Further Analysis of the Household Electricity Survey

Savings, beliefs and demographic change

15 May 2014

Reference 475/09/2012

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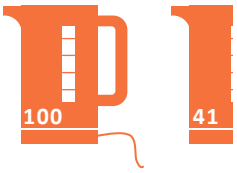
Average energy savings per household from

Washing clothes at 40°C or less

24 kWh/year (p17)

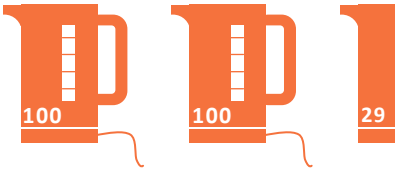
141 kettles*



Not overfilling the kettle

39 kWh/year (p21)

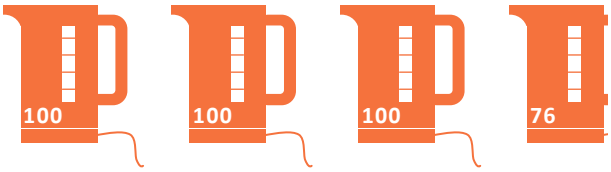
229 kettles



Turning off standby appliances

64 kWh/year (p29)

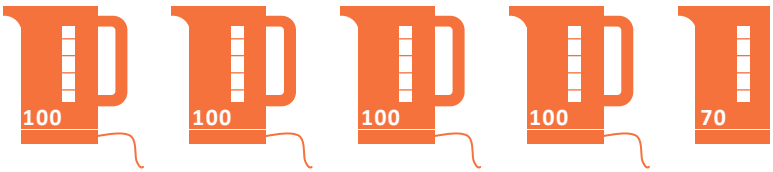
376 kettles



Not leaving PCs on

80 kWh/year (p15)

470 kettles



***boiling 1 full kettle=170 Wh**

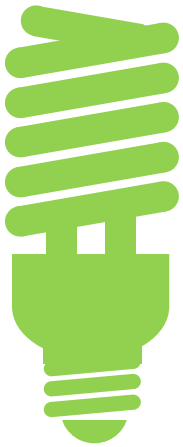
Range of lighting use (averages, households of two or more, p19)

'Never leave lights on'

490 kWh/year

Average among 2+ households

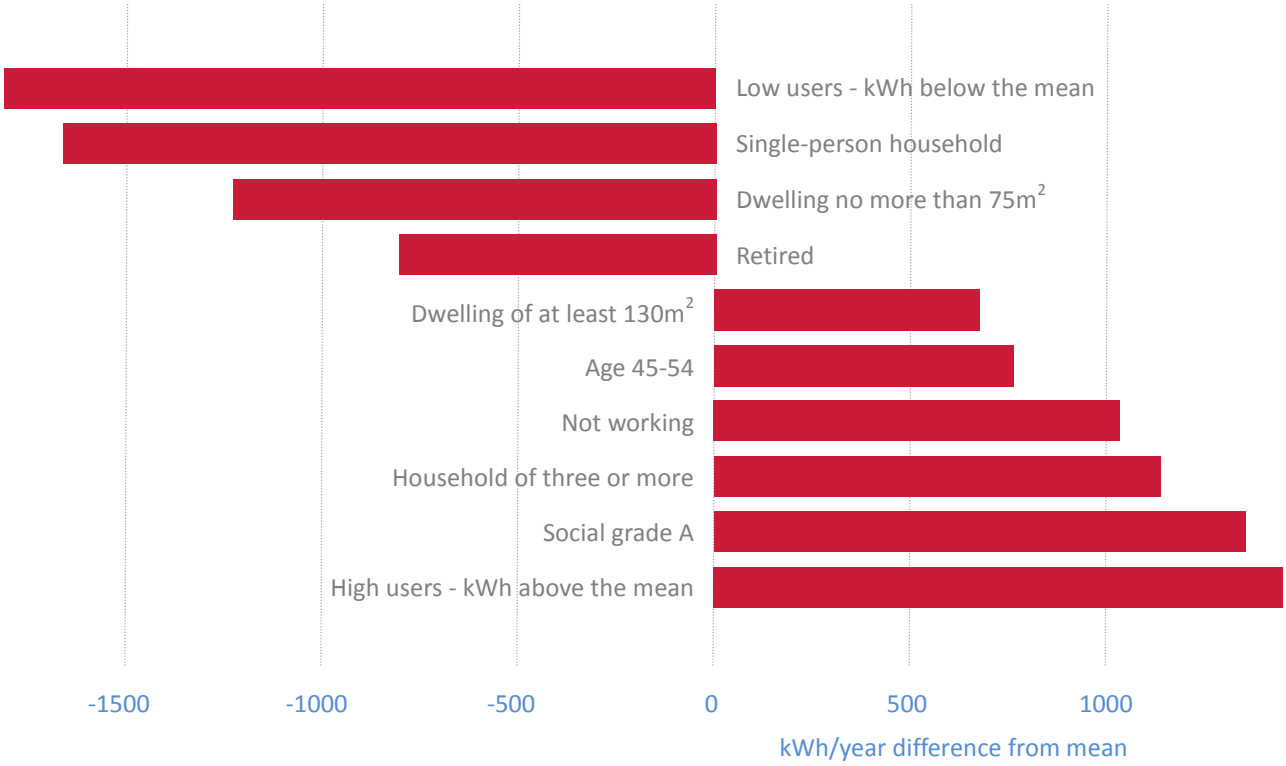
613 kWh/year



'Often leave lights on'

840 kWh/year

Significant factors for high or low electricity use (not heating, p47)



Optimum rebates for different appliances (highest energy savings per pound, p69)

Tumble Dryer
£450

Freezer
£450

Fridge-freezer
£450

Fridge
£400

Washing machine
£350

Contents

Executive Summary

Overview

The Household Electricity Survey monitored a total of 250 owner-occupier households across England from 2010 to 2011. It was the most detailed survey of electricity use in English homes ever undertaken. This is the fourth research report written by Cambridge Architectural Research, Loughborough University and Element Energy presenting further analysis of the Household Electricity Survey (HES)[1].

This report presents our work examining how social factors affect electricity use: householders' beliefs, their socio-economic group, demographic changes over time, and the potential costs and benefits of introducing a replacement scheme for old appliances. The material builds on the findings of our first three reports, responding to the next set of topics drawn up by DECC and DEFRA. The report covers the following six questions:

1. How is electricity use affected by environmental beliefs?
2. How do potential savings differ between groups?
3. How does social group affect electricity use by pensioners?
4. What impact will demographic changes have on energy use?
5. What does the HES tell us about high and low use households?
6. What opportunities are there to save energy by introducing an appliance exchange scheme?

The methods of analysis were different for each question, but to give an overview we selected pertinent data from the large HES database. Where necessary, we cleaned the data and put it into a form that could be interrogated using the statistical programming language R and/or Excel. We created tables and graphs so readers can see data for themselves, and where appropriate we carried out statistical tests to look for significant relationships in the data. We also did literature-based work to identify published research connected to each question, summarised in blue boxes in each section.

[1] The first report, *Early Findings*, covers questions related to demand side management. The second report, *Electrical appliances at home: tuning in to energy saving*, covers appliances ownership and use. The third, *Energy use at home: models, labels and unusual appliances*, examines energy models, energy labels, and larger appliances that are not found in all homes. The first two reports are available here: https://www.gov.uk/government/publications/household-electricity-survey (accessed 01.04.14)

How is electricity use affected by environmental beliefs?

■ On average, households that always run washing machines at 40°C or less save 85 Wh per washing cycle, or around 24 kWh/year. Two-person households that 'never' leave lights on in unused rooms use 350 kWh/year less than two-person households that 'often' leave lights on, on average.

■ Households that said the effects of climate change are too far into the future to worry them use *less*, rather than more, electricity. However, this was largely due to their age: older households (over 65) were much more likely to say climate change is too far off to worry them, and also had lower energy use.

