How to make efficient use of kettles: Understanding usage patterns

David Murray, Jing Liao, Lina Stankovic, Vladimir Stankovic

Department of Electronic and Electrical Engineering, Faculty of Engineering, University of Strathclyde, Glasgow, UK

Abstract

According to a survey by the Energy Savings Trust three-quarters of UK households overfill their kettle, wasting GBP68 million per year. This paper focuses on patterns of behaviour with respect to kettle use and how these could be influenced by providing feedback to make kettle usage more efficient. Firstly, we study how kettles are used across 14 UK households for a two-year period, which allows analysis of seasonal patterns as well as changes due to the holiday season. We also examine usage patterns based on the type of occupant and how their daily routines affect usage. Secondly, a case study is described where a standard kettle has been replaced with an 'eco' kettle during the monitoring period, which allows to analyse if energy consumption has been reduced due to using a more energy efficient kettle. We look at the usage patterns and investigate potential change in behaviour that has occurred since the switch. Our main findings based on monitoring diverse UK homes with a range of kettles, is that the total consumption is less dependent on the type of kettle used, and more dependent on the established household usage patterns and habits. We also show, through our case study, that usage of kettles can be improved by optimising usage patterns to best utilise the type of kettle.

1 Introduction

The roll out of smart energy meters in UK homes is set to begin in 2015 and is planned to be completed by 2020 [1][2]. The goal is to increase the energy efficiency of UK homes by promoting behavioural changes and providing appliance retrofit advice via data supplied from smart meters. Through the feedback that smart meters are able to provide we can aim to educate the consumer about their appliance usage and promote energy positive behaviours.

In this paper, using the data gathered from a two-year field study, we look at the electric kettle, identify patterns of usage, analyse consumption, predict consumption via suitable models and show how kettles could be used more efficiently. The kettle is one of the most (inefficiently) used appliances in the UK as well as the appliance with the highest rates of ownership (according to UK's Department for Environment, Food and Rural Affairs' 2008 report [3] 97% of UK households possessed a kettle). In a survey of 86,000 homes in the UK, by the Energy Saving Trust, it was found that three-quarters of British households admit to overfill their kettle when boiling water and are subsequently wasting £68 million each year. More than nine in ten people (95%) use the kettle every day, with 40% doing this five times a day or more [4].

Kettle is also the main cause of the so-called TV pickup effect, that manifests itself in significant and synchronised usage of appliances during TV programmes' breaks. This is especially a problem in the UK where individual programmes often attract massive audience, and householders use commercial breaks for boiling water and opening of refrigerator door.

Many empirical studies of consumers' attitudes and interactions with energy-consuming appliances have been reported recently [5][6]. Interestingly, despite the fact that kettle usage patterns significantly affect energy consumption, the consumer behaviour with respect to the usage of kettle has not been in the research focus so far. Previous research into the energy consumption of the kettle [7] details the monitoring of energy consumption of the appliance and the different mathematical tools which can be used to model the relationships between consumed power, water volume and temperature during kettle's operation. We build on [**Error! Bookmark not defined.**], but while [**Error! Bookmark not defined.**] focuses on a single kettle, we study a large sample size, analyse how different households use their kettles, and develop and validate generic mathematical models.

In particular, we study the usage patterns of kettle in 14 UK homes over a two-year period. This was enabled by measuring only the timestamped kettle power consumption via a plug monitor that

measures active power every 6-8 sec. The monitored houses are of different occupancy and age groups (e.g., retirees, working couples, families with children and single occupants) and possess different types of kettle. These households were chosen with a mix of technical and non-technical backgrounds, and were fitted with energy monitoring equipment (gas, electricity for up to 9 individual appliances), environmental sensors and smart home kit to automate/pre-schedule appliance and heating use. Our analysis shows that kettle usage patterns are semi-regular with clear peak times (morning, evening around dinner) and sporadic usage otherwise during the day. Usage patterns are correlated to working patterns, family size, and age group: working couples will likely have no or only few uses between the hours of 9am and 5pm, while retired couples would have more sporadic usage of kettle.

Since we measure only the energy consumption of the kettle, we also develop mathematical models to predict water volume and temperature in the kettle, based on measured energy consumption. We show the difference between 'smart' / 'eco' and 'dumb' kettles and whether they represent a sound investment in money and environmental friendliness. A 'dumb' kettle is defined as a kettle that boils water to 100°C with no additional 'boil' temperatures and no 'keep warm' or additional functionalities. The case study of the household with the 'eco' kettle also discusses householder's reaction to feedback on their relative energy consumption before and after the introduction of their 'eco' kettle.

The paper is organized as follows. Section 2 reviews the current state of the art on kettle efficiency, design, usage patterns research and feedback design mechanisms. Section 3 describes our methodology. Sections 4 describes our models and results of our analysis. Section 5 discusses a case study involving 'smart' kettles.

2 Background

Kettle design has remained fairly static for many years. This is partly due to the heating element contained in many kettles being as optimised as it can be within reasonable limits. Heating efficiency of the element itself is 100% as the energy supplied is completely converted to heat. However, most kettles are around 80-90% efficient (efficiency is decreased due to heat dissipation and transference to the body of the kettle).

Recently, the market for household appliances has been evolving; suppliers are beginning to term their appliances "smart" in order to entice customers. These appliances usually come equipped with additional quality of life improvements, quicker operation, more preprogramed settings, etc. This has not, however, affected the main body of the kettle and is often located on the baseplate that is used in wireless kettles.

Kettle design has also trended towards producing larger kettles in terms of volume. For example, modern kettles are holding upwards of 1.5 litres, and in some cases, as much as 2 litres which can lead to even more water being wasted by those who habitually overfill. Kettle design partly has a role to play on overfilling: many kettles feature volume indicators; these usually start at the 2 cup level (500ml) as a minimum fill so that there is enough water to cover the element in the increased base area. A person planning to make one cup of tea is effectively wasting at least 50% of the energy required straight away if they follow the filling guide.

