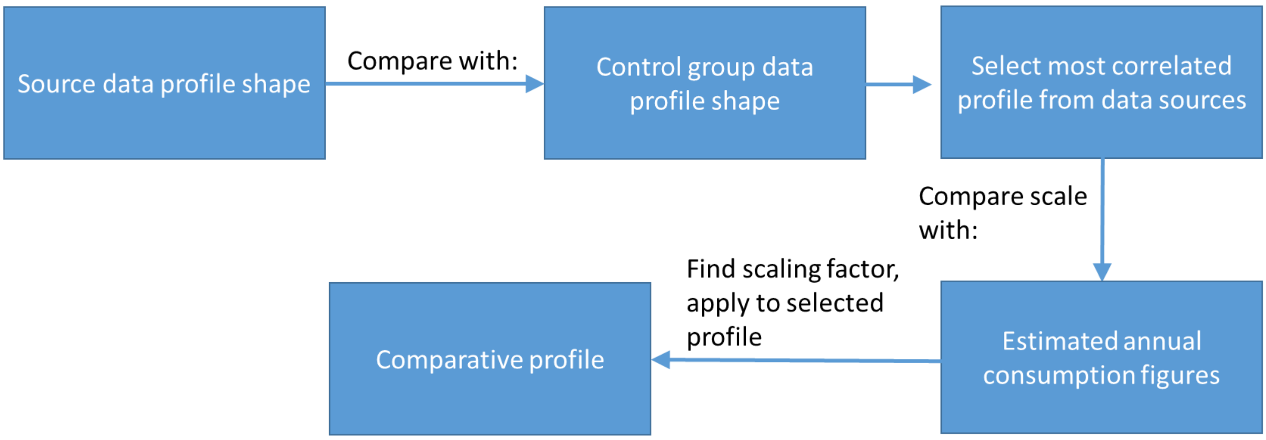

Figure 34 Process diagram for the generation of a comparative profile

Two elements needed to be considered in order to develop a comparative profile: Profile shape and profile scale.

6.2.3.1 Comparisons based on profile shape

The data sources available (Elexon, Ovo and Low Carbon London) were plotted together to compare profile shape, see figure 34 below. (Elexon profile in orange, Ovo in yellow and Low Carbon London data in Blue).

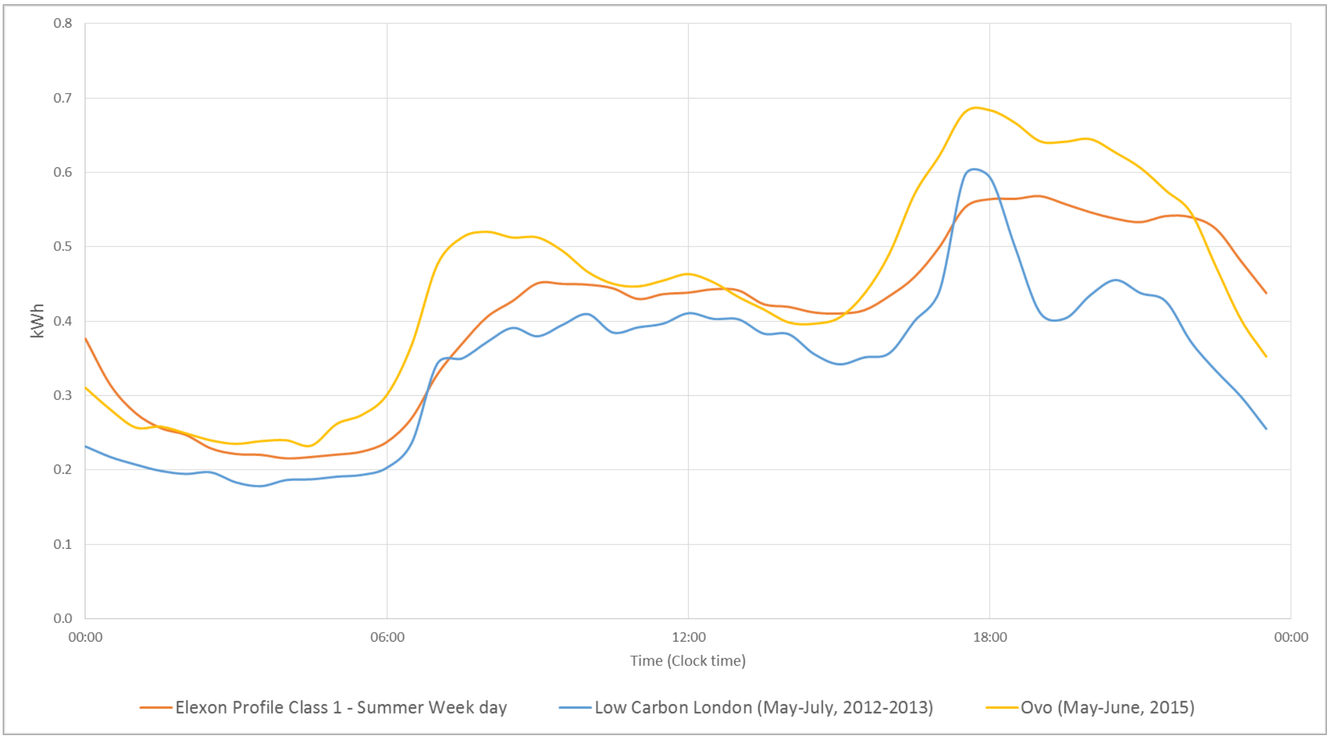

Figure 35 Illustrative comparative profiles for a typical summer weekday[10]