■ There is some link between households' stated behaviour towards switching off unused appliances and electricity use, but there is seldom a statistically significant relationship (p-value 0.05 or less) between stated and actual behaviour. This means that policy-makers cannot rely on stated behaviours alone in assessing how often householders turn off unused TVs and desktop computers, or how much hot water they use for showers.

How do potential savings differ between social groups?

■ By separating the potential savings different households could make into socio-economic groups from A to E, we examined whether there is any sign that electricity savings differ between these groups. We found limited evidence of higher potential savings for Groups A to C2 from avoiding leaving appliances on in standby mode.

■ We also found that Groups A and B had significantly lower potential savings from replacing TVs with smaller (22") units. On average, these groups could save only 121 kWh/year, against a mean saving of 161 kWh/year for all households. (Savings from smaller TVs may be somewhat lower now because of the EU Eco-Design Directive limiting TV power use.) Conversely, we found that Groups D and E had significantly lower potential savings from using smaller fridges and fridge-freezers (though there were relatively small samples for these).

How does social group affect electricity use by pensioners?

■ Socio-economic group emerged as a stronger driver of electricity use by appliance category for pensioners than for non-pensioners. Pensioners in social groups A and B have similar usage to the average for non-pensioners, whereas pensioners in other social groups use less electricity.

■ Socio-economic group could be helpful in identifying pensioner households with greater (or less) potential to save energy. Higher social groups tended to use more energy, while lower ones tended to use less – much less for ICT and washing appliances (although there were only eight lower grade pensioners in the survey).

What impact will demographic changes have?

■ The Government's Department for Communities and Local Government publishes a forecast of demographic changes through to 2021. It anticipates a 10% rise in the number of households, and major increases in the number of households aged 65 and above.

■ We combined this with data from the HES about electricity use by households in different age bands, and found that lower average electricity use by older households slightly reduced the effect of a larger population. (If older households in future follow the consumption patterns of today's older households.) The effect of age and population increase alone appears to raise electricity use by 9% over ten years.

What does the HES tell us about high and low use households?

■ We ran a series of different tests to analyse electricity use in high and low use households. We found the factors contributing to high use were (largest first): being in socio-economic group A, having three or more people in the household, not working (but not retired), age 45-54, and having a dwelling floor area of at least 130 m^2.

■ Conversely, the most significant low-use factors, in order of decreasing effect were: living alone, having dwelling floor area below 75m^2, and being retired.

■ We also found some correlation between high electricity use for appliances and space heating. Households saying that they left a TV or computer on when they were not using them, those leaving mobile phone chargers switched on, and those claiming to buy energy efficient appliances all also had above-average electricity use.

What opportunities are there to save energy with an appliance exchange scheme?

■ We collected sales price data for new appliances with different energy labels, and compared this against actual energy use data from the HES households. We worked out the percentage savings with rebates at different levels for replacing old appliances, and the annual expected savings.

■ We suggested rebates from £350 to £450 for cold appliances, washing machines and tumble dryers – based on the largest improvement in energy efficiency per pound spent. We calculated that replacing the HES appliances would save between 27% (freezers) and 60% (tumble dryers) of the annual energy use, which would save from 51 to 225 kWh/year of electricity, depending on the appliance and how it is used.

■ However, using the economic evaluation method in the Treasury's Green Book showed that introducing a rebate scheme to fund the full cost of replacing these appliances, before they malfunction, would not be justified on economic grounds alone.

Introduction

The Household Electricity Survey monitored a total of 250 owner-occupier households across England from 2010 to 2011. Twenty-six of these households were monitored for a full year. The remaining 224 were monitored for one month, on a rolling basis throughout the trial.

The study had four broad objectives at the outset[2]:

1. To identify and catalogue the range and quantity of electrically powered appliances, products and gadgets found in the typical home.
2. To understand their patterns of use - in particular, their impact on peak electricity demand.
3. To monitor total electricity consumption of the home as well as individually monitoring the majority of appliances in the household.
4. To collect 'user habit' data when using a range of appliances through the use of diaries.

Participants kept detailed diaries of how they used certain appliances, which can be matched against actual energy use monitoring for their homes. Each household filled in a diary every day for one week. The households monitored for a year did this twice. The diaries covered use of wet appliances, tumble dryers, ovens and hobs. They had between 13 and 85 appliances in their homes, with about a third of households owning between 30 and 40 appliances.

Seasonal adjustments

Most of the households in the survey were only monitored for a month, and these figures were unduly affected by the time of year when they were monitored. As a result, for some of the Department's questions we had to adjust the data for these homes to account for seasonal differences. For example, fridges and freezers use more energy in the summer, but lighting is used more in the winter.

We used data from the 26 households monitored over a whole year to generate seasonality factors for each appliance type – cold appliances, electric cooking, lighting, washing, AV, ICT, water heating and space heating. (For water heating there was no significant difference between the seasons.)

We calculated the electricity use on each day for each appliance type, averaging over the total usage for the 26 households. Then we normalised this by dividing by the total use over the year, times 365 to get a factor for each day.

The results were very noisy, so we used regression analysis and least squares to find a best fit curve, based on sine and cosine functions. We generated a separate adjustment curve for each of the eight appliance types where there was a link between energy use and the time of year.

[2] DECC/EST/DEFRA (2012) Powering the Nation. London: DECC/EST/DEFRA.

The adjustments result in increased uncertainty, which is hard to quantify, particularly for heating due to the small sample. (None of the households monitored for a year used electricity for their main heating.) For heating we avoid using the adjusted figures where possible.

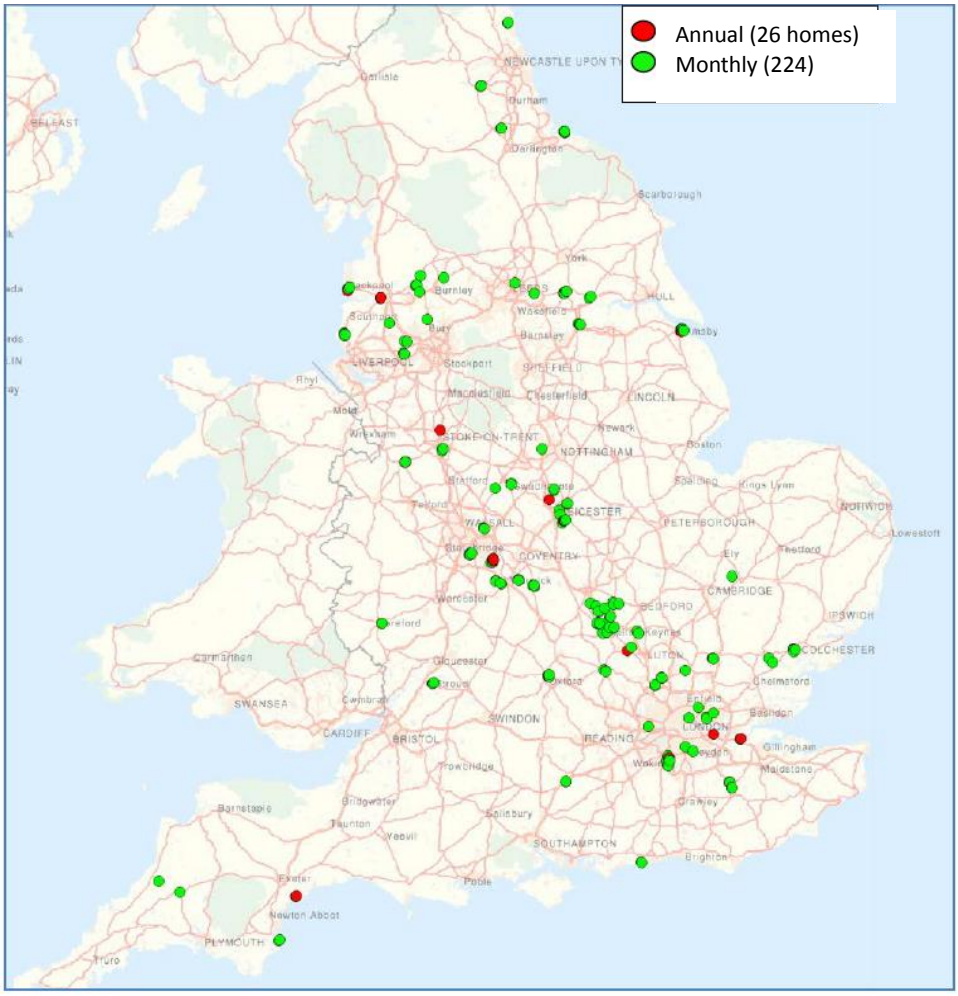
The sample of homes was not perfectly representative – partly because only homeowners were included and partly because they were more energy-conscious than average households. However they were fairly typical in terms of social grade, number of residents, life stage, and property age[3]. There were also fewer than the average number of households with primary electric heating (3.5% against an average across the population of 8%[4]), flats were under-represented (4% against 20% nationally[4]), and the average floor area was 5.5% larger. Average (mean) electricity use across homes in the sample was 4,093 kWh/year, against a mean of 4,154 kWh across all UK homes[5]. The location of households that participated is shown on the map below.