Kettles in general have a power rating of 2200-3000 Watts (W). Kettles marketed as "Eco" generally tend to have a lower rated power band (1350 W) but feature a more insulated thermos style design which is intended to keep water hot enough to make another cup or to reduce the amount of reheating required. One such kettle is the Vektra which is a highly insulated thermos styled kettle, meant to provide saving of up to 55% which would make it an ideal candidate to replace a standard kettle [8][9].

Kettles are also not subject to any efficiency labelling guidelines; this means that the consumer may not understand that a lower rated kettle will take much longer to boil than a high rated one but consume the same amount of power. This time distinction however might help encourage energy efficient behaviour as the occupant is aware that the kettle will take much longer to boil if it is over filled. However, a study showed that 86% of people do not choose kettles based on their features but on looks to match a kitchen design/already owned products [10].

Behaviour in regards to filling is something that is simple to change - if the householder first fills the cup they intend to use they are able to minimise any loss through over filling. Analysing people's

behaviour may show that people already have developed good usage habits in which case providing kettle retrofit information may be more beneficial in helping to save energy. Variable temperature kettles provide multiple options: in some cases boiled water may not always be the most efficient option or result in the best tasting drink. Many speciality teas and coffee's recommend temperature ranging from 70 degrees up to 95 degrees (ideal to stop coffee burning). These temperatures represent a reasonable saving especially over the course of a year. Finally, a change to a kettle with a lower minimum fill level may be the best course of action for single occupant households or those with few users. It would also benefit a household where people are actively aware of their energy footprint which makes a kettle, where they can easily see and dictate the water level ideal.

3 Methodology

Since our sensor measures only consumed energy, it is necessary to infer water volume and temperature to provide feedback on possible energy waste. In this section we present the proposed mathematical modelling method whose goal is to infer the amount of water the kettle was filled with only from the total power consumed and the time taken to heat the water from the average UK autumn/winter/spring tap water temperature (8-12°C) to boiling point. The model comprises two parameters, water temperature and water volume, and hence can also be used for summer data when tap water temperatures are above 15°C (typical in the summer). The model is also used to infer if the kettle water has been re-boiled taking into account the duration between boils and the power consumption.

3.1 Mathematical Modelling

Since we cannot directly measure volume of water in the monitored houses, we develop a mathematical model to estimate the level of water in the kettle based on the measured power. Our modelling work is based on a training dataset generated using exhaustive lab experiments which consist of recording kettles' energy consumption and time duration for different water volume levels and starting/stopping water temperature.

Using three different types of kettle: 'smart', 'eco' and traditional, 'dumb' kettle (which is representative of the majority of the UK market), we carried out 84 experiments collecting data for training and 10 experiments to validate the model for each type of kettle. The experiments studied the relationship among 5 features: time duration, starting water temperature, stopping water temperature, water volume, and power consumption.

Our experimental results obtained by filling the kettle with different volumes of water and stopping the kettle once a particular temperature is reached, averaged over three experimental kettles, are shown in Fig.1. While the starting temperature of the water may not seem important since water is rarely heated from above 30°C degrees, analysing this feature, together with the other features, help determine which model is the most suitable.

It can be seen from Fig. 1(a) that the relationship between the starting water temperature and the consumed power is nearly linear. A similar, close-to-linear, relationship holds between the time duration and the initial water temperature and consumed power (see Figs. 1(b), (c), and (d)). Based on these, we decide to use linear methods to build the model.

In the previous work [**Error! Bookmark not defined.**], we compared three linear methods - polynomial linear [11] (high error), locally weighted linear regression [12] (largest range prediction), and the linear interpolation [13] (limited range) method. The results from [7] indicate that the model with locally weighted linear regression gives the best estimate although linear interpolation has the best accuracy but has a limited range.

Fig. 2 shows the kettle model generated by the weighted linear regression method and the residual error analysis with the x-axis denoting the starting water temperature, y-axis the water volume and z-axis the consumed power. In this model, active power is considered as a hyper-layer and is not shown in the figure. The dots on the left hand plot represent collected data, while the coloured surface is the kettle model.
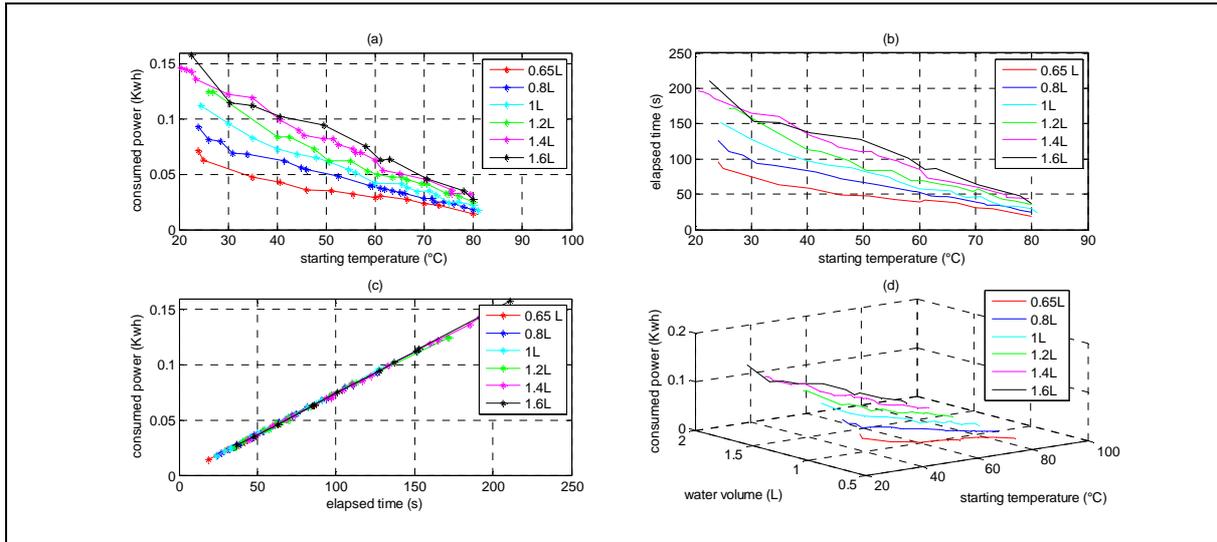
Figure 1: Measured relationships between consumed power, water temperature and volume (in litres (L)) averaged over three experimental kettles.

