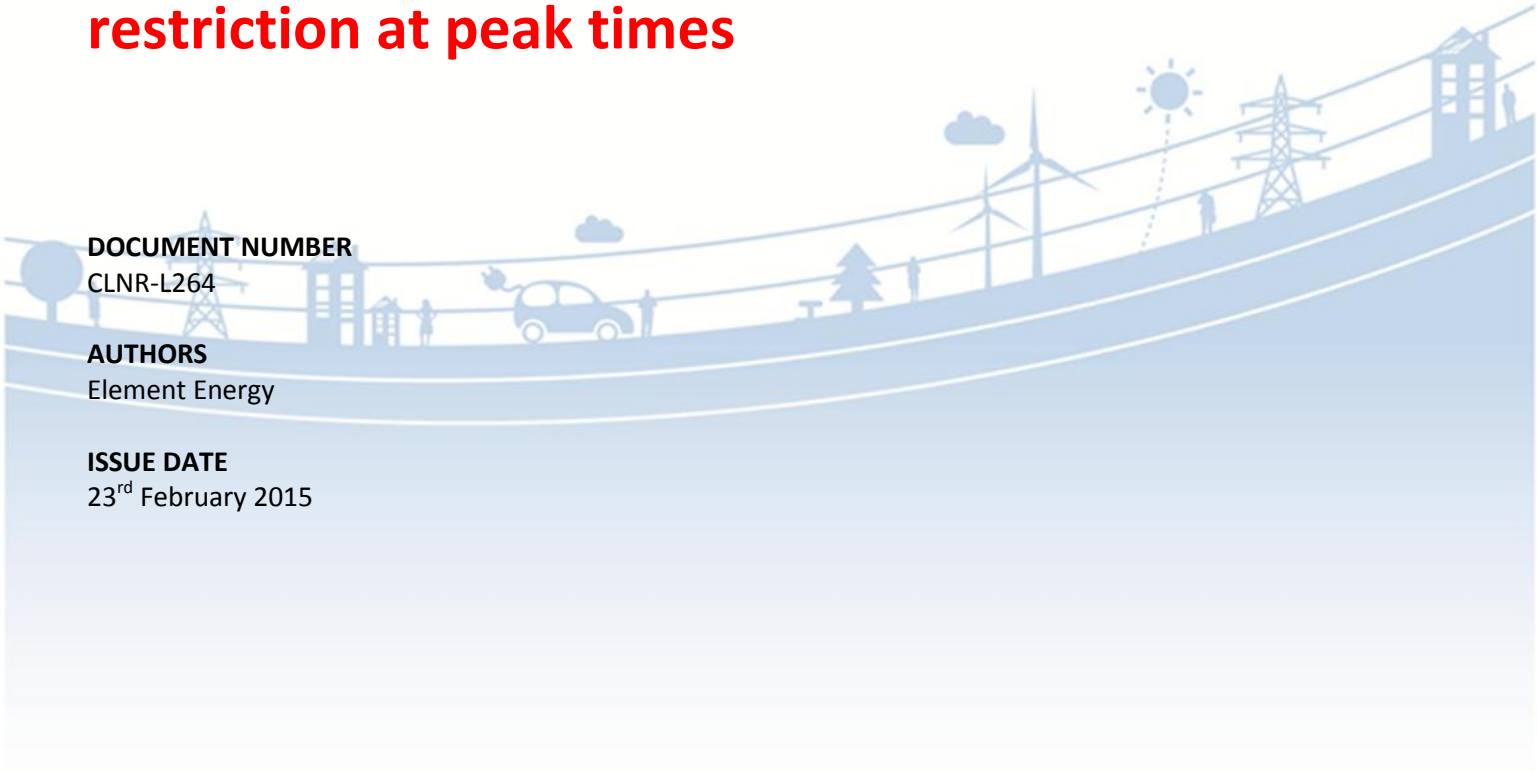
Customer-Led Network Revolution

Insight Report:
Shifting domestic demand through appliance restriction at peak times



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Executive Summary

As the deployment of non-dispatchable forms of energy generation increases and existing electricity network assets approach their rated capabilities, it is increasingly important to understand to what extent it is possible to shift electricity demand away from the times of greatest network stress. As part of the Customer Led Network Revolution project, several low carbon technologies and pricing structures were trialled for this purpose.

This report considers two test cells which explored restricting the use of devices during peak consumption hours. In test cell (TC) 10a (wet white goods - WWG), customers were provided with a smart washing machine, set to a default which restricted operation during weekday evening peak hours, and with a time of use tariff which penalises consumption during those hours. The customer could override the default setting if necessary. In TC12 customers were provided with heat pumps and were also on a time of use tariff.

For the wet white goods test cell, the tariff and restricted hours operation appears to have been successful, indicating that laundry (and therefore potentially other wet white good activities such as dishwashing) is a load which can be shifted in time using a tariff. This is supported by the following:

- Compared to the baseline domestic customer in TC 2a, on weekdays customers in TC10a show a wet white appliance demand which is higher in the mornings and lower in the 4-8pm peak-pricing period. This indicates that customers may be planning their energy consumption in advance of the peak.
- For TC10a there is evidence of increased consumption on weekdays from 9pm (just after the end of the peak tariff period). This suggests customers are, on average, delaying use of the washing machine until after peak hours.
- For TC10a wet white good demand was highest during weekends, coinciding with the cheapest period of the time of use tariff.