The profiles plotted in figure 34 could only be compared for relative profile shape, as the Low Carbon London data had not be adjusted for location and annual temperature differences, nor sunrise/sunset variation. It should also be noted that for the Low Carbon London plot, the data was an average from just three customers, purely to illustrate the comparative process.

The plots in figure 34 were all for the period May – July, (the period used by Elexon for their 'summer' profile), but for different years, so temperature variation as well as sunset and geographic location factors still needed to be taken into account. As already mentioned, the

[10] It is worth noting that the profiles as generated from the low carbon London data in figure 1. have not been adjusted for regional/annual temperature changes, nor sunrise/sunset deviation from Cornwall

plot in figure 33 was also mixing weekday and week-averaged data, purely to illustrate the method.

The profiles illustrated in figure 34 would be compared to the profiles generated by the control group over the same period. This would provide an indication of which dataset (Elexon, Low Carbon London, Community-Led Network Revolution, Ovo) most closely resembled the control group. It was unlikely that the control group profile would exactly match one of the dataset profiles already sourced, but it was likely there would be significant correlation with one of them. There was, however, a risk that the control group would change their behaviour as a result of taking part in the trial. This would be mitigated by WREN explaining the importance of behaving as normal and reiterating that they were on a flat tariff.

The dataset profile with the highest correlation to the control group profile would be selected as the baseline profile shape. Whilst not perfect, this type of comparison could be relied on to benchmark the profile being seen in the control group, and would provide a useful proxy in the absence of baseline data gathered from trial participants. As the sunshine tariff trial was primarily focused on the shift of demand, directly comparing the profile shapes generated by the trial to this displayed in figure 34 would give an indication of any significant changes.

Each of the sources listed in section 6.2.1 above would readily produce average profiles for spring, summer and autumn periods, giving three profiles each, with three of the sources able to be refined further into weekday/weekend profiles.

It was expected that the profile that was most relevant to customers participating in the trial would be those provided by Ovo. This was due to the following considerations:

- Off-gas grid: the geographic boundary of the Sunshine Tariff trial covers both gas-grid connected and off-gas grid housing. Although the Ovo data does not have metadata covering the gas-connection status of the customer, it was likely that the *mix* of households with access to the gas grid would be similar to that of Wadebridge. (50% of homes in Cornwall were not connected to the gas grid[11]).
- Geographic temperature variation would have nominal impact as the Ovo data was from Cornish households, within a reasonable distance of Wadebridge
- Sunrise/sunset variation would have nominal impact when comparing the Ovo data to Wadebridge.

[11] https://www.cornwall.gov.uk/media/3624351/Consultation-Responses-DECC-Bio-energy-strategy.doc

These profiles were available as a single profile for each of the months from May – September, averaged across around 200 customers in Cornwall with smart meters. This profile would need to be assessed in relation to local impacts, such as the prevalence of PV arrays and plug-in vehicles (see section 6.2.5) and scaled to reflect the average consumption demand of Wadebridge (see section 6.2.4).

6.2.3.2 Sunrise, Sunset and geographic factors

The Elexon profile methodology applied two sunset variables when calculating consumption profiles. Firstly the sunset variable, which was expressed as minutes before or after 18:00 hours to account for how sunset affects illumination i.e. when the lights were switched on. The other sunset variable was sunset squared which was used to predict seasonal effects across the country. Such variables would need to be applied to the Low Carbon London (if it was used) and CLNR data to appropriately adjust profiles for comparison with the control data, in particular when examining profiles for plug-in vehicle and PV array activity.

The Ovo data from 2015 does not need to be adjusted for sunrise/sunset time or geographic variation, as it was taken from 200 customers around Cornwall, where these variations would be small. This supports the use of Ovo's profile over that of other sources, as making such allowances for sunrise/sunset and geography would inevitably introduce additional uncertainty into the final profile.

6.2.4 Establishing the profile scale

Comparisons of just the profile shape were useful when considering whether a shift in demand had taken place, but it was necessary to consider the scale of the profiles in order to estimate the amount of consumption shifted. By applying an accurate scaling to the selected profile, it could then be directly compared to profiles generated by the trial and benchmarked against other profiles, such as that produced by Elexon.