It can be seen from Fig 2 that there is a good agreement between the data points and the model with insignificant residual error.
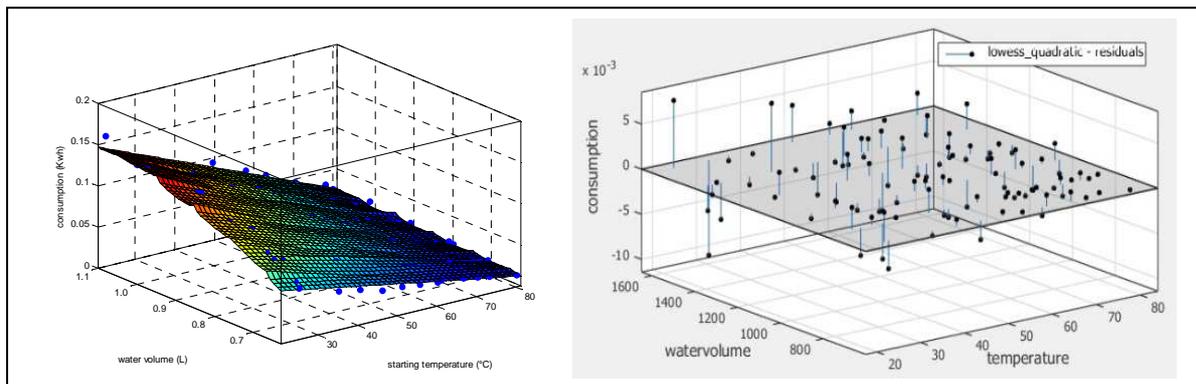
Figure 2: Kettle model and residual error analysis.

3.2 Model validation

Depending on the parameter being estimated, we apply the proposed model in three ways: (1) estimating the consumed power based on the initial temperature and water volume; (2) estimating water volume based on the power consumption and initial temperature; (3) estimating the initial temperature based on the water volume and power consumption. For testing purposes, we randomly select 12 instances of kettle use across each type of kettle using the testing data. Table 1 shows the three different estimations using the proposed model with weighted linear regression.

Table 1: Estimation results

	'dumb' kettle				'eco' kettle				'smart' kettle			
Test #	1	2	3	4	5	6	7	8	9	10	11	12
AP (W)	2668	2710	2694	2683	2604	2083	2062	2381	2612	2493	1855	2373
EC (Wh)	0.13	0.06	0.05	0.05	0.11	0.01	0.02	0.03	0.16	0.06	0.01	0.02
RC (Wh)	0.14	0.06	0.05	0.05	0.11	0.02	0.02	0.03	0.17	0.06	0.01	0.03
EWV (L)	1.54	0.90	1.16	1.36	1.20	0.97	0.94	1.16	1.50	1.53	1.10	0.61
RWV (L)	1.65	0.95	1.10	1.25	1.00	1.00	0.75	1.25	1.50	1.50	1.25	0.50
ET (℃)	29.37	52.04	60.42	61.90	16.88	91.06	86.46	80.20	17.98	69.91	89.79	72.97
RT (℃)	29.5	48	62	64	17	95	90	80	18	70	90	80

AP – Active Power, EC – Estimated Consumption, RC – Real Consumption, EWV – Estimated Water Volume, RWV – Real Water Volume, ET – Estimated Temperature, RT – Real Temperature.

As shown in Table 1, the weighted linear regression model accurately estimates all parameters, for the 'dumb' and 'smart' kettle. The estimation for the 'eco' kettle is the worst, and it is particularly inaccurate when the water is close to boiling temperature (i.e., 90°C), when the error sharply increases to 3.54°C. This can be explained by the extra insulation in the 'eco' build, which improves heat retention and speeds up boiling without any additional power. Therefore, this model is suited for most kettles except for those with insulated carafes, such as the 'eco' kettle, for some temperature range.

Table 2 presents the prediction errors, averaged over all three kettles, for the results shown in Table 1. The estimation error of temperature is 1.21°C which is considered insignificant, as it does not affect our analysis on usage patterns.

Table 2: Estimation errors for the proposed kettle model

| Error	Consumption (Wh)	Water Volume (mL)	Temperature (°C)
Mean Absolute Errors (MSE)	0.086	0.025	1.210
Squared Absolute Errors	1.316	0.159	10.08

4 Usage Patterns

Our goal is to demonstrate that there are certain predictable patterns in kettle use, e.g., a high likeliness of usage in the morning. Each household monitored has its own distinct usage patterns. However, there is some similarity that can be observed. This is especially evident in households where occupants work as this dictates their schedule leading up to the workday.

Figure 3 shows results, presented as rose charts, for all 14 monitored houses for three different months during Autumn-Winter 2014. Each bar shows the number of times kettles are used in these houses during specific one-hour period. It can be seen that October and November have similar patterns with morning, lunch and 4-5pm usage peaks, attributed to the average UK working day. The usage pattern for December however shows a much more even distribution, the peaks are still apparent but much less defined. This is expected because the holidays affect the days householders are at home, or has increased likelihood of guests. We also note that the colder weather increases the uses throughout the day.