Although the “restricted hours” function of the smart washing machine could be manually overridden, the fact that this step had to be taken to operate the device during peak hours may have served as a persistent reminder of the pricing arrangement, constantly supporting the effect of the ToU tariff.

Regarding the heat pumps, for TC12 there is little change between weekdays and weekends and no evident reduction in consumption during peak hours in response to the ToU tariff. However, there is a peak in demand just before the 4-8pm peak period, which could indicate the system preparing or charging up in advance of the peak hours. There are a number of factors which could have contributed to the more limited impact seen with heat pumps, compared with washing. Space and water heating are considered to be less flexible than other loads – this is likely to be the case especially in the cases where there is no heat store. Also the trial customers were advised to not interfere with the settings of the heat pump, but rather choose an adequate temperature and leave the controls alone. The results suggest that customers may have followed this advice, potentially

missing out on the opportunity to save on heating when it was not required. Contrasting this with the daily “over-ride” requirement for use of the washing machine indicates that a ToU tariff may be significantly more effective when paired with a regular reminder of its impact.

1 Trial Overview

1.1 Description

This report details the analysis of the impact of different tariffs and low carbon technologies on domestic customers' ability to shift electrical demand throughout the day and comprises of the following test cells (TCs):

- **TC10a (WWG)** looks at 78 customers[1] who were provided with a "smart washing machine" with restricted operation hours. On the default setting the machine does not work between 4-8pm (the "restricted hours"), although customers are able to override this setting. In addition, these customers were put on a Time of Use (ToU) tariff (See 2.2 below), meaning that electrical demand during the 4-8pm period is charged at a premium.
- **TC12** looks at 5 customers[2] with air source heat pumps (ASHPs) who were also placed on a ToU tariff.

Where relevant, the following will be used as baseline groups to compare the results against:

- **TC1a** ("Basic profiling of domestic smart meter customers" – whole-house demand data for households with no new tariffs or low carbon technologies)
- **TC2a** ("Enhanced profiling of domestic smart meter customers" - separate demand data for different appliance types as well as for the overall household, for households with no new tariffs or low carbon technologies)
- **TC3** ("Enhanced profiling of domestic customers with air source heat pumps" – heat pump demand data for households with no tariff change)
- **TC14** ("Domestic customers with air source heat pumps on direct control trials" – heat pump demand data for households with no tariff change, where the DNO had direct control capability over the heat pumps)

1.2 Purpose

These trials were designed to support Learning Outcomes 1 and 2. Specifically, they provide the data needed to understand:

- Customers' patterns of electricity consumption;
- Whether a ToU tariff can shift electricity consumption for heating from an ASHP away to different times of the day
- Whether a ToU tariff in combination with a restricted-hours washing machine can shift electricity consumption to different times of the day

[1] Averaging 40 at any given time from April 2013 to March 2014. There were over 120 customers with unique IDs who participated in the trial but a lower number had consistently good data over an acceptable time period.
[2] Averaging 4.84 at any given time from January to December 2013

2 Trial Design

2.1 Participation and recruitment

For each of the test cells considered, participants were offered a subsidy of £50-worth of vouchers on joining the trial, and a further £50-worth of vouchers at the end of the trial. All the equipment installed for the purposes of the trial (see section 2.2) was provided free of charge, with the exception of the heat pump installation, which was part-subsidised via a DECC grant.

Recruitment to the TC12 (heat pumps) trial was slow and fell short of the target [1]. Contributing factors included: requirements for participants to be British Gas customers; to agree to a ToU tariff; and cover part of the heat pump cost.

However, TC10a WWG recruitment did approach its target, partly due to the comparative ease of installation and willingness of customers to take on a smart washing machine provided for free.

2.2 Equipment and tariff

For both test cells, where not already present, the following equipment was installed:

- **Mains isolation switch** to allow isolation of mains power and safe installation of the secondary meter;
- **Metering:** a secondary meter on the mains electrical supply to monitor energy consumption;
- **Communications:** a hub was installed to collect the metering data.

Additionally:

- For TC10a a smart washing machine – which would not work between 4-8pm unless the restriction was manually overridden – and the communications link to control it were installed free of charge
- For TC12, air source heat pumps were partially funded via a DECC grant, with the balance paid by the householder or the social housing provider.

For both test cells, the customers' tariff was changed to a ToU tariff with the following bands:

Time period	ToU price
Weekdays 7am - 4pm (daytime)	4% below standard price
Weekdays 4pm – 8pm (peak time)	99% above standard price
Weekdays 8pm – 7am and weekends (off-peak)	31% below standard price

3 Trial Results

3.1 Data available

Both test cells have a very high availability of valid data. For a full year of monitoring:

- **TC10a:** on average, each month has 28 days of good data (see Table A1 in appendix for full figures).
- **TC12:** on average, each month has 29 days of good data (see Table A2 in appendix for full figures).