There were several sources available to project partners that provided figures for consumption:

- The data provided by Ovo for 10 months during 2015
- Data provided by Elexon
- The Estimated Annual Consumption (EAC) figure generated for every customer connected to the network
- BEIS figures from 2013 for annual consumption by postcode.[12]

[12] https://www.gov.uk/government/statistics/postcode-level-electricity-estimates-2013-experimental

It was possible to ascertain the total annual consumption of Wadebridge participants through EAC (Estimated Annual Consumption) provided to the project partners by WPD. The EAC values could be plotted to establish the variation of expected consumption for unrestricted, domestic customers on both standard and economy profiles (Elexon profiles 1 and 2).

In addition, BEIS had published figures for annual electricity consumption for every postcode in the UK. This dataset had been assessed for postcodes eligible for participation in the trial. The mean average consumption for the Wadebridge area per year, according to these figures was **3947 kWh** with the median average as **3539 kWh**.

6.2.4.1 The Estimated Annual Consumption figure (EAC)

It was not possible to obtain the EAC on an individual customer basis due to data protection issues. Therefore, a range of options could be explored to establish a reliable EAC for participants on the trial:

- Average anonymised EACs for all profile 1 and 2 customers in Wadebridge. These values could be plotted to show the spread of EACs across the Wadebridge area and an average figure selected (see figure 35)
- Historic annual consumption values for trial customers were gathered by WREN during the recruitment phase. These figures could be plotted against the anonymous EACs provided by WPD to check their veracity and highlight the most likely range of EAC in the trial participants
- Estimation of the EAC from extrapolation of data gathered from the control group
- Asking customers for their consent for WPD or Tempus to release their EAC.

It was not possible to assess which route would yield the highest correlation until data was gathered from the control group from April 2016.