Figure 3: Kettle use based on hour of day
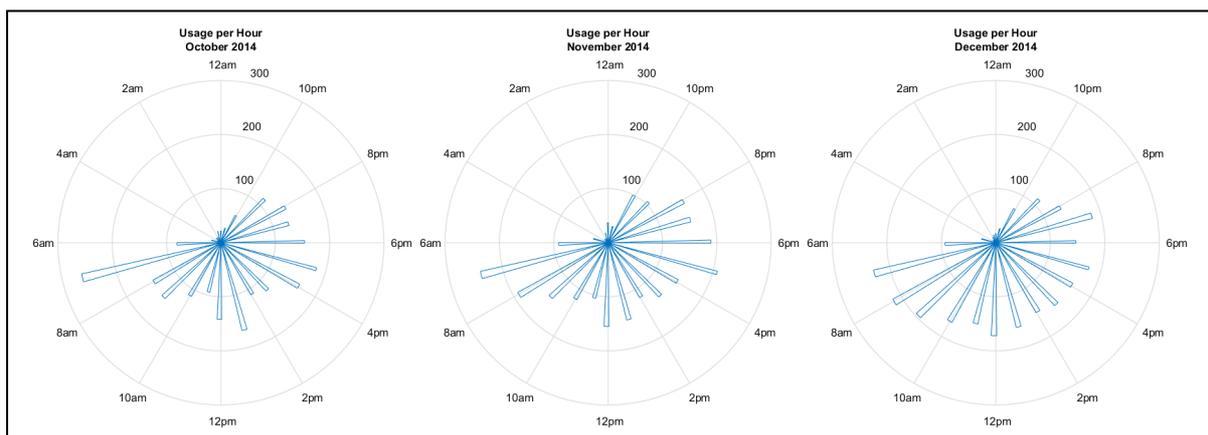
Kettle uses from 14 houses combined to show the average kettle usage pattern; a use is defined as an event lasting longer than 10 seconds.

Kettle Usage Weekdays House 20 / Kettle Usage Weekends House 20
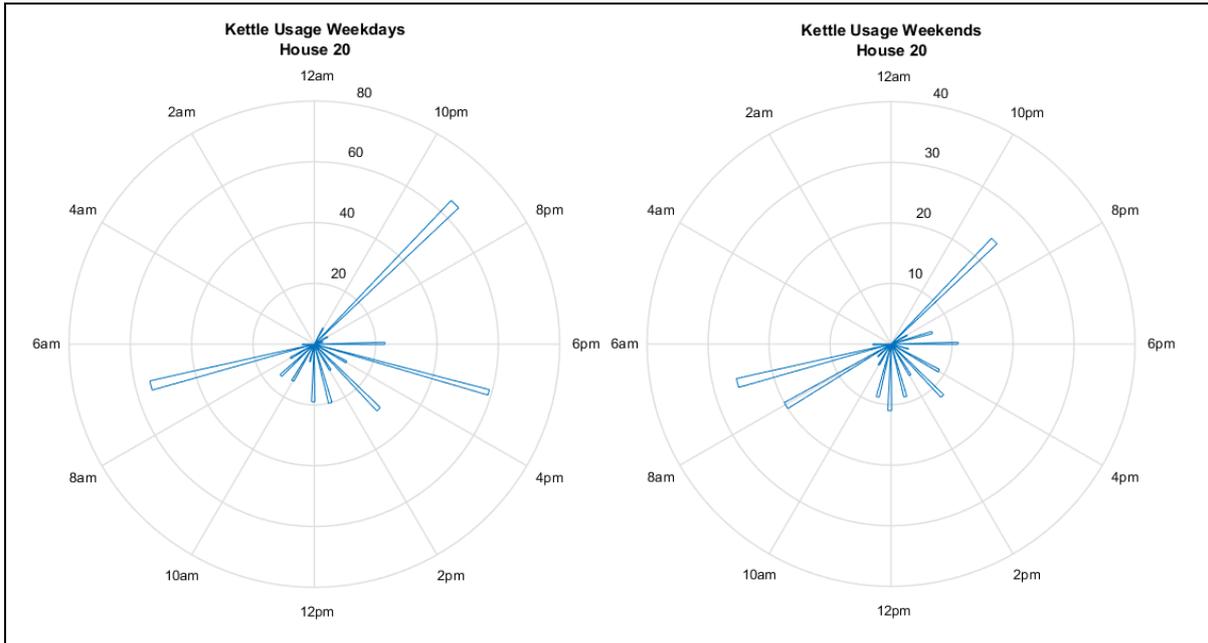
House 20 is occupied by a family of three with one child. Data for House 20 is grouped by weekday or weekend. A use is defined as an event lasting longer than 10 seconds.

Figure 4 shows results for one particular house (House 20) for the period October 2014 - December 2014 broken down as workday and weekend. There is a striking difference between weekday and weekend usage. Weekday peaks are 7am, 5pm and 9pm peaking at the normal meal times and the house specific night time. The week has the same morning and nigh peaks but with no 5pm peak and similar usage levels throughout the day. Usage at the end of the day remains fairly consistent and may signify a regimented time for sleep. This latter observation is useful for social scientists to understand activities in the home and their energy-consequences.

Kettle Usage Time House 11 / Kettle Usage Time House 13
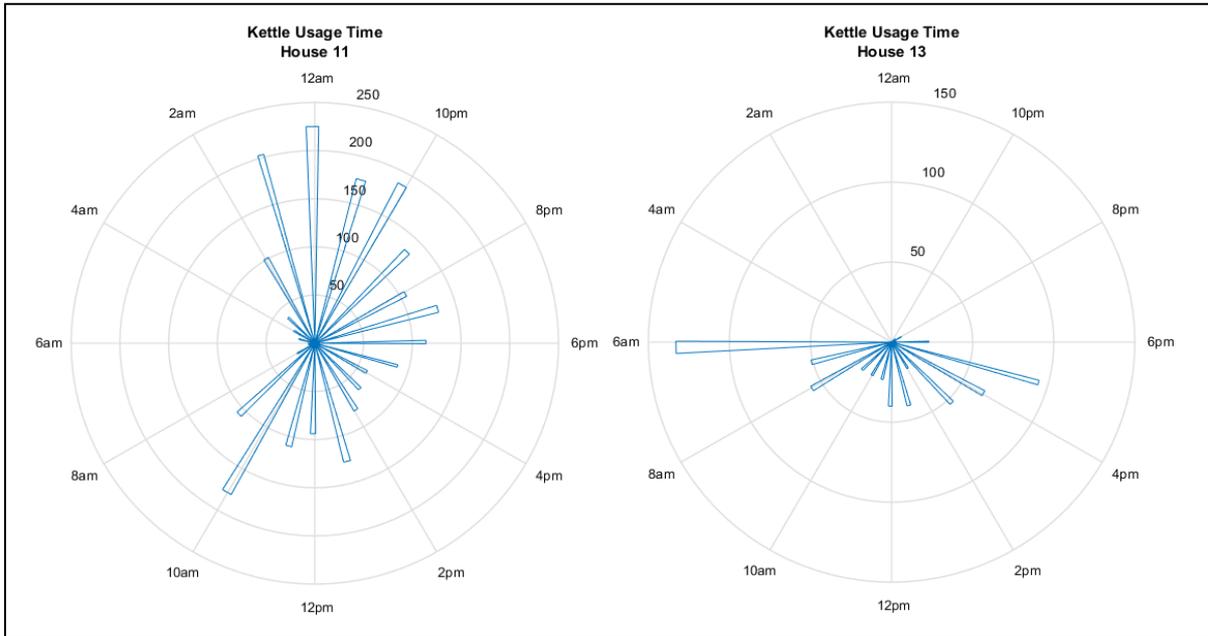
House 11 (left), House 13 (right), occupied by a single retired occupant and a couple with two small children, respectively. Kettle usage over period 27 June 2014 – 20 January 2015