3.2 Annual average daily load profiles

Figure 1 shows the annual average daily heat pump load profile for TC12. This is dominated by a peak at 4am averaging 1kW, which is of the same order of magnitude as a household average electricity consumption. Except for this early morning peak, the heat pump demand is higher during the daytime than at night. Despite the limited number of users, the shape of the mean, minimum and maximum profiles is fairly consistent.

Figure 2 shows the annual average daily demand profile for the smart washing machines in TC10a. The main demand peak is around 10-11am, which does not coincide with the times of greatest network stress. There is a secondary peak towards 9pm, just after the end of the restricted (and peak tariff) period. Although the peak consumption of individual devices is around 2kW, the use of the washing machines has a high diversity, which explains the comparatively low average demand values.

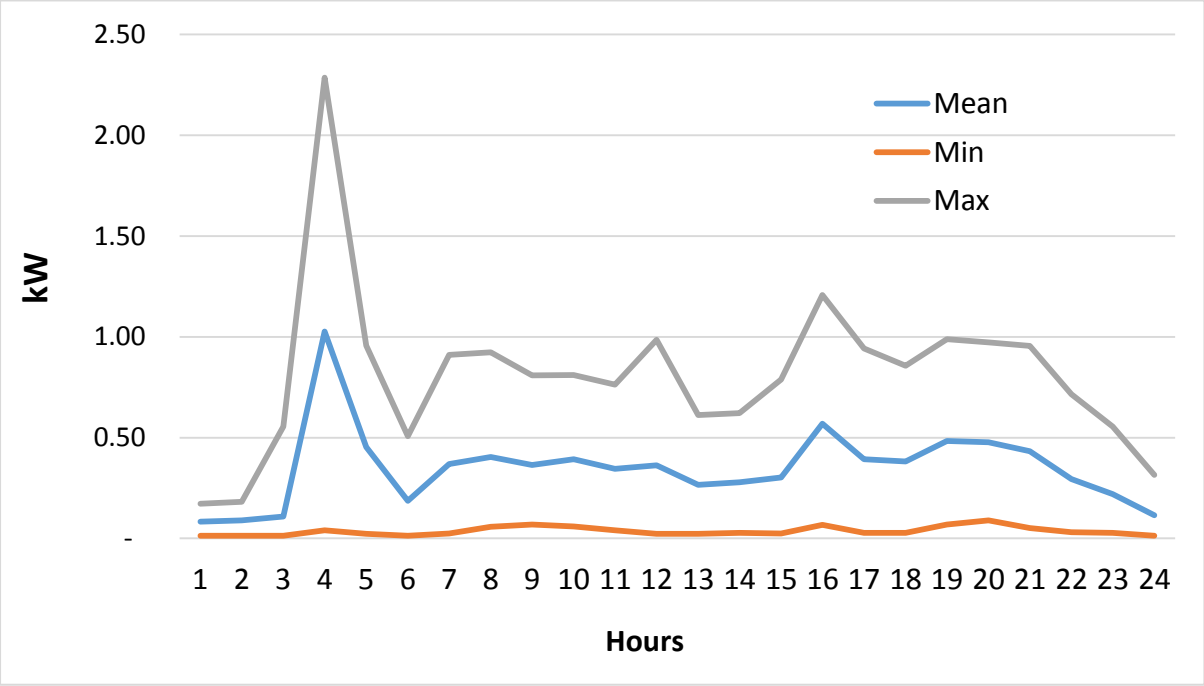

Figure 1: TC12 Heat Pump consumption (kW) – annual average across all customers.