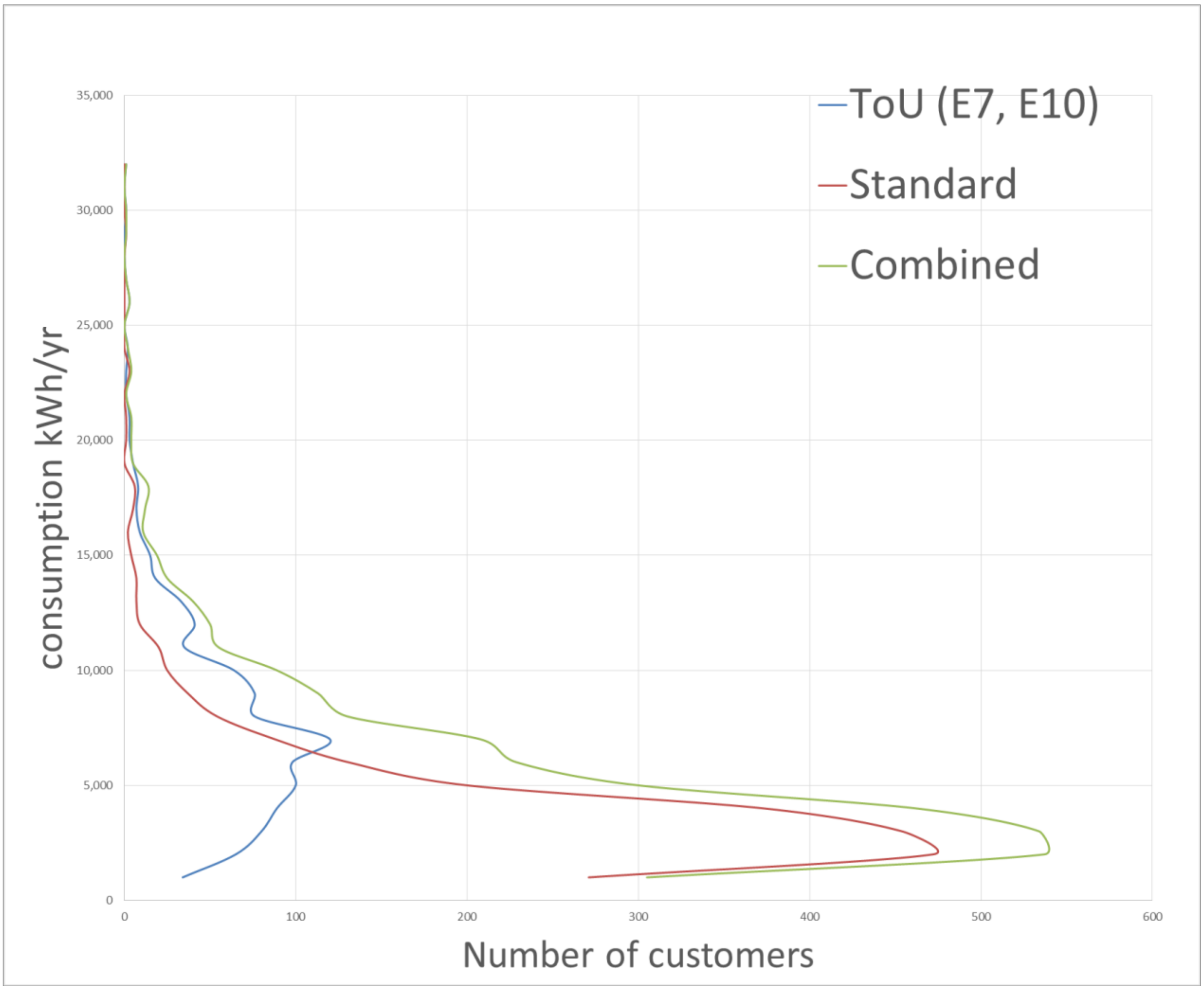

Figure 36 EAC values in kWh for unrestricted domestic customers in Wadebridge

The EAC values plotted in figure 35 show the breadth of consumption levels recorded by Elexon in the Wadebridge area. Some outliers (such as 124 customers with an EAC value of zero, or under 500 kWhs) can reasonably be excluded from further analysis, as it could be assumed that any customer participating in the sunshine tariff trial would certainly have an EAC of greater than 500 kW. Basic modelling shows that a domestic property running no more than lighting, a fridge, a kettle, a washing machine and electric oven would consume around 680 kWh/yr.

By excluding these outliers, the mean average EAC for Wadebridge was **3918 kWh per year.** This correlated well with the values derived from BEIS's measured data (3947 kWh/yr, 1 percent difference) Elexon (4127 kWh/yr, 5 percent difference) and reasonably well with the values derived from Ovo (4557 kWh/yr, 14 percent difference).

What could be derived from each of these analyses was that the Ovo data, whilst the most relevant to Cornwall conditions, was likely to include a number of rural properties that had far higher electricity consumption than was observed in a town centre such as Wadebridge. Both the EAC data generated by Elexon, and the BEIS data which was measured from electricity meters, registered lower annual consumption values than those resulting from Ovo modelling. As such, the Ovo profile should be scaled down to reflect the lower annual consumption value observed in the Wadebridge area.

6.2.4.2 Gas grid considerations

Early metadata analysis on customers who had already signed up to the trial indicated that the mean average electricity consumption was far higher than the region of 3900 kWh calculated in 6.4.2.1. This was based on annual consumption figures as given by most (but not all) customers as part of the trial sign up process. Of the 60 customers who had signed up to the trial by 1 April 2016, around 50% were in properties that were not connected to the gas grid. Early assessment of the trial customer metadata gave the following insight:

Table 22 Annual consumption of gas grid and off-gas grid connected properties

	Gas grid connected properties	Off-gas grid properties
Lowest annual consumption figure for a customer to date kWh/yr	980	1012
Highest annual consumption figure for a customer to date kWh/yr	22000	30000
Median average consumption per year kWh/yr	**2837**	**5628**
Mean average consumption per year kWh/yr	4419	6641
Median of total annual consumption from all customers kWh/yr	**3757**	

As can be seen from the values above, an initial assessment of the customers showed a substantial range of electricity consumptions, both for gas connected properties and off-gas properties. For this reason, the median value was the best way of assessing an average consumption figure: **2837 kWh/yr** for properties on the gas grid and **5628 kWh/yr** for properties off the gas grid.

As can be seen in figure 36, approximately half of the sunshine Trial catchment area was not connected to the gas grid, indicating that a substantial number of sunshine tariff participants would not have gas available for heating and cooking.