Figure 5 (left) shows kettle usage patterns for House 11. House 11 has the usage pattern of a 'night owl'. Indeed, usage is unusually low during the most expected hours of usage (7-9 am); instead, the usage usually starts at midday and continues over the afternoon till late with a final spike at midnight

dropping of as 2am passes. The low usage throughout the, suggests that the occupants do not have a work schedule that they have to keep to. This more unusual pattern can therefore be attributed to there being a single retired occupant in the property who has a nocturnal sleeping pattern. This is confirmed by discussions with the occupant.

Figure 5 (right) shows kettle usage for House 13. House 13 has a more regular pattern in relation to today's general working lifestyle - a large peak at 6am signifies the waking time of at least one occupant and a secondary peak at 5pm signifies their return home after work. This is expected as the occupants of House 13 are a couple with two small children; hence, usage throughout the day confirms that one member works full time and the other cares for the children. Our household surveys confirm this conclusion.

The level that kettle had been filled to during operation is also studied. Each household has a clear preferred limit as shown in Figure 6 for five houses. Ideally, usage should be a large peak at the expected consumption for the number of occupants multiplied by the number of hot drinks being prepared. Patterns have emerged however, showing households with residents that tend to stay at home for longer periods of time (retirees, stay at home parents) tend to consume more per usage (fill the kettle more, boil more than needed). In some cases while the consumption is in line with the number of people in the household, there is still room for improvement and a decrease in re-boiling will help overall consumption.
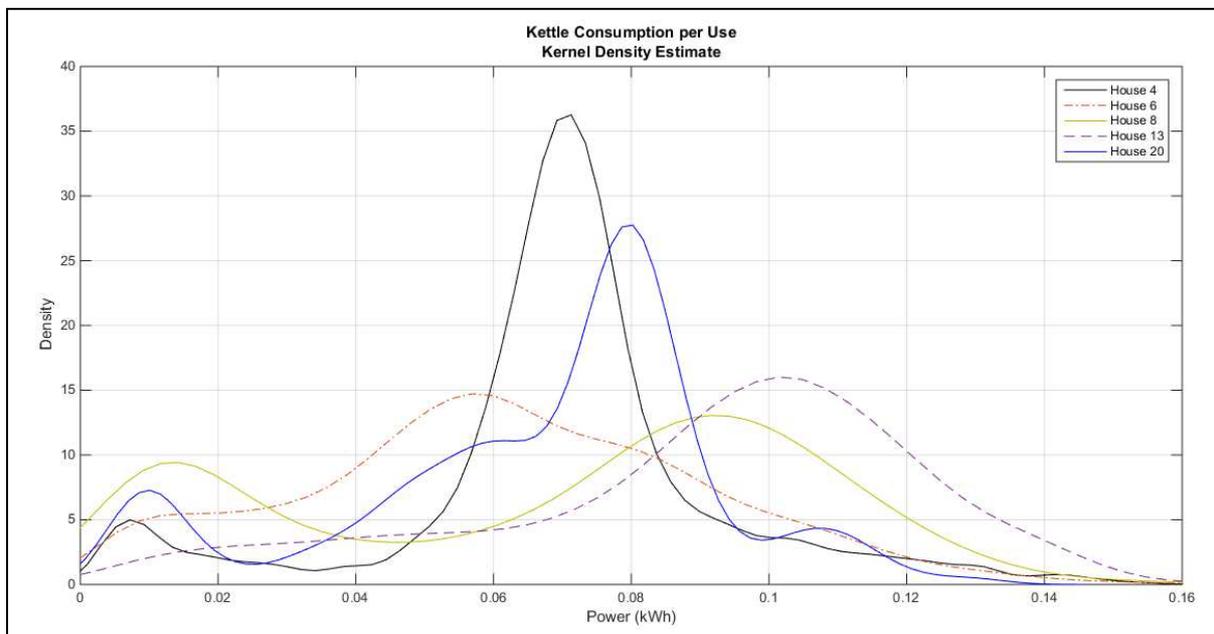
Figure 6: Kettle consumption Density per use