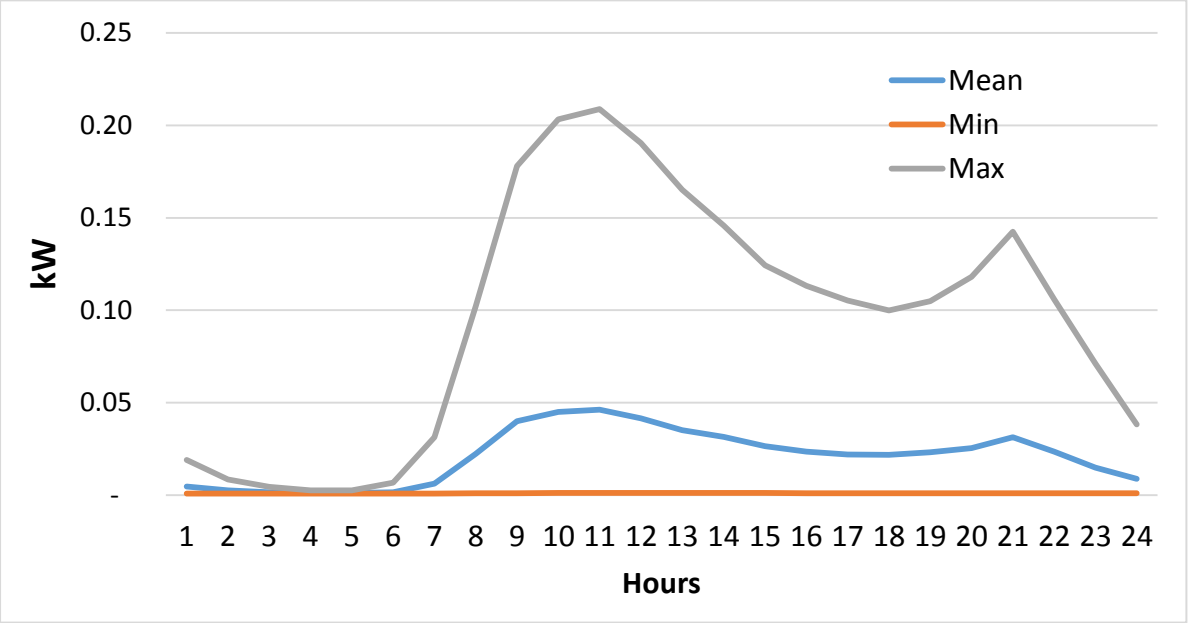

Figure 2: TC10a WWG consumption (kW) – annual average across all customers

3.3 Day of the week

Figure 3 shows that the average daily heat pump demand profiles are very similar for weekdays and weekends. There is a slightly higher evening consumption on weekdays which is not consistent with the ToU tariff incentive to reduce demand during this period, although the difference is small not statistically significant. Participants of the trial were advised to select a temperature they were comfortable with and then not change the heat pump settings, and the lack of significant differences between the weekday and weekend profiles suggests that participants mostly followed these instructions.

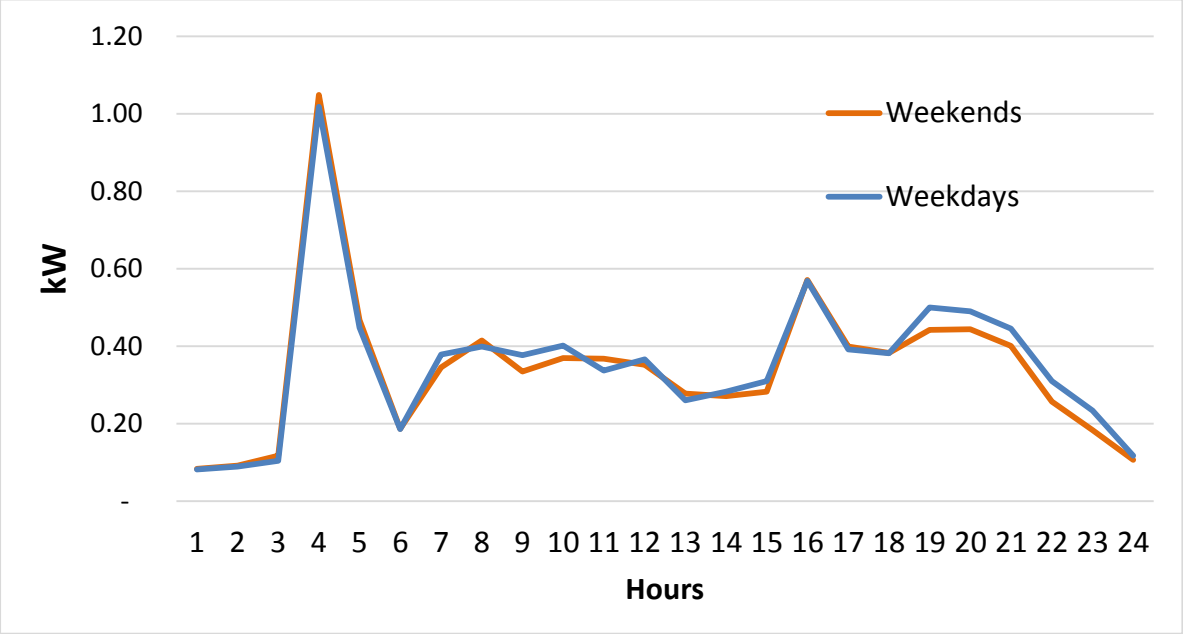

Figure 3: TC12 heat pump consumption - split by day of week

Turning to TC10a, Figure 4 shows that the demand profile for the restricted hours wet white goods varies significantly between weekdays and weekends.

Looking at the 4-8pm period, consumption is higher during weekends, which is consistent with the peak pricing and restricted hours during weekday evenings. On weekends, average WWG consumption continues to decrease after 8pm, whereas on weekdays a secondary peak is seen at 9pm, just after the end of the restricted period.

During the daytime, a higher consumption is seen on weekends, which may be explained by a higher household occupancy coinciding with the cheapest tariff, and the ability to save up washing until the weekend. The peak demand occurs around midday on weekends, and is almost twice as large as the weekday peak, which occurs at 9am (and is therefore outside the peak hours).