This data offers an unparalleled source of very detailed electricity profiles. It has already provided unmatched insights into the way electricity is used in English homes. In our previous reports we examined the scope for demand shifting, baseload electricity demand, changes in the size and efficiency of appliances, and how different socio-economic groups and ages use electricity. We also wrote a report about how smart meters could be used as the starting point for a National Monitoring Survey.

[3] Zimmerman et al (2012) Household Electricity Survey: A study of domestic electrical product usage. Milton Keynes: Intertek/EST/DECC/DEFRA.

[4] Palmer J, Cooper I (2014) UK Housing Energy Fact File 2013. London: DECC. https://www.gov.uk/government/publications/united-kingdom-housing-energy-fact-file-2013

[5] DECC (2012) Energy Consumption in the UK. London: DECC. (Tables 3.1 and 3.3.)



Participants came from most parts of England, although they were not perfectly representative – the south-west was under-represented and the north was over-represented. Source: Zimmermann et al, 2012[6].

This report, by Cambridge Architectural Research Ltd, Loughborough University and Element Energy, is the fourth in a series of five reports that investigate different questions drawn up by DECC and DEFRA. These questions were unexplored, or not explored in full, in the original analysis of the Household Electricity Survey[3] (HES).

Working closely together, we scrutinised and analysed the data in a variety of different ways to explore specific questions. We established a secure database for the data, and used tools including SPSS, R (both specialist statistics packages), Excel and SQL (structured query language) for analysis. Where necessary we used programming for functions that were not supported in these packages. We carried out standard statistical tests (t-tests and others), and we focused quite explicitly on uncertainty in the data and the analysis.

[6] Zimmerman et al (2012) Household Electricity Survey: A study of domestic electrical product usage. Milton Keynes: Intertek/EST/DECC/DEFRA.

We wrote five detailed reports over the 14 months of this project:

- One on 'Demand side management and grids'[7]
- 'Tuning in to energy saving', on appliances ownership and usage patterns[8]
- 'Energy use at home: models, labels and unusual appliances'
- This report, examining how social factors affect electricity use: beliefs, the socio-economic group, demographic changes, and the potential cost and benefit of a replacement scheme for old appliances, and
- The Final Report – giving an overview of the whole project and summarising the main findings to emerge.

Limitations of the data

Studies like the Household Electricity Survey are unusual because they are complex to organise, and very expensive. Inevitably, there are some compromises in assembling such a rich set of data – largely linked to the modest sample size. Ideally, there would have been thousands, or perhaps tens of thousands of households participating in the study, including both rented and privately-owned homes. Ideally, all homes would have been monitored for the full 12 months rather than having some of them monitored for just one month. Some commentators hold that gender is an important determinant of energy use at home, and ideally we would have data on the gender makeup of households and/or individual participants, but this data was not collected.

It is possible that people living in rented property use electric appliances differently from owner occupiers, although we know of no empirical work in the UK that demonstrates this.

The Departments asked us to draw out policy recommendations from the work where possible. They and we recognise that policy recommendations would be more robust if based on a larger sample – especially for work focused on subsets of the homes in the study (e.g. homes with electric heating, or pensioners). The small sample makes it impossible to extrapolate reliably to all homes, but it is a starting point, and where possible we combine with other sources of empirical data.

In many parts of this work we see associations (or the absence of associations) between demographic profiles and patterns of energy use. We suggest explanations for these patterns where appropriate, with caveats, but we would not claim that our interpretations are categorical or definitive, and it is very seldom possible to infer unambiguous causality from the correlations.

[7] Palmer J, Terry N, Kane T (2013) Further Analysis of the Household Electricity Use Survey: Early findings – demand side management. London: DECC/DEFRA.

[8] Palmer J, et al (2013) Electrical Appliances at Home: Tuning in to energy saving. London: DECC/DEFRA.

Comparing electricity use with environmental beliefs

The HES survey asked householders about their beliefs and attitudes concerning the environment and about their energy efficiency habits. For example, it asked *How concerned, if at all, are you about climate change, sometimes referred to as 'global warming'?* and to what extent they agreed with the statement *For the sake of the environment, car users should pay higher taxes*. Householders were also asked how often they would '*Leave the lights on when [they] are not in the room'*.

In this part of the report we compare the answers given with those found in the 2009 DEFRA tracker survey on public attitudes and behaviours towards the environment[9], to see how the relatively small sample of HES households (250 respondents) compares to the larger survey (2009 respondents). This survey was used in preference to more recent surveys because it took place close in time to the HES household recruitment. We also compare what the HES householders said about their energy efficiency habits with what they actually did, and how much energy they saved by these actions. Finally, we investigate to what extent their beliefs and attitudes affected their overall electricity use (if at all).

When comparing statements about energy habits with actual recorded actions there is a difficulty in that the survey was completed by a single person in the household, whereas the data records electricity use due to the activities of all household residents. In fact we see very different patterns for single-person households, compared to two persons and larger, which may indicate that the respondent usually answered as a representative for the whole household, rather than just for themselves.

Comparing the HES survey with the 2009 tracker survey

Some of the questions used in HES are identical to those in the tracker survey. In these cases we have compared the answers directly. In other cases we have attempted to map corresponding answers.

The tables below compare the answers for cases where the questions were identical.

Which of these best describes how you feel about your current lifestyle and the environment?	**HES %**	**2009 Tracker**
I'm happy with what I do at the moment	40%	45%
I'd like to do a bit more to help the environment	46%	47%
I'd like to do a lot more to help the environment	14%	8%

[9] Alex Thornton (2009). Public attitudes and behaviours towards the environment - tracker survey: A report to the Department for Environment, Food and Rural Affairs. TNS. Defra, London

Which of these would you say best describes your current lifestyle?	HES %	2009 Tracker %
I don't really do anything that is environmentally-friendly	1	2
I do one or two things that are environmentally-friendly	25	22
I do quite a few things that are environmentally-friendly	52	47
I'm environmentally-friendly in most things I do	19	25
I'm environmentally-friendly in everything I do	2	2

In both surveys the most common answers are the same. However, fewer of the HES households are happy with their current lifestyle and more of them want to do more on the environmental front. More of them say they do quite a few things that are 'environmentally friendly', but less of them claim to be doing most things or everything they could.

Five of the energy-saving habits in the HES survey were also in the tracker survey, but the nature of the answers was different. In the HES the answers were 'Always', 'Very often', 'Quite often', 'Sometimes', 'Occasionally', 'Never' or 'Don't Know'. In the tracker survey the answers were 'Pre-contemplation', 'Rejection', 'Contemplation', 'Maintenance', 'Relapse' and 'Unclassified', For comparison we have compared the number recording 'Maintenance' in the tracker survey with those reporting at least 'Quite often' in the HES.