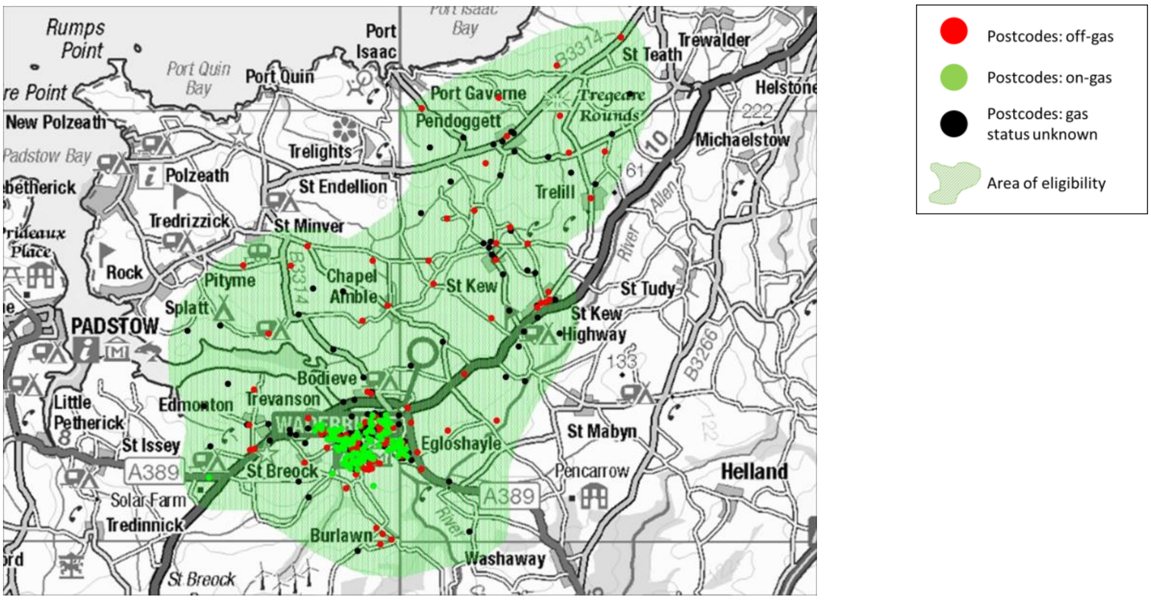

Figure 37 Geographic areas eligible for participation on the trial: gas connected, off-gas properties and unknown

This emerging difference in electricity consumptions (noting that this was based on just 60 properties involved in the trial) leads to an important point: It may be necessary to split the data gathered on the trial into two streams, customers on gas, and those off-gas, utilising a different profile scale for each. This could be assessed once a more significant amount of data had been gathered.

However, it was important to note that the Ovo data, the Elexon data and the consumption data published by BEIS were not split according to gas connections. The median value of annual consumptions as given by customers signed up to the trial was **3757 kWh/yr**, similar to the average EAC for Wadebridge and the value derived from BEIS data.

The Elexon, BEIS and initial customer sign-up data all suggested that with gas and off-gas customers aggregated, the expected average consumption for a trial customer would be around 3900 kWh/yr.

6.2.4.3 Applying EAC data to profiles

The EAC data could be split roughly according to the seasonal patterns of consumption using the Elexon and Ovo datasets. The Elexon data could also be further split into an average daily consumption, but as the data provided by Ovo did not have this split, an average across the whole week was taken for the Elexon profiles.

Comparing the monthly consumption values for Ovo and Elexon produced a close correlation, with the Ovo data suggesting that customers in Cornwall typically used slightly more electricity than the UK standard profile suggests. This may have been due to the number of Cornish households that were off the gas grid.

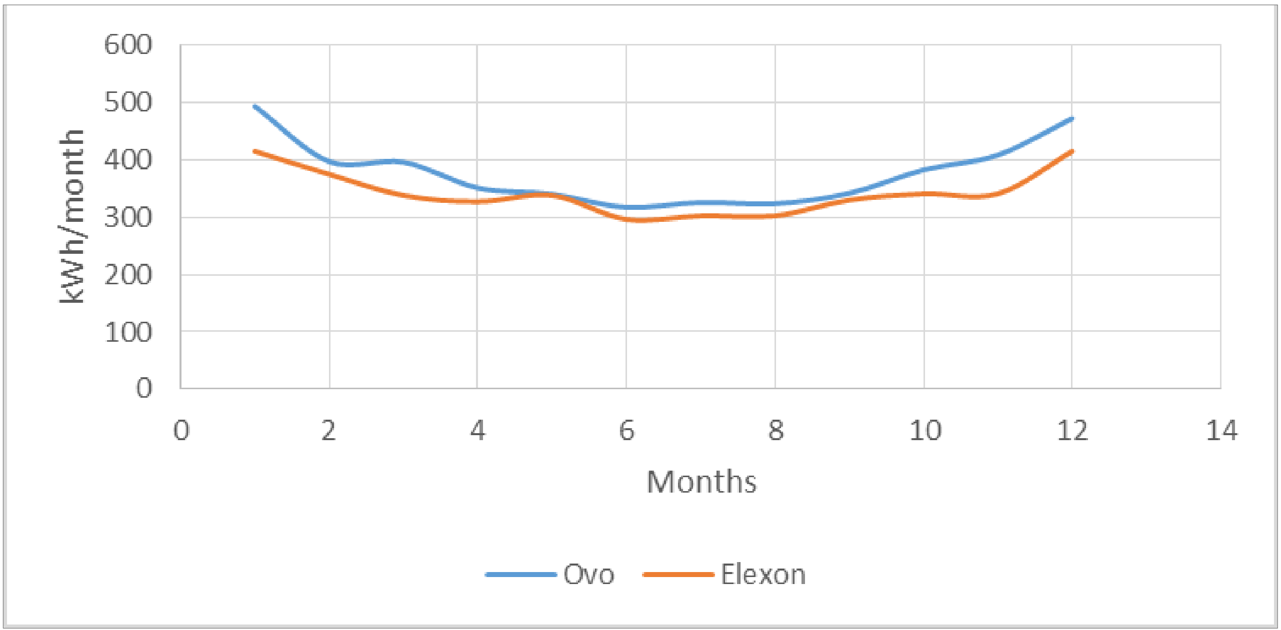

Figure 38 Comparison of monthly average electricity consumption

The total annual consumption figures as modelled by Ovo and Elexon could be compared with the EAC data for Wadebridge and an estimated monthly EAC could be calculated, as shown in table 23.