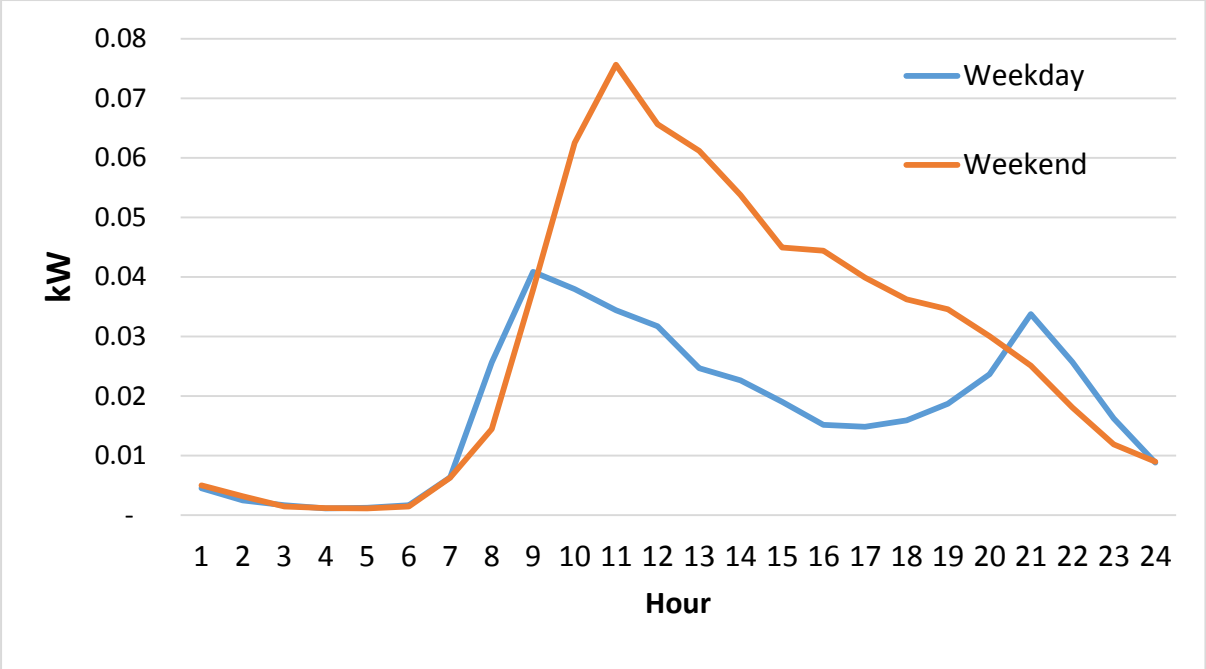

Figure 4: TC10a WWG consumption - split by time of the week

3.4 Time of the year

Figure 5 shows the daily heat pump demand profiles for TC12 averaged for each month. As may be expected, consumption is lower in the summer months, when the heating requirement is lowest. Three distinct categories are apparent: November to March (the colder months), July and August (high summer, with near-zero consumption for some of the day), and mid-season.

All months show a peak around 4pm, just at the start of the peak tariff period, which could indicate an attempt to store up heat and avoid or reduce demand during the peak period. However during the winter months, demand peaks around 7-8pm, suggesting the stored heat is not sufficient to maintain the required temperature.

Throughout the year, the 4am peak is still present, although it reduces significantly in the summer months.