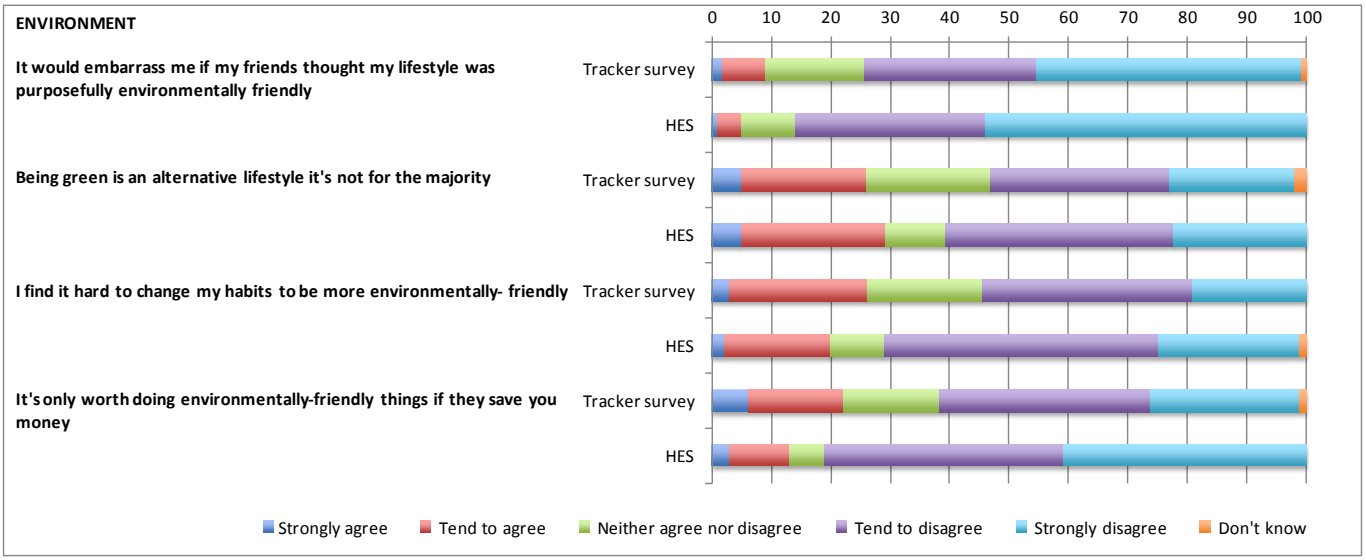
	HES %	2009 Tracker %
Only boiling the kettle with as much water as you need	77	84
Washing clothes at 40 degrees or less	89	77
Cutting down on the use of hot water at home	48	64

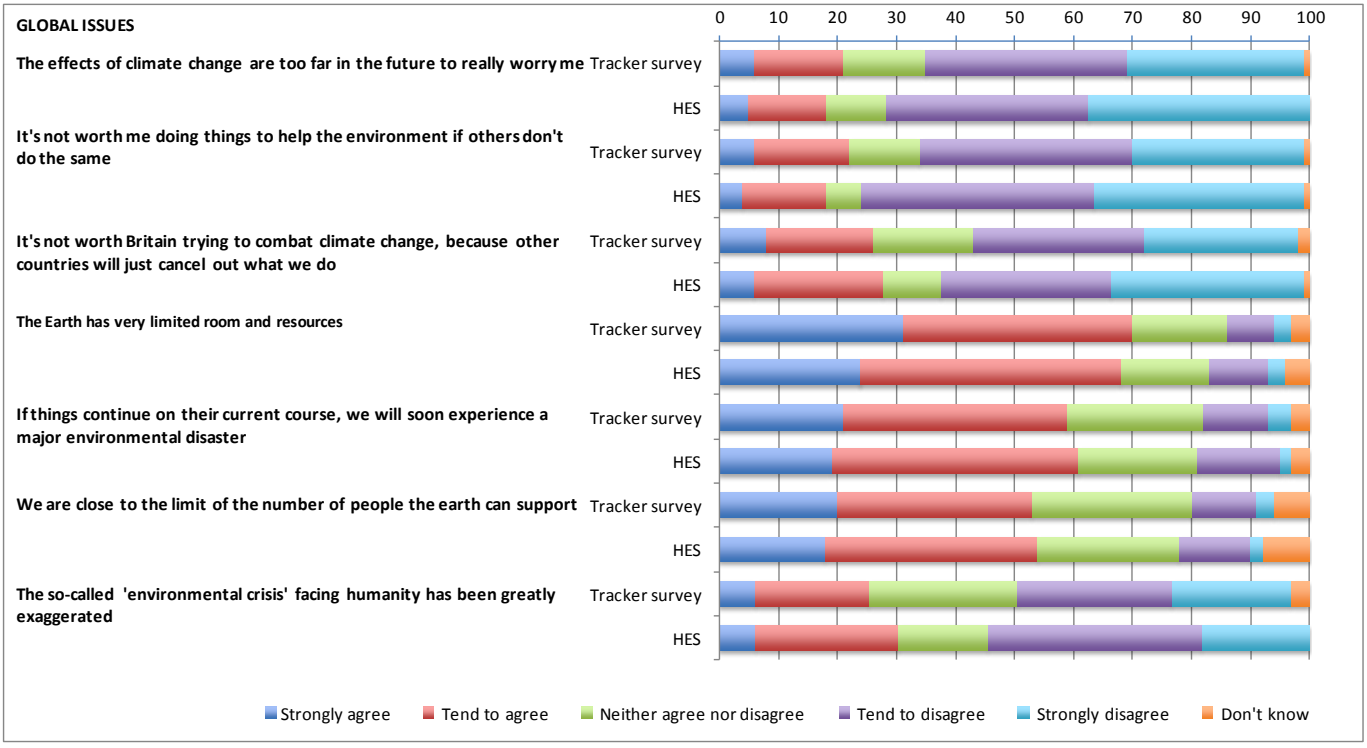
Based on this crude comparison, the HES householders were more likely than the tracker survey respondents to say they washed clothes at 40 degrees or less, but less likely to say they cut down on the use of hot water or took care not to overfill the kettle.

Overall the HES householders said they did less 'environmentally friendly' things, but they wanted to do more.

There were another eleven questions asked in both surveys: seven on barriers and motivations and four on ecological world view. These were given as statements and the householders asked to give their agreement on a Likert scale. The charts below compare the answers: for each pair of bars the top one is from the tracker survey and the bottom one is from the HES, and we have separated the questions into those based on 'Environment', and those on 'Global issues'.

For the barrier questions, the HES respondents were consistently more likely to disagree with the barriers suggested, but their ecological world view answers were very similar to those given in the tracker survey.





Comparing actual behaviour with what they said

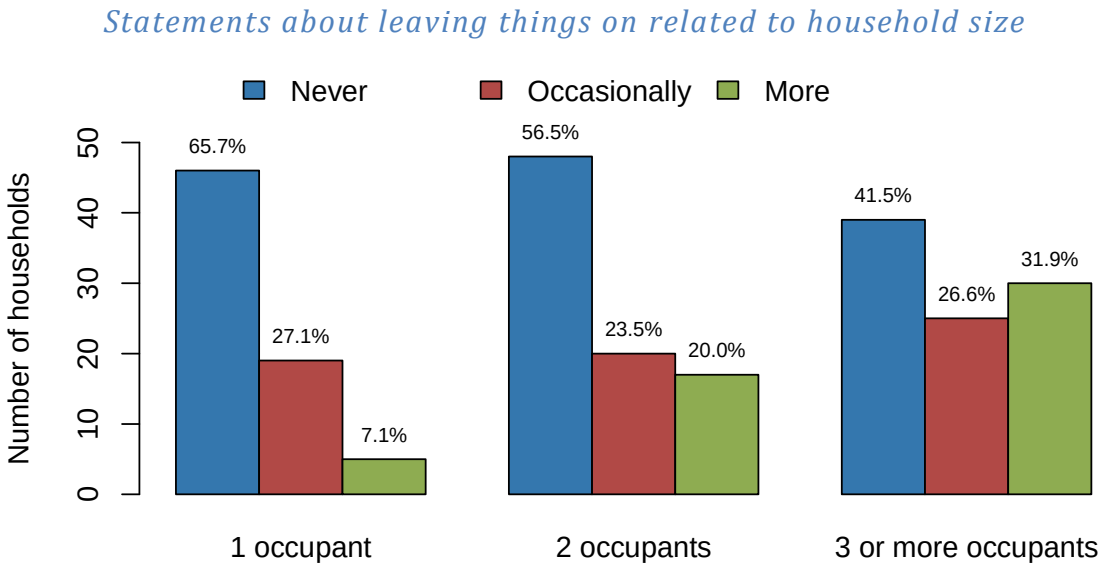
For the questions on energy saving habits there were six answer categories ranging from 'Always' to 'Never'. We grouped categories together where appropriate to obtain more equal sizes for each group. We then compared the answers given by different sized households.