Table 23 Monthly and annual consumption from different data sets

Modelled monthly and annual consumption (kWh)			
	Ovo	Elexon	Estimated EAC
January	494.2	415.6	409.7
February	397.6	375.4	349.1
March	396.6	338.6	331.2
April	351.7	327.6	306.7
May	340.7	338.6	307.2
June	317.7	296.8	277.4
July	326.4	302.9	284.1
August	324.1	302.9	283.1
September	342.4	330.4	304.0
October	383.1	341.4	326.7
November	409.2	341.4	338.0
December	473.0	415.6	400.6
Total (kWh/yr)	**4556.6**	**4127.3**	**3917.8**

A daily consumption value could also be calculated, for example using the Ovo data, which was the most relevant to the Wadebridge households. As already stated, the Ovo data was provided as an average daily profile (averaged across weekdays and weekends) for each month from May until January. Each of these typical profiles was scaled so that the consumption over the year matched the EAC value of 3918 kWh, split by percentage into the relevant monthly figures.

Table 24 Scaling factors required for scaling the monthly Ovo data to monthly EAC values

	May	June	July	August	Sept	Oct	Nov	Dec	Jan
Ovo - total daily consumption kWh	11.10	10.39	10.35	11.11	11.25	12.38	14.00	14.99	15.97
EAC - total daily consumption kWh	9.40	9.10	9.10	9.00	9.80	10.60	11.70	13.10	13.70
Scaling factor	0.85	0.88	0.88	0.81	0.87	0.86	0.84	0.87	0.86

The scaling factors shown above were applied to each Half-Hour (HH) segment of the Ovo profile to give the same profile shape at a new daily demand (see figure 38).

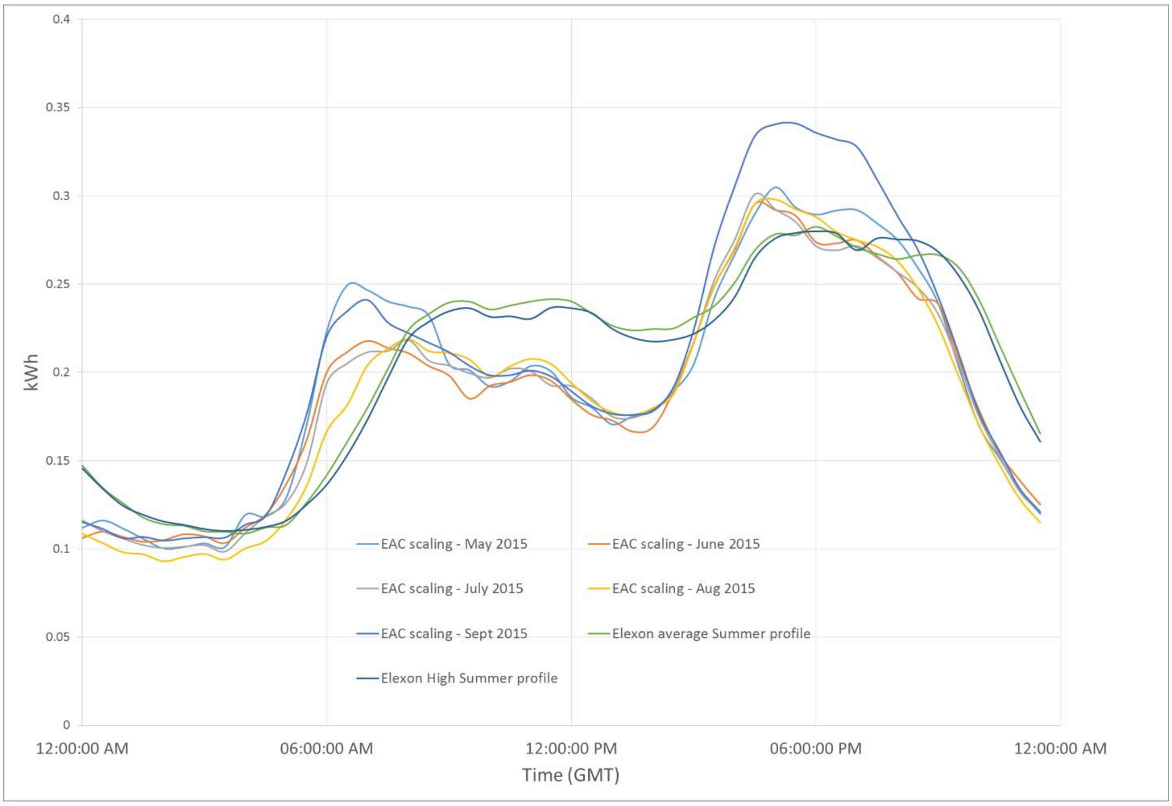

Figure 39 Ovo profiles scaled with EAC and compared to summer and high summer Elexon profiles

To check the above methodology, the resulting plot could be compared to that emerging from the control group.