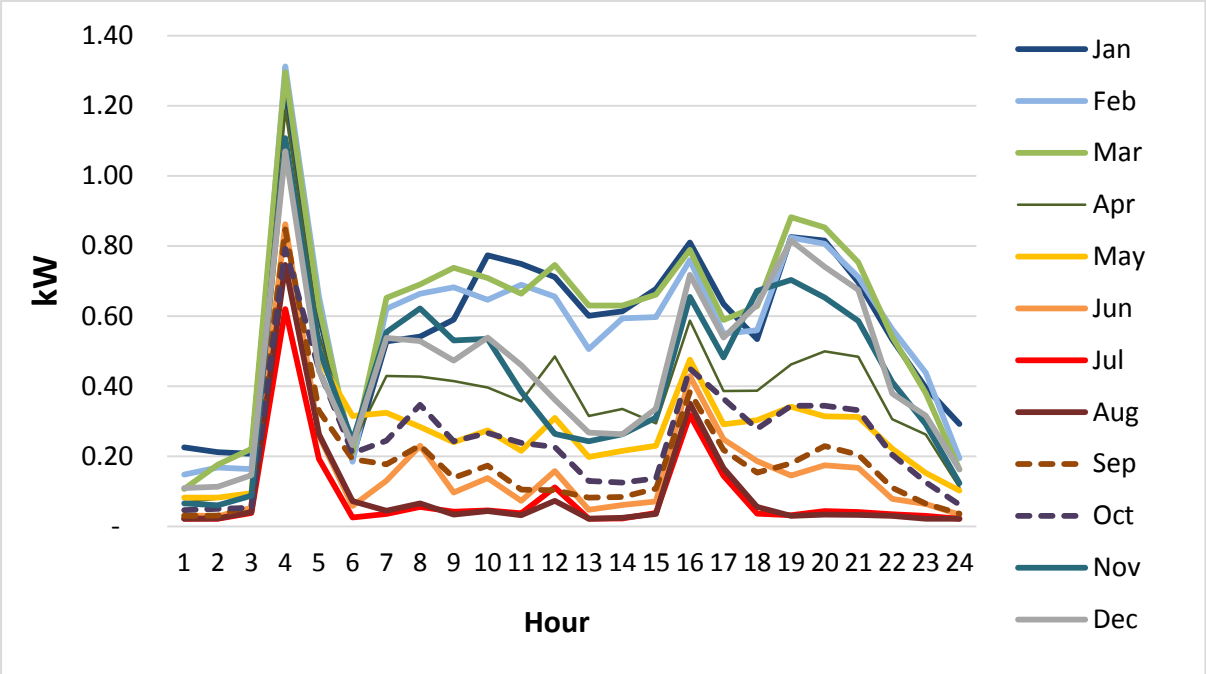

Figure 4: TC12 Heat pump consumption, averaged for each month

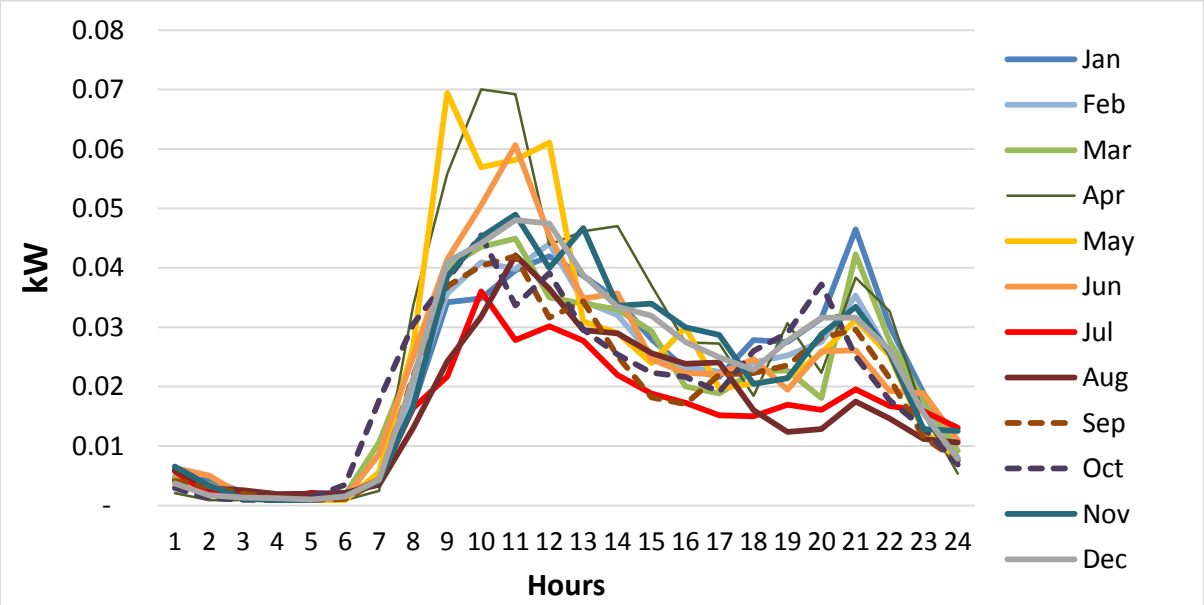

Figure 5: TC10a WWG consumption, averaged for each month

Figure 6 shows WWG daily demand profiles for TC10a averaged for each month. In this case there is no clear seasonal variation, with April to June seeming to have the highest peak consumption around 10-11am.

This lack of seasonal variation is consistent with the fact that frequency or requirement for washing is not so closely related to time of the year.

3.5 Demand peaks and effect of interventions

3.5.1 TC12 (Air source heat pumps with ToU tariff)

From a network perspective, the 4am heat pump demand peak visible in both TC12 and TC3 (baseline heat pump test cell) might be a cause for concern, creating a substantial new peak at a time when this was not expected. However, it is reasonable to suggest this peak arises from an installation setting of the batch of heat pumps used in the trial, and is not inherent to heat pumps per se. In practice, even a pre-heating setting such as this would, under widespread deployment, be expected to be more diversified.

Focussing on the evening periods, TC12 shows a secondary peak at 4pm which is not visible in TC3 or TC14, which suggests a heat pump pre-heat setting in advance of the 4-8pm peak pricing period. Finally, there is a third peak around 7-8pm in winter months (apparent in both TC12 and TC3), which suggests a need for continued heating despite the ToU tariff.

Comparing against TC3 to understand the impact of the ToU tariff (Figure 6), there is no apparent reduction in overall demand between 4-8pm which would suggest a response to the ToU tariff.