In many cases the values compared are not normally distributed, which makes testing for significant differences using a simple t-test invalid. Where indicated, we replaced this test with the Wilcoxon test, which uses the ranking of each value to test significance instead of the value itself. So the largest value has rank 1, the next rank 2, and so on. This makes the tests valid but unfortunately it is then not possible to give uncertainty ranges for the mean values. We also omitted values where there were less than five samples.

How often do they leave the TV or PC on at home when they are not using them?

For this analysis of the HES households we grouped together the answers 'Sometimes' up to 'Always' to obtain more evenly sized categories. We determined the average hours of use of each appliance by counting time intervals where the power drawn was above a cutoff (20W for a TV, 10W for a desktop computer). Where the household had more than one appliance (many had more than one TV), we used the total for all of them. This means that in some cases the number of hours/day is greater than 24.

The hours of use are strongly related to the size of the household so we performed this analysis separately for each group. The chart below shows the answers given by household size.



Single-person households rarely reported leaving things on more than occasionally, whereas a third of households with more than two people did. However, the chart below shows that the measured use of TVs was largely unrelated to the answers given. (The bar for 1 occupant/More has been omitted because there were only four such households, not enough for a significant average).

Hours of use for TVs relating to household size and statements about leaving things on

For desktop computers there may be a small effect, with the 'More' group running their computers three hours more each day than the most careful. However the difference is only statistically significant in larger households. A difference of three hours corresponds to 80 kWh/year (assuming 70 W on-mode power for the desktop).[10]

Hours of use for Desktop Computers relating to household size and statements about leaving things on

In this chart the bar for one-person household/More is omitted because there was only one case, not enough for a reasonable average.

The table below shows desktop computer hours of use/day according to the answer to 'How often do you leave your TV or PC on at home when you are not using them?' The sample size for households saying they 'never' leave the TV or desktop computer when not using them is

[10] This is different from the estimate of savings from using a laptop instead of a desktop in Intertek (2012) Household Electricity Survey: A study of domestic electrical product usage. London: EST/DEFRA/DECC. That was based on substitution, not three hours' less use.

far larger than the other two groups, and this contributes to the significant result for large households. (One-person households are omitted from the table because there are too few of them for useful analysis.) Overall this suggests there is some link between households' stated behaviour towards switching off unused appliances in the case of desktop computers, although not for TVs. This means that policy-makers cannot rely on stated behaviours alone in assessing the extent to which households turn off unused appliances.

	Two-person households			Larger households		
Answer	Desktop use Hours/day	Sample size	P-value*	Desktop use Hours/day	Sample size	P-value*
Never	7.2	23	0.26	**4.4**	**20**	**0.03**
Occasionally	7.7	7	0.47	6.8	10	0.63
More	10.1	7	0.67	8.0	13	0.68

* Using the Wilcoxon Signed-Rank test

How often do they cut down on the use of hot water at home?

There were 85 households with electric showers who answered this question, and for each of these we determined the average duration and energy use each time the shower was used. We did not use showering frequency because this is affected by hygiene requirements outside of our knowledge (though in fact we found that households showering more than once per person per day spent less time in the shower on each occasion).

We compared the mean shower duration and energy use for each household with their answer to this survey question. There were 59 households saying they tried to reduce hot water at least sometimes, another 12 tried to reduce hot water occasionally, and 14 never did. However, the shower usage was not consistent with their answers to the hot water question. The households reporting they did cut down on energy use had the longest and most energy-using showers. This suggests that policy-makers and others should not rely on self-reported behavior in assessing how household use hot water for showers.

	Sample size	Mean shower Duration (minutes)	P-value*	Mean Energy Use (kWh)	P-value*
Never	14	7.6	0.10	0.71	0.21
Occasionally	12	8.7	0.84	0.68	0.34
More	59	8.7	0.53	0.84	0.52

* Using Wilcoxon Signed-Rank test

The HES householders' average showers were rather longer than the 7 minutes (weekdays) and 8 minutes (weekends) reported in the Waterwise survey[11] However, that survey relied on self-reporting rather than measurement.

How often do they wash clothes at 40 degrees or less?

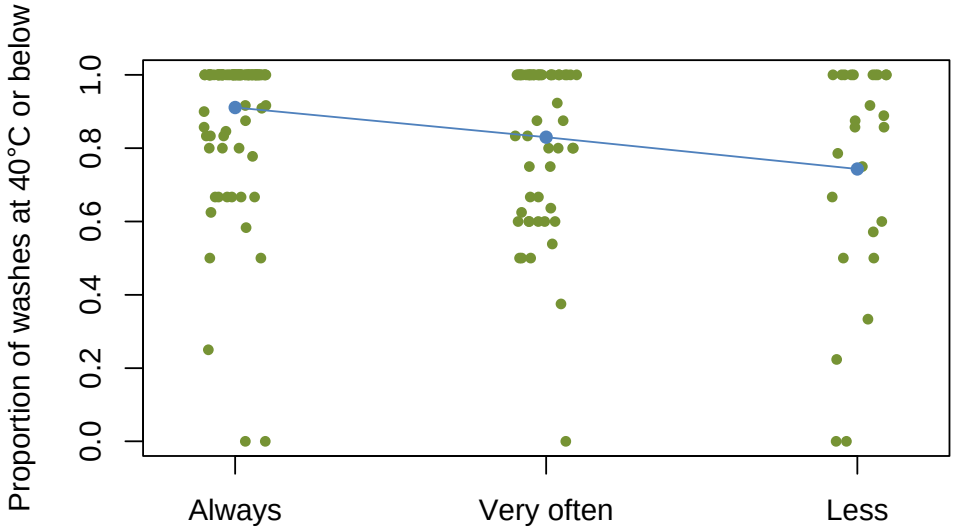
From the diary data we determined the average wash temperature for each household and the proportion of their wash cycles at or below 40°C. For this analysis we ignored cases where the wash temperatures were not given (43 out of 1,206 entries). There were 178 households with washing machines, and of these about half said they always ran at 40°C or less. We grouped the categories from 'Quite often' to 'Never' to obtain more even group sizes. The table below shows the results. On average, households saying they always washed at 40°C or less did so 91% of the time, compared to 74% for the group saying they washed less often at 40°C.