Figure 6 shows that different households have different levels of consumption per boil. We know from our household survey that all of these houses have standard kettles. It can be seen that House 4 (a retired couple) boils consistently at the same level with a small peak at low consumption showing re-boils. Re-boils are assumed if energy consumption is below a reference value of joules needed to heat water from 12 to 100 $^{\circ}$C, (92109.6 Joules). It can be seen that House 6 does not have a concentrated fill pattern peaking at a slightly lower level than House 4 but remaining high across higher values as well. Houses 13 and 8 can be seen to consistently fill the kettle more but vary more than House 4. Using this data and the proposed mathematical models, the estimated fill levels for House 4 and House 8 are calculated and shown in the Figure 7.
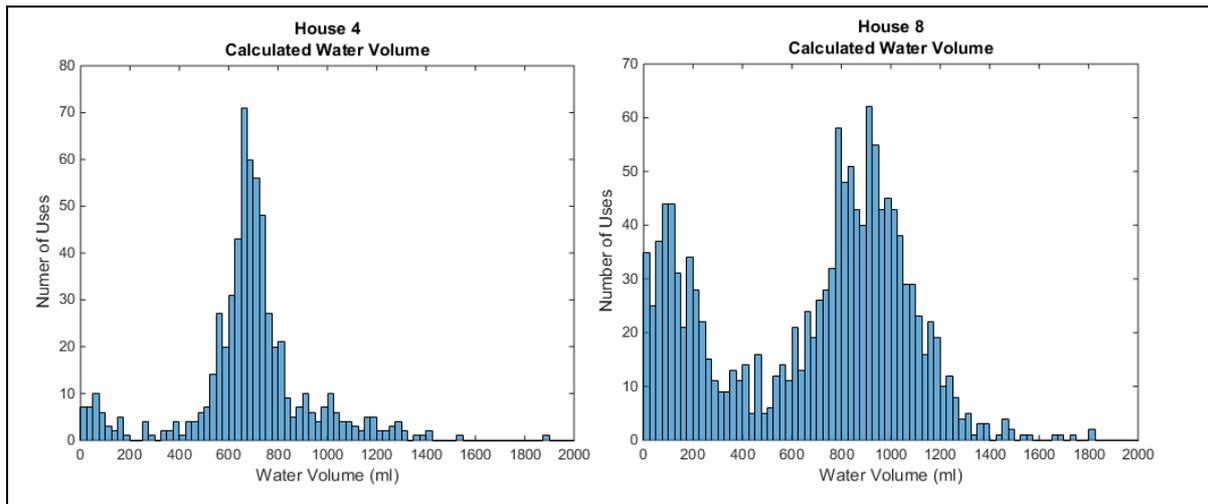
Figure 7: Estimated filled volume levels using the proposed modelling.

House 4 (left), House 8 (right) Kettle usage over period 27 June 14 – 20 January 2015.

It can be seen from Figure 7 (left) that House 4, which is occupied by a retired couple tend to fill the kettle to a suitable level with respect to the number of occupants filling in general around 600-700mL of water each time. It can be concluded that this behaviour is ecologically friendly under the assumption that there will only be two drinks being prepared for the majority of occurrences. House 8 Figure 7 (right), on the other hand, which is also occupied by a retired couple have a higher fill volume peaking at around 1L (with the assumption that one cup is roughly 250mL). This shows a less efficient usage pattern; there are also a greater number of low-level volumes which would represent re-boiling of the kettle. Reducing the amount the kettle is filled will save energy and also help in eliminating re-boils as the kettle will not have the water necessary to produce more cups of water. Feeding this information back to House 8 will help them to reconsider their usage habits, to either reinforce their current model of use or to highlight the need to reduce the amount of water added to the kettle each time.

Incidentally, the power rating of the kettle has little effect over how the kettle is normally filled: lower rated kettles which take longer per boil are filled in a similar way to higher rated kettles. It can therefore be assumed that time is not a major consideration in kettle usage for occupants.

The effect of seasons on kettle usage is something that can be visualised in Figure 8. During our study period the expected trend of increased usage as winter approaches has proved correct with an upward trend from July to December. The slight decrease in August is attributed to a number of households going on holiday.
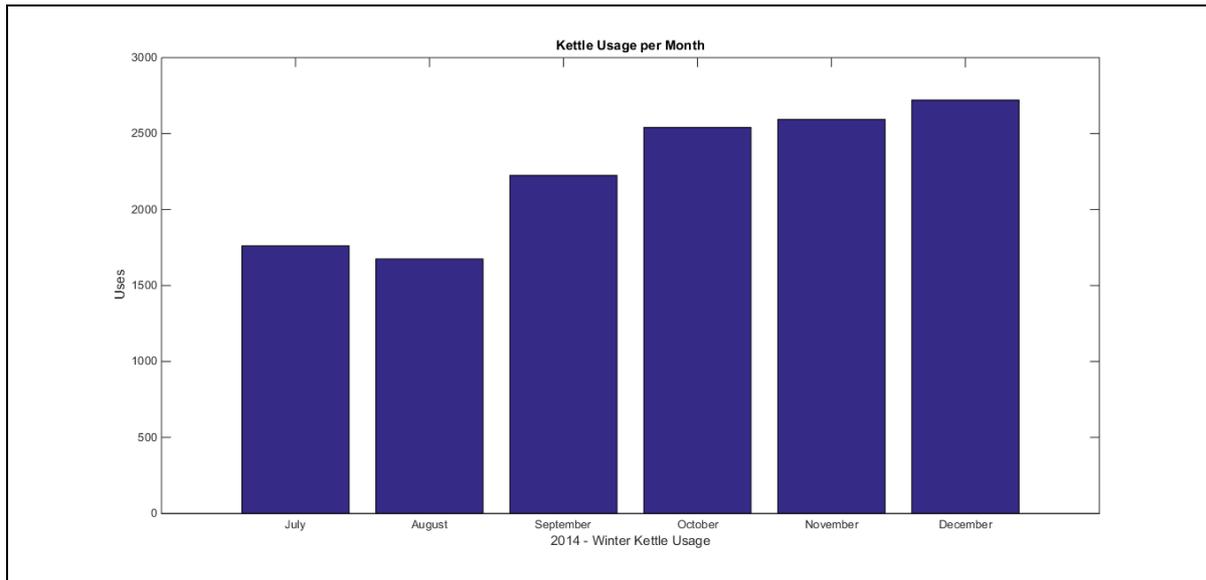
Figure 8: Kettle usage in the period July-December 2014. Kettles with full month recording from 14 houses

A major factor in consumption is the occupancy of the household. Table 3 shows the consumption for each house over the month of December 2014. It can be seen that consumption varies significantly even in households with a similar number of occupants. It can be seen that kWh per use also varies. Referring back to Figure 7 House 4 and 8, although they have different filling patterns their consumption is very similar when number of usages are taken into account. Although House 8 has a significantly higher number of uses the cost per use is similar, throughout the year the cost to house 8 remains in line with House 4 suggesting that re-boiling doesn't strongly affect consumption. Noticeably some houses have a much higher kWh per use than others. For example, Houses 9 and 12 are close to 0.1 kWh per use (a relatively high value), for House 12 this can be attributed to a fill pattern similar to House 4 (Figure 7) but with the highest peak at 1.2L, in these cases comparison with other households may help to reduce the cost to the residents.