An aggregated comparative profile would be created for the whole trial population, as well as for each subgroup. This would then be used to compare with actual aggregated demand curves for each group to estimate the shift in demand.

6.2.5 Handling onsite generation and/or storage (including plug-in vehicles)

It was already known that a number of customers participating in the trial has solar PV installations and plug-in vehicles at their properties. The impact of this on the trial was twofold:

- The onsite generation of electricity or use of storage would have an impact on the consumption profile for that customer
- The financial benefit for the customer to switch demand to the middle of the day would be impacted.

As part of the trial recruitment process, each customer was asked if they had any distributed generation (DG) or storage installations on site. As such, customers on the trial that had such equipment could be easily identified in each subgroup, or indeed the control.

Analysis of data from the Household Electricity Usage Study (HEUS)[13] demonstrated what the impact of solar PV had on electricity usage profiles, as illustrated in the figure below.

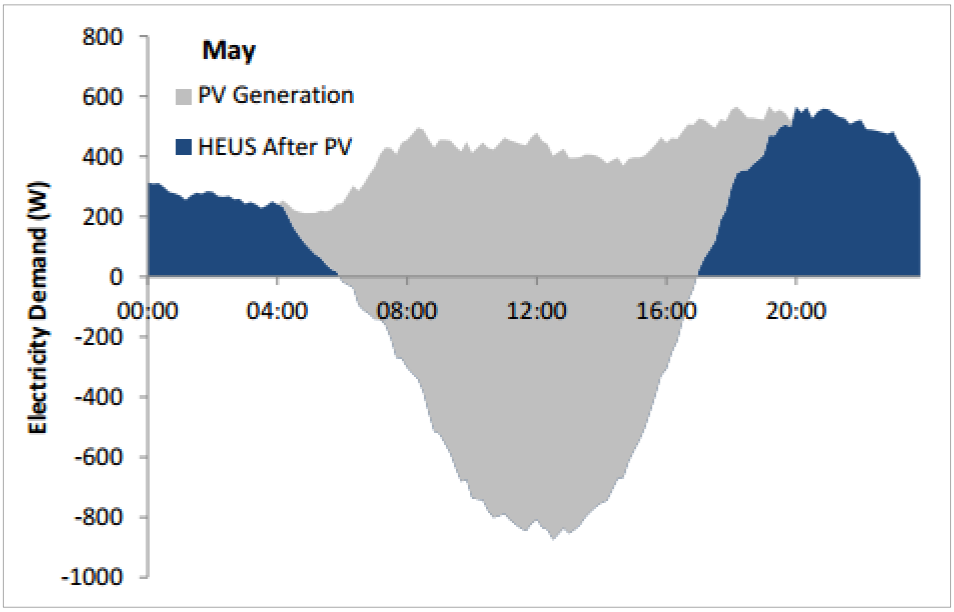

Figure 40 Average diurnal electricity generation of a domestic solar photovoltaic system (3 kW capacity) in May, overlaid on the average HEUS household profile for May

This strongly suggested that households with PV would not be able shift enough demand to the sunshine hours in order to support an offset connection, unless their consumption was high.

Conversely, an EV (or battery) owner would have a greater ability to shift demand into the middle of the day. Figure 40 below illustrates the aggregated average charging patterns for EVs, the peak of which was after 4pm.

[13] Element Energy (2014) Further Analysis of Data from the Household Electricity Usage Study: Correlation of Consumption with Low Carbon Technologies