Answer	Sample size	Mean temperature (C)	P-value*	Proportion at or below 40C	P-value*
Always	**97**	**38.3**	**<0.001**	**91%**	**< 0.001**
Very often	55	41.5	0.58	83%	0.71
Less often	26	43.2	0.15	74%	0.33

* Using Wilcoxon Signed-Rank test

[11] Walker, G., 2009 The Water and Energy Implications of Bathing and Showering Behaviours and Technologies. London: Waterwise/EST.
http://www.waterwise.org.uk/data/resources/27/final-water-and-energy-implications-of-personal-bathing.pdf [Accessed 27 March 2014]

Proportion of washes at 40°C or less, related to stated behaviour



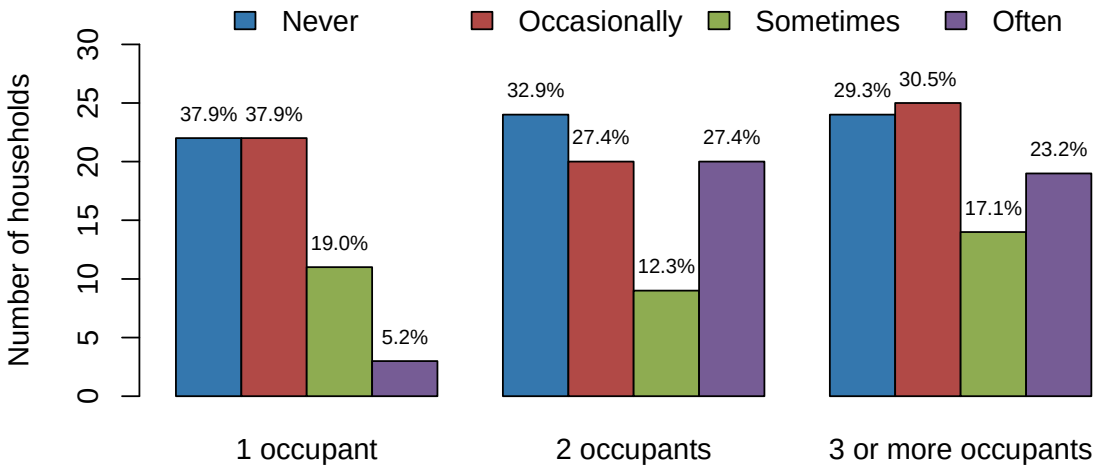
From our earlier work[12] we know that washing machines do use less energy at lower temperatures, though there are many other factors involved. Using data captured from washing cycles we compared the average cycle energy consumption for each household with the average temperature reported from the diary data. Linear regression gave a significant relationship ($p < 0.0001$) with an increase of 17 Wh/°C. The difference between the best and worst categories in the table above is 5°C, suggesting a saving of 85 Wh/cycle for the households running always at 40°C or less. At 5.5 cycles per week this comes to 24 kWh/year. However, many other factors could affect these savings, such as the type of washing machine, frequency of use, which programs are used, and so on.

How often do they leave the lights on when they are not in the room?

We compared the answers to this question with the overall annual lighting energy use for the household. As with our previous analysis on lights left on[12], we excluded households that were monitored only in summer, or where there was no lighting circuit monitored. This left 213 households. Lighting use is strongly related to household size, so we performed the analysis for three size groups. Larger households were much more likely to report that they 'often' left lights on, see graph below.

[12] Palmer, J. et al (2014) Electrical Appliances at Home: Tuning in to energy saving. London: DECC/DEFRA.

Stated behaviour about leaving lights on, by household size

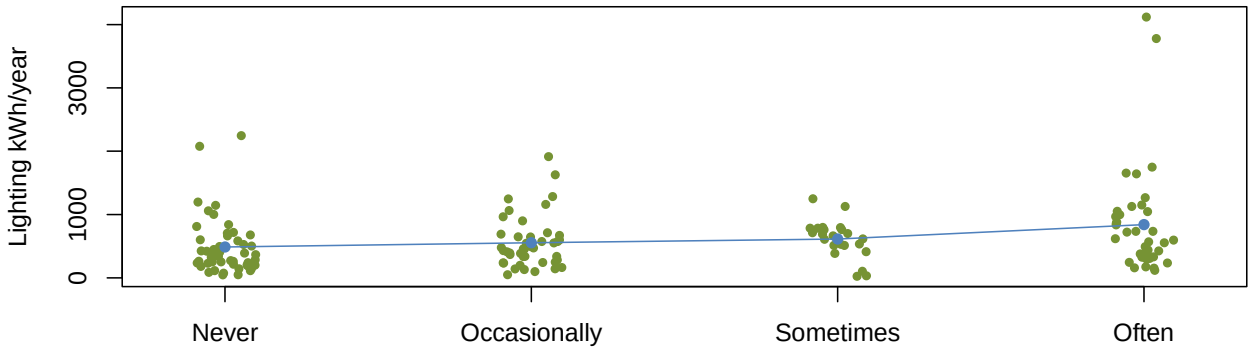


Among households with two or more people, there is a consistent trend of increasing lighting energy use among householders who say they leave lights on.

The next table shows households with at least two people. This suggests that *reported* behavior in relation to leaving lights on is linked to *actual* energy use for the household for lighting, although the link is not strong enough to show a statistically significant relationship at the 5% level.

	Sample size	Mean lighting kWh/year	P-value
Never	48	490	0.06
Occasionally	45	550	0.31
Sometimes	23	610	0.98
Often	39	840	0.10

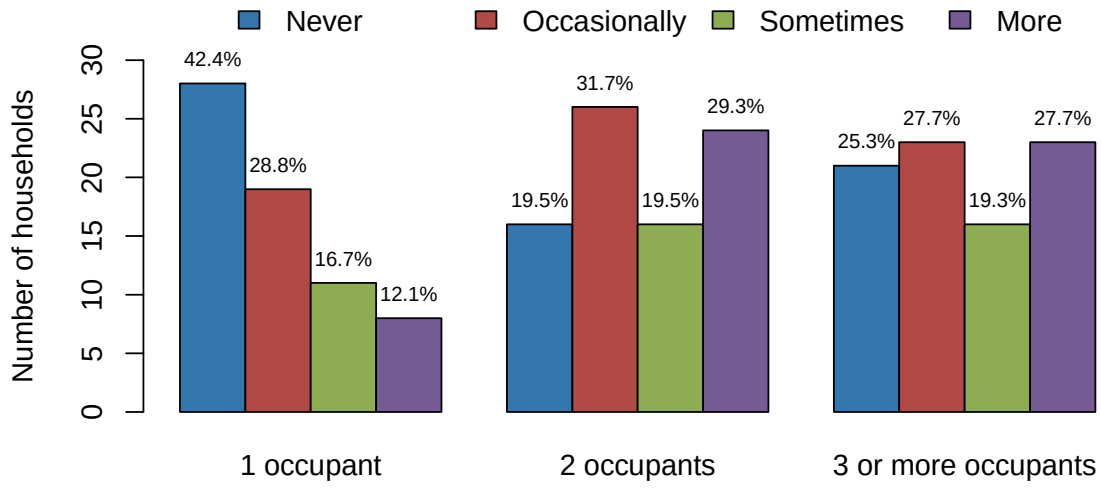
Annual lighting energy use by stated behaviour about leaving lights on, for households with at least two people



How often do they boil the kettle with more water than they are going to use?

We determined the energy used each time a kettle was run, and calculated the average cycle energy for each household. Single person households were much more likely to say they never boiled more water than necessary.

Stated behaviour for boiling kettles with more water than needed, by household size

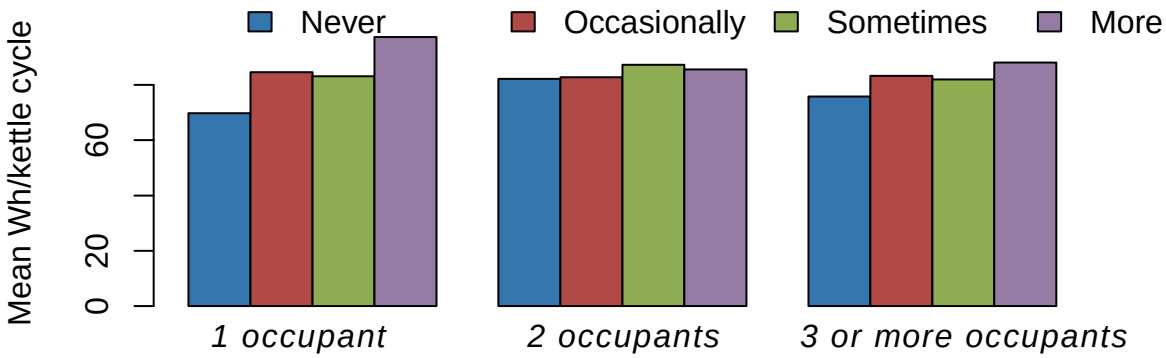


In fact there was little difference in kettle energy use, except in the single person households, as shown in the chart below.