Table 3: Consumption of households with occupancy

House	Occupancy (Under 18) R – Retired	Percentage of Total Use	kWh (Month Total)	Total Monthly Cost (14.05p/kWh)	Uses	kWh per Use
2	4 (2)	4%	17.81	£2.50	244	0.072
3	2	2%	12.52	£1.75	199	0.062
4	2 R	2%	6.94	£0.97	101	0.068
5	4 (2)	3%	19.81	£2.78	270	0.073
6	2	4%	15.31	£2.15	255	0.060
7	4 (2)	2%	9.09	£1.27	120	0.075
8	2 R	3%	16.34	£2.29	239	0.067
9	2	4%	23.94	£3.36	243	0.098
11	1	7%	11.95	£1.67	165	0.072
12	3	6%	19.09	£2.68	195	0.097
13	4 (2)	2%	5.99	£0.84	68	0.088
17	3 (1)	6%	21.03	£2.95	335	0.062
19	4 (2)	4%	9.20	£1.29	160	0.057
20	3	4%	11.94	£1.67	177	0.067

5 Case Study

During the time we have been monitoring energy usage two houses have replaced their kettle. One house opted to buy a smart kettle which featured temperature control 70-100°C and a keep warm feature, marketed as a "smart" kettle. The other household purchased an "eco" kettle which featured a

thermos design style which offers a high thermal retention to in theory avoid re-boiling; the model is the Vektra referenced in Section 2 [8][9]. In the case of the eco kettle the investment was aimed at saving money - the household consists of a semi-retired couple that has made other eco-friendly additions to the house including solar panels. Our case study focuses on this household to see if the 'eco' kettle is a sensible investment.

The vacuum, eco, kettle study is useful as the household introduced this kettle as an energy saving measure during our recording period; we can therefore look at their usage before and after the change to show the advantage/disadvantage of this new kettle.
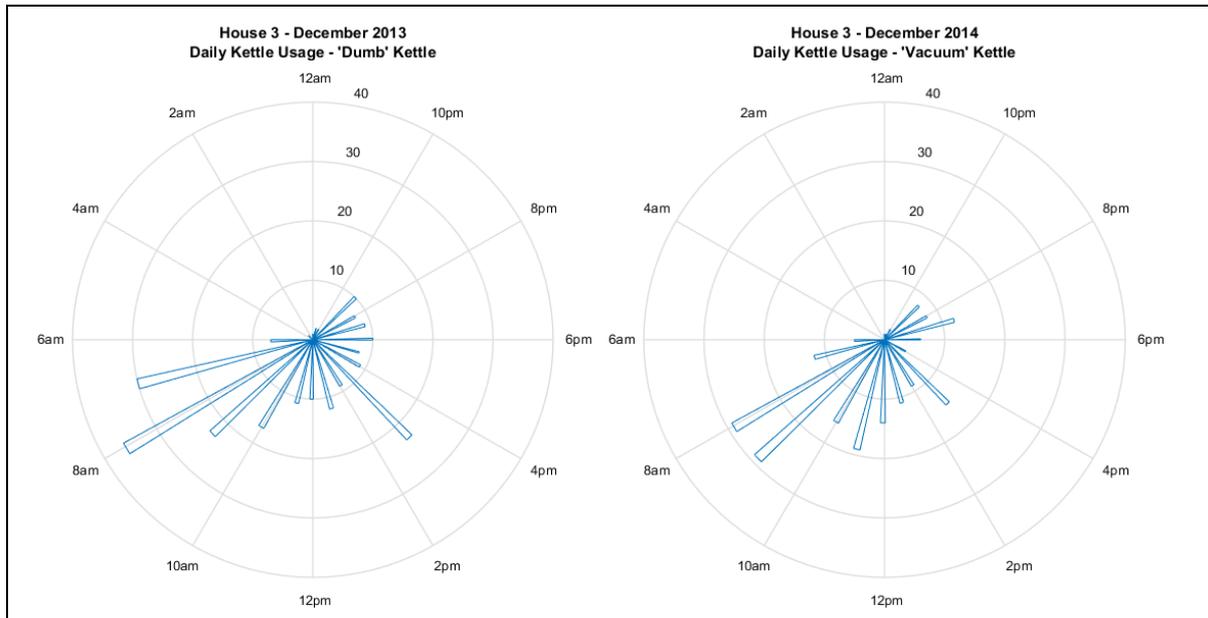
Figure 9: Hourly Usage of House 3. December 13 with 'dumb' kettle in use, December 14 with Vacuum (eco) kettle in use.