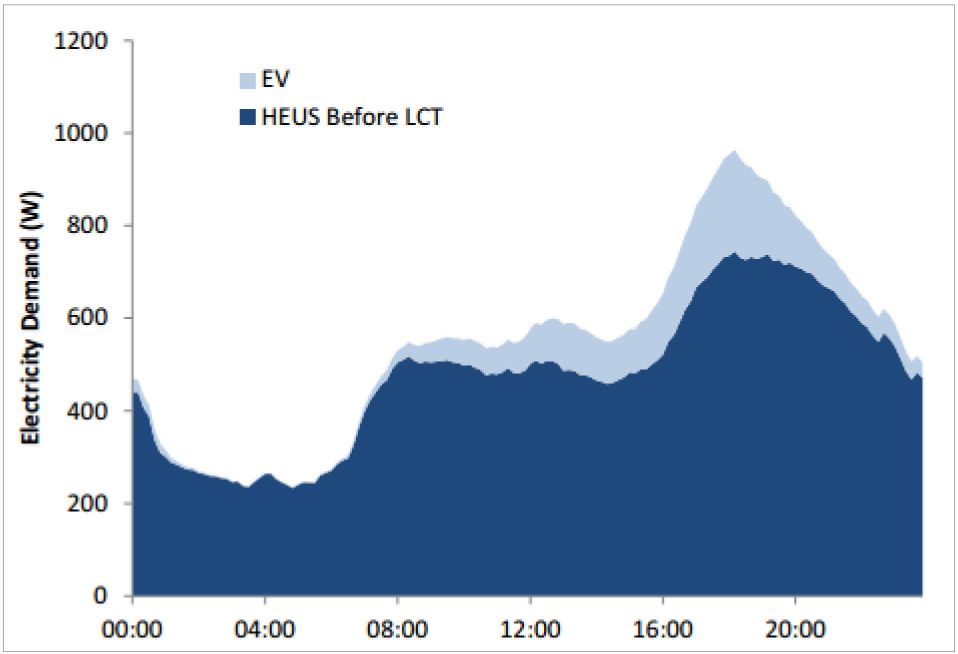

Figure 41 Annual average diurnal electricity demand from an EV overlaid on the average HEUS household profile. The EV profile was for a single vehicle that reflects the aggregated average charging patterns and vehicle types expected in the national EV stock

The significance of DG and storage on the profile would need to be compared between profiles from households both with and without these technologies. In extreme cases, profiles that were clear outliers could be considered separately and excluded from the general analyses.

6.3 Handling instances of unusually high or low consumption

It was also already known that a number of customers signed up to the trial had consumption that was far higher (anecdotal evidence that at least one domestic customer had consumption in the high domestic range, some 7,500 kWh/yr) or far lower (900 kWh/yr) than the UK average of around 4000 kWh/yr. With the small sample size, outliers to this extreme needed to be carefully monitored.

Similar to the method outlined in section 5.5, by plotting each customers' profile in the subgroup, it would be possible to assess the range of profiles being generated and identify outliers. Depending on the overall spread of results in the subgroup, outliers could be investigated further as a separate stream, or excluded from the general analysis.

6.4 Confidence levels associated with the comparative profile

It was suggested in the 'Sunshine Tariff feasibility study' that a sample size of 240 out of a total population of 26,700,000 households would give us a confidence interval of 6.33. This meant that if there was a demand shift in 50% of the sample of 240, we could be 95% confident that between 43.66% and 56.33% of the whole population would exhibit the same shift.

Table 25 Confidence intervals according to potential sample size (excluding control group[14])

Sample Size	50	75	100	150	200	240
Population	26,700,000	26,700,000	26,700,000	26,700,000	26,700,000	26,700,000
Confidence interval	13.86	11.32	9.8	8	6.93	6.33

Confidence level: 95%, Percentage: 50%[15]

By comparison, a sample size of just 100 would mean that we could be 95% confident that the whole population would lie within a range of 19.6% of whatever result the sample gave us. For the purposes of this trial, an example would be:

> **Out of a sample size of 100, 50% of the sample managed to shift 10% of their demand. At a 95% confidence level, this would indicate that for the entire UK population of residential households, (26,700,000), we could be 95% confident that between 40.2% and 59.8% would achieve this 10% shift.**

The project partners proposed that a sample size of 100 (plus the control of 25), would give results that had a reasonable degree of confidence, provided this was taken into account when forming conclusions and recommendations. However, the sample size dropped below 100, so the confidence interval in the outcomes became wider, making it harder to draw robust conclusions.

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[14] The control group would not receive any interventions, so should not be included in any statistical analysis of the active sample

[15] NOTE: the 'Percentage: 50%' term simply indicates that it is 50/50 whether any one participant shows a shift in demand. If 99% of participants showed a demand shift, the chances for error are small regardless of sample size. If the percentages are 51% and 49% the chances of error are much greater.

6.5 Conclusions

There was significant learning to be gained from delivering and monitoring the Sunshine Tariff, in both quantitative and qualitative form. Despite the challenges in establishing a *measured* baseline of data from trial participants, the methodology outlined in this appendix would enable robust analysis of the data generated by the trial. By combining analysis of the control group, trial data and comparative profiles, it would be possible to assess the relative success of different interventions, and the impact of the trial as a whole.

The sample sizes had a significant bearing on exactly what conclusions could be reached from quantitative analysis alone, and the small sample size meant a lower level of confidence. However, even with small sample sizes, there was learning that could be gleaned regarding participant attitudes to energy and their responses to interventions. This could be achieved by looking in more detail at individual profiles over time and discussions with customers.

The methodology outlined here constitutes the basis for analysing the quantitative data produced by the Sunshine Tariff. However, the methodology should be flexible so that if the emerging data does not fit with the assumptions made here, then changes could be made. In particular, the impact of distributed generation and electric vehicles were likely to have a significant impact on individual profiles, but until it became clear how many participants had this equipment, it was not possible to ascertain the impact on profiles on aggregate.

It was proposed that the initial comparative profile was:

- Based on the Ovo, Cornwall smart data profile shape (combined average across weekdays and weekends)
- Scaled to the EAC for Wadebridge
- Displayed as a different profile for each of the trial months (April – September)
- Adapted for trial customers that have PV arrays and electric vehicles.