Single-person households' kettle use	Mean Wh/cycle	Sample size	P-value*
Never	**70**	**28**	**0.003**
Occasionally	85	19	0.44
Sometimes	83	11	0.45
More	97	8	0.08

* Using Wilcoxon test

Mean kettle cycle energy by household size and stated behaviour for boiling the kettle with more water than necessary



For the single-person households, the difference in energy use between 'Never' and 'More' was 27 Wh. On average they used their kettles approximately four times per day, which suggests that those who often overfill the kettle could save 39 kWh/year – enough to boil around 1000 mugs of tea (assuming 40 Wh per mug).

Other evidence on savings from not overfilling the kettle

A paper study estimating potential savings from not overfilling the kettle in 2012[13] suggested 83 kWh/year could be saved. There was considerable uncertainty in this figure: the range was from 20 to 347 kWh/year. However, our estimate of 39 kWh/year is not directly comparable because it applies only to single person households. Larger savings may be possible in larger households, but the absence of any significant link here may be a limitation of the survey asking one person to represent the whole household in households of more than one person.

The EST's research[14] in 2013 found that the average household boils a kettle 24 times a week, with two-fifths of households boiling five times a day or more. It found that three-quarters of people boil more water than they need. The EST report did not specify savings per household, but working backwards from its estimate of £68m/year saving for all British households, we infer a per household saving of £2.62/year, or 17 kWh/year. This is less than half that suggested by the HES survey, but the EST study was based on a self-reported survey, not actual energy monitoring.

[13] Palmer, J. et al (2012) How much energy could be saved by making small changes to everyday household behaviours? London: DECC.

[14] EST (2013) At home with water. London: EST. http://www.energysavingtrust.org.uk/About-us/The-Foundation/At-Home-with-Water (accessed 01.04.14)

Buying energy-efficient appliances

The householders were asked what they thought about buying energy efficient appliances. They were asked *Which of these statements applies to you personally at the moment with regard to buying energy efficient ('A' rated or better) appliances, excluding energy saving light bulbs*. We reclassified their answers as shown in the table below, and compared these with the energy classes of some of the appliances that were monitored in their dwelling.

Original classifications	Our classification	Number in sample
I've bought energy efficient appliances and intend to do it again	Maintenance	175
I'm thinking about buying energy efficient appliances	Contemplation	30
I haven't really thought about buying energy efficient appliances OR I haven't heard of energy efficient appliances	Pre-contemplation	31
I've tried buying energy efficient appliances, but I've given up OR I've bought energy efficient appliances, but I probably won't do it again	Relapse	7
I don't really want to buy energy efficient appliances OR I've thought about buying energy efficient appliances, but probably won't do it	Reject	4

* Often energy efficiency is a small part of the decision to buy a new appliance. It may not be the main reason or a reason at all why one model is bought over another.

We selected three of the most common appliances for our analysis: washing machines, tumble dryers, and fridges and freezers. We rejected appliances bought before 2005 because the question referred to their behaviour 'at the moment'.

There were 110 fridges and freezers of various kinds of known energy grade and bought in 2005 or later. However, of these 97 were A-rated, leaving too little variation find any differences in the behaviour groups. (This could be linked to low-rated appliances being withdrawn from the market – even households with no particular desire to purchase energy-efficient appliances do so because these are the (modern) ones available from retailers.)

There were 92 washing machines and only 64 of them were grade A, there were also some A+ washing machines. The table below shows our analysis by behaviour group. There was very little difference between the *Maintenance* group and the other groups.

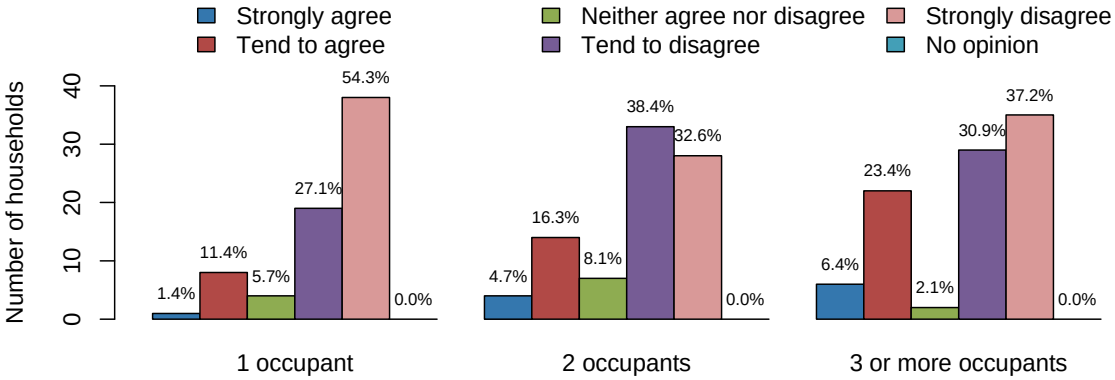
	Better than A	A	Worse than A
Maintenance	14 (22%)	48 (74%)	3(5%)
Never	6 (24%)	16 (64%)	3 (12%)
Relapse	0	2 (100%)	0

There were only 43 washing machines, of which 35 were grade C, and 34 were in the Maintenance group, so there was not enough variation to do an analysis.

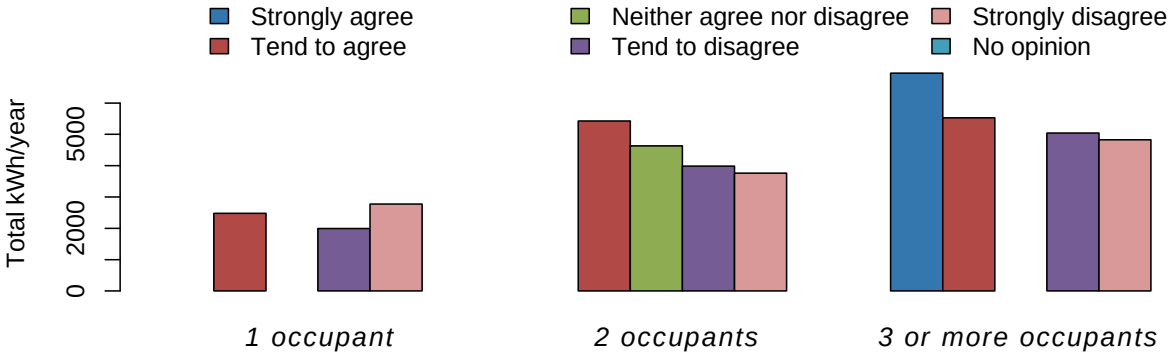
Comparing environmental beliefs and attitudes with overall energy use

The householders were asked to rate 17 statements about the environment and policy on a Likert scale with six answers – from 'Strongly Agree' to 'Strongly Disagree'. We compared their answers with overall energy use (total annual electricity in kWh/year, including electric heating). Since household size is also an important factor driving energy use we took this into account in our tests. We were able to perform this analysis for all 250 households. Their answers did not correlate significantly with their overall energy use except for the question regarding water use.

I don't pay much attention to the amount of water I use at home



Householders who said they do not pay attention to the amount of water they use tended to use more electricity. Energy use is also closely related to household size, and the agreement between stated attention to water and measured energy consumption was stronger among larger households. The chart below shows the same trend persists in households with at least two people.