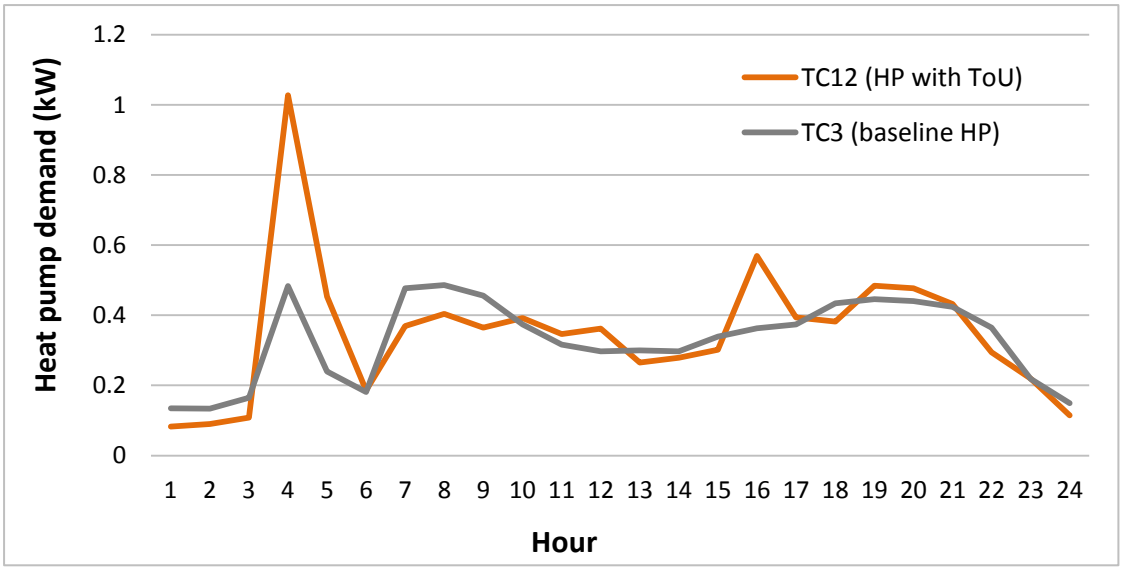

Figure 6: Annual average heat pump demand profiles for TC12 and TC3

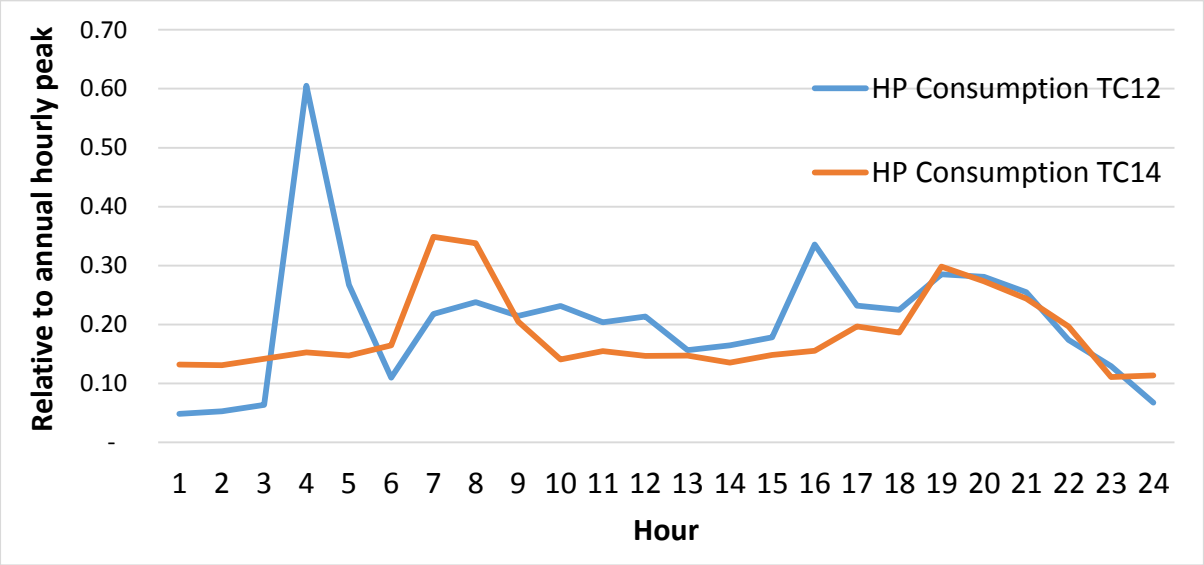

Figure 7: Heat pump consumption comparison between TC12 and TC14; annual average profiles

Figure 7 compares normalised heat pump demand profiles for TC12 (ToU tariff) and TC14 (direct control). Normalised profiles are used as TC12 has only 48% of the annual demand and 43% of peak consumption compared to TC14. This is due to the increased size of the heat pump device in TC14 which also carried a thermal store operated during direct control interruptions. Normalising involves dividing the hourly average consumption by the peak average hourly consumption recorded in each test cell

TC14 does not have 4pm or 4am peak, which is most likely due to the larger device with greater storage smoothing out the load across the day. Instead, the peak in TC14 happens around 7-8 am, mainly down to the installation settings of the heat pump.

From comparing the shapes of the curves alone, no demand reduction in the 4-8pm period due to ToU tariff (which could be attributed to the effect of a Time of Use tariff) is statistically significant.

3.5.2 TC10a (WWG)

The impact of the ToU tariff and restricted hours setting on wet white goods demand in TC10a is show in Figure 8, which compares against wet white goods demand in TC2a, (baseline enhanced profiling of domestic customers). On weekdays, TC10 (restricted hours and ToU) shows a lower demand during the peak 4-8pm period and a higher peak earlier in the day (around 9-10am, away from the peak pricing time and the period of greatest network stress).

For TC10a, there is a steep increase in demand between 8pm and 9pm, which may indicate a “saving up” of laundry until just after the end of the peak period with the after 8pm payback occurring at 9pm

The devices were used once every two days on average, supporting the idea that there is some scope for moving the demand around.