The usage pattern between 'dumb' and vacuum kettle can be seen in Figure 9. The 'dumb' kettle usage is higher than that of vacuum kettle, the hours of use have changed between years as well. The pattern helps to show the effect the vacuum kettle has had, usage is lower and the pattern shows a reduced usage after large spikes, this shows that after a use the thermal insulation reduces the number of uses for a period afterwards. This effect can best be seen at 11am usage in 2014 where the subsequent hours have a decreasing usage pattern with a spike at 3pm, 4 hours after (the vacuum kettle claims to keep water warm enough for tea for 4 hours). The average time between uses increased between 2013 -2014 by 45 minutes again suggesting that the design of the kettle is a contributing factor in the change of behaviour seen.
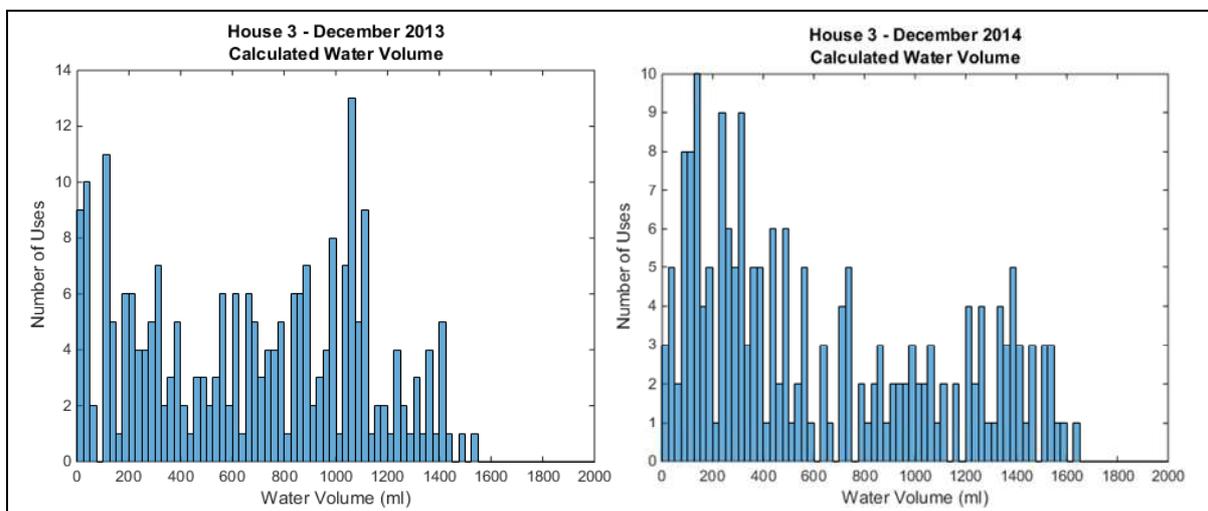
Figure 10: Consumption histogram of 'Dumb' kettle (left) vs. Vacuum kettle (right) in House 3.

It can be seen that the usage pattern of House 3 (Fig. 10) has changed since the introduction of the vacuum kettle. The vacuum kettle has fundamentally changed the way the kettle is being used in the household. In the period where the dumb kettle is in use there is a close to even spread of heating 1 litre, and re-heating 1 cup. This has radically changed during the period of use with the vacuum kettle where there is a much large proportion of small boils as well as a peak at 1.5 litre boils. We know from interviewing the household that they used the vacuum kettle by initially heating the full amount of water (capacity 1.5L) and then as the day continues reheat until requiring a complete refill. These months are a good comparison, being in the same month of the year reduces the season effect and usage was 241 and 199 for 2013 and 2014, respectively. The difference in uses can be attributed to the need to boil the vacuum kettle less. The difference in consumption can be seen from Table 4.

Table 4: 'Dumb' vs 'Eco' kettle consumption

Year	Uses	Consumption (Kilo Joules)	kWh	Cost (13.52p/kWh)
2013 – December ['dumb]	241	63,253	17.57	£2.38
2014 – December ['eco']	199	45,075	12.52	£1.69

It can be seen that the eco-kettle has a significantly fewer number of uses and therefore the associated cost has been reduced by close to £0.70 in the comparative months of December. Over the period of a year this could mean a possibility for saving around £8.00. This represents close to a 50% saving based on the figure found on CarbonFootprint.com [14]. This helps demonstrate that a desire to become more eco-friendly is possible by making little changes to appliances. The initial cost of the kettle however is around £80, therefore there is a significant period of time before the kettle will be 'saving' money.

5.1 Feedback

The residents of House 3 were given a breakdown of usage as above, along with textual explanation of the findings. A survey was completed prior to delivery of the consumption breakdown to assess the residents' thoughts. The survey revealed a number of traits about the household. The residents were committed to being eco-friendly and were positive about buying other products aimed at consumption reduction; they believed that they had changed their habits significantly as they actively inducted the vacuum kettle into their routine. As shown above, this can be seen in the comparisons made, in both usage and water consumption which led to a more economical usage style. They also made a note of the fact that they try to avoid re-heating water and this is backed by the fact that only 7% of their kettle usage is within a 5 minute window of a previous usage. Shortly after the time period included in this work the household stopped using this vacuum kettle due to a fault which once fixed never made it back into daily usage. Interestingly, this was not due to any effects on performance, but due to the noise the kettle made, which was annoying to the occupants. The feedback however was well received and the residents believed that this would be of benefit, and expressed that a monthly breakdown of appliance usage would be suitable.

6 Conclusion

This paper presents a detailed analysis of kettles usage in UK households by building a mathematical kettle model which can help analyse usage patterns and provide information about how the kettle is being used and where energy could be saved by adjusting habits. The kettle model can estimate a number of factors which would help for generating feedback. Based on the proposed kettle model, the usage patterns of households including sleeping patterns, daily schedule and interaction habits with the kettle has been studied. The studies show that, in-line with previous studies, most households do overfill their kettle. However a bigger factor is reheating water soon after it has boiled. In these cases households that appear to not overfill, based on the number of occupants, waste energy on reheating. Days of the week can affect the pattern of consumption. There is also a seasonal effect on consumption.

The case study conducted in one house, shows that there has been a fundamental change in kettle usage since the introduction of the 'eco' kettle. The household went from filling around a litre of water

to filling much closer to the new kettles' maximum of 1.5 Litres which indicates the household is actively attempting to reduce their consumption. This case study also shows that the household might adjust their usage habits to meet the energy saving goals.

The analysis of kettle usage can be customized to provide feedback to individual households, assuming the households' willingness to be eco-friendly. The problem of overfilling will only be tackled by someone who is in a positive mind-set. The habit of reheating, less than 5 minutes after boiling (in 6 of the 14 houses more than 10% of boils were done within 5 minutes of the previous boil ending), is prevalent across many of the households in our study, which can be addressed by informing them that their habit of refilling/reheating is detrimental to being economical. This process of reheating could also be contributed to a lack of communication or forgetfulness: if a person is unaware the kettle has been boiled recently or has left it for a period of time there is a tendency to reheat.

Acknowledgements

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