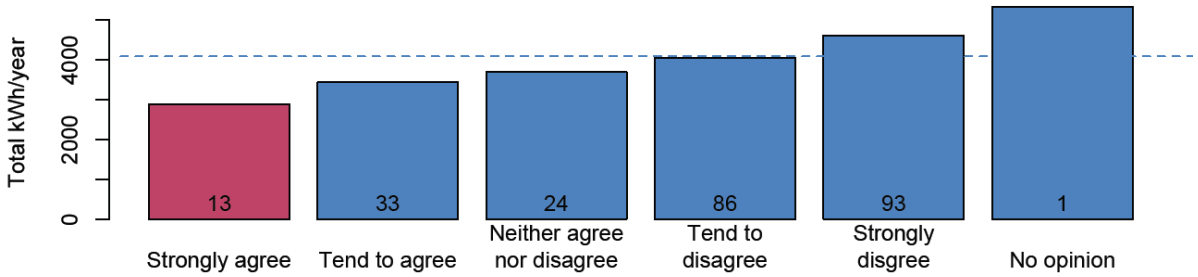


This table omits single person households because too few of them agreed with the statement to show a trend in the answers. It includes all those with two or more people. None of the groups are significantly different from the mean, but the trend is consistent, with those paying less attention to water using more energy.

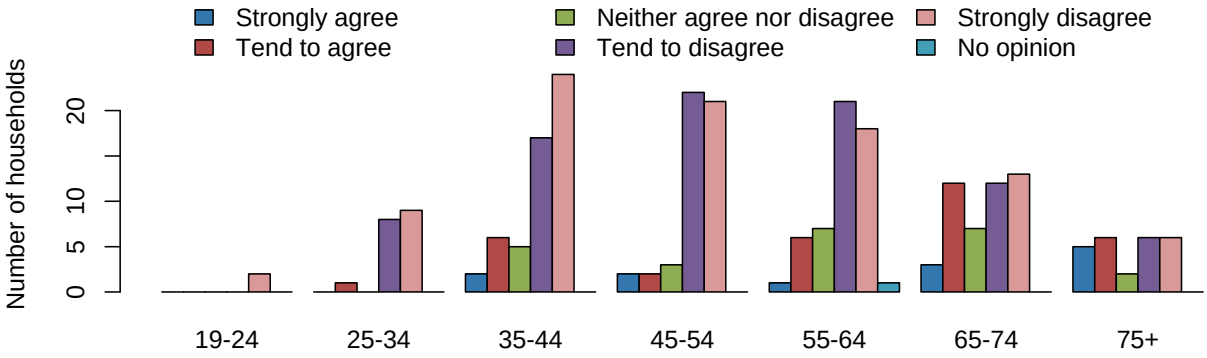
I don't pay attention to water	Number in sample (dwellings with two or more residents)	Mean kWh/year	p-value
Strongly agree	10	5,760	0.35
Tend to agree	36	5,490	0.23
Neither agree nor disagree	9	4,720	1.0
No opinion	0	-	-
Tend to disagree	62	4480	0.31
Strongly disagree	63	4350	0.14

The effects of climate change are too far in the future to really worry me

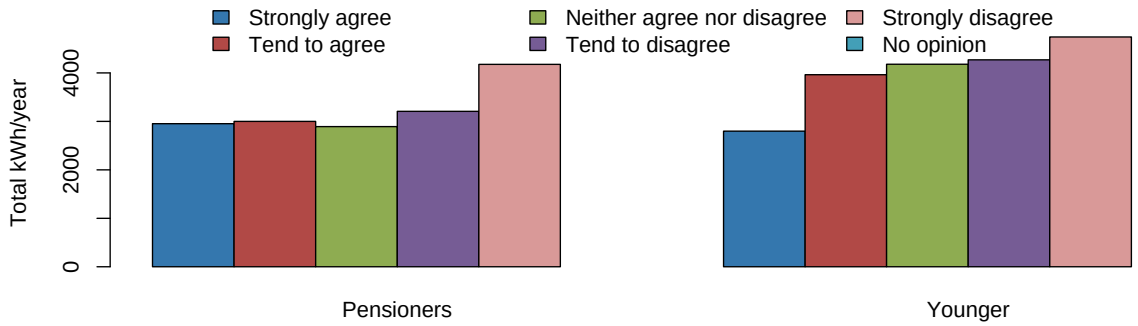
Taken all together, householders who strongly agreed they were not worried about climate change because it was too far in the future in fact used less electricity rather than more, counter to the hypothesis that households concerned about climate change use less electricity.



However, we found this was largely due to the effect of age, as older households were much more likely to agree with this statement, and also had lower energy consumption.



When we separated the pensioner households from younger ones (defined here as under 65) there was no significant relationship between this statement and energy use in the pensioner group, and only a weak trend among the younger households.



Climate change is too far in the future to worry me	Pensioners			Younger (under 65)		
	Sample size	Mean kWh/year	p-value	Sample size	Mean kWh/year	p-value
Strongly agree	8	3000	0.38	**5**	**2800**	**0.04**
Tend to agree	18	3000	0.38	15	4000	0.57
Neither agree nor disagree	9	2900	0.25	15	4200	0.63
Tend to disagree	18	3200	0.76	68	4300	0.65
Strongly disagree	19	4200	0.44	74	4700	0.25
No opinion	0	-	-	1	5300	-

Observations and recommendations

■ Comparing the 250 HES householders with respondents to the 2009 DEFRA Tracker survey respondents, they had similar views on the environment and climate change. However, the HES householders were more likely to disagree with suggested barriers to behavior change, and although more of them claimed to do some 'environmentally friendly' things, fewer of them said they do most of what was possible.

■ Single householders were much more likely to say they are careful about energy use, for example not leaving things on when not needed, or boiling more water in the kettle than needed.

■ What householders said was sometimes an indicator of what they did but not always. We found claims to avoid leaving appliances on when not in use had no discernible effect on the hours of TV being on, but were significant for computers being on. Similarly, claims to save hot water were not related to length of showers but single-person households did show a link between kettle use and claims to not overfill. This means that policy makers should be careful about relying on stated behaviours alone as evidence.

■ Where householders did practice what they claimed to there were considerable savings. In households with at least two people the more careful households ran their desktop computers three hours less per day, saving approximately 80 kWh/year.

■ Lighting energy use was strongly related to statements about leaving lights on: few single person households said they left them on often, but for households with at least two people the most careful group ('never' leaving lights on) used little more than half the energy of the most careless group ('often' or more), a difference of 350 kWh/year.

Other evidence comparing energy use and beliefs

Studies on environmental attitudes and behaviours have shown that over the last 20 years, the general population has become more aware of environmental issues. A study[15] of 24 countries found that societies with higher levels of environmental concern had lower CO_2 emissions per unit of goods/services produced.

However, the study said this may be partly a result of the correlation between the state of development and higher levels of tertiary service sector activity, which have lower CO_2 emissions intensity. At the individual level, the study reported that environmental concerns only tended to translate into environmental behaviours if behaviours are not 'cost intensive', like recycling. More expensive behaviours (e.g. energy saving activities or choosing public transport) depended more on financial and material incentives than attitudes.

Since March 2012, DECC has conducted quarterly surveys of public attitudes to energy and environmental issues[16]. These continue from similar studies commissioned by DEFRA since the mid-1980s. The most recent data release, in February 2014, found that around three-quarters of respondents claimed to give a fair amount or a lot of thought into saving energy at home. This is similar to the level of responses since July 2012: between 73% and 81%. Some differences were found among respondents, with a higher proportion of 'fair amount or a lot of thought' responses in social grades A & B than in grades D & E, and from retired occupants than those in full-time employment.

The studies found that the majority of respondents claimed to do things to reduce their domestic energy consumption – at least quite often. Energy-saving behaviour mentioned included minimising waste water in kettles (34%), using low-temperature washing cycles (57% at 30°C or lower), and reducing indoor temperatures in empty rooms (58% to 64% between 2012 and 2014).

The 2011-2012 edition of the British Social Attitudes survey[17] also evaluated public attitudes towards the environment. This suggested that the proportion who always or often reduce energy use at home, or save/re-use water was 39% and 32% respectively. By contrast, 86% always or often make an effort to recycle, double the response in 1993.

■ Households that say they often overfill the kettle could save 39 kWh/year by boiling no more water than they need – enough to boil around 1000 mugs of