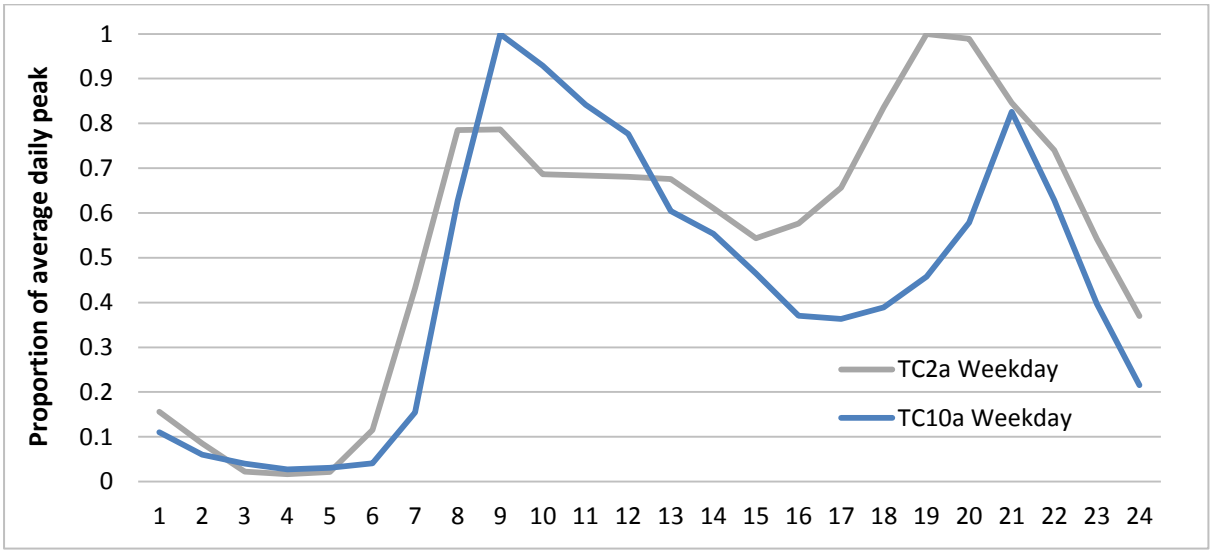

Figure 8: Normalised average annual weekday wet white goods demand profile - TC2a vs TC10a

4 Conclusions

For wet white goods, restricted hours and a ToU tariff are observed to have a noticeable and beneficial impact on the consumption profile. Some conclusions arising from this are:

- Relative to the control test cell, washing occurred more outside times of peak loads, indicating that the default was effective in restricting use at these times. Also, the over-ride feature – while permitting use at peak times – may in fact have served as a continuous reminder of the ToU pricing arrangement and so contributed to a reduced use in peak times
- A certain amount of demand flexibility is inherent in laundry. By extension this may apply to similar processes such as dishwashing and tumble dryers.
- The combined effect of the ToU tariff and restricted hours is especially visible comparing the weekday daily profiles against the TC2a WWG baseline. For TC10 the highest peak is in the morning period (compared to in the evening period for TC2a) and a “spike” in demand is seen after the end of the peak time tariff rate (which is not visible in TC2a).

For heat pumps, the ToU tariff is not seen to have a significant effect on HP use. Contributing factors include:

- People may be less familiar with operation of heat pumps than conventional heating, and so are less confident about adjusting their heating system to maximise savings. For this particular set of trials, customers were advised to choose a temperature they were comfortable with and then not touch the heat pump controls. The results suggest that on average customers followed this advice, but this also meant a lower ability to react to the ToU tariff.
- Unlike washing, which is carried out more occasionally, space and water heating are usually considered to be less flexible: they are required more frequently and in response to ambient temperatures. There is therefore less of a scope for shifting heating demand to other times, particularly in the absence of a heat store.

5 References

[1] **CLNR-L036** "Project Lessons Learned from Trial Recruitment", Rebekah Phillips et al, July 2013

[2] **CLNR Residential Propositions,** British Gas, February 2013

[3] **DEI-CLNR-DC027** "Technical Note: Test Cell 20 Trial Design Note", Pádraig Lyons, September 2011

6 Appendix: Data tables

Table A1: Data availability for TC10a (WWG)

	Days with good consumer data	Weekdays with good consumer data	Weekend days with good consumer data
Jan 2014	29	23	6
Feb2014	25	18	7
Mar 2014	29	20	9
Apr 2013	29	21	8
May 2013	31	23	8
Jun 2013	27	17	10
Jul 2013	27	19	8
Aug 2013	31	22	9
Sep 2013	30	21	9
Oct 2013	31	23	8
Nov 2013	21	14	7
Dec 2013	31	22	9

Table A2: Data availability for TC12

	Days with good consumer data	Weekdays with good consumer data	Weekend days with good consumer data
Jan 2013	31	23	8
Feb 2013	28	20	8
Mar 2013	31	21	10
Apr 2013	30	22	8
May 2013	31	23	8
Jun 2013	30	20	10
Jul 2013	31	23	8
Aug 2013	15	11	4
Sep 2013	30	21	9
Oct 2013	30	22	8
Nov 2013	30	21	9
Dec 2013	31	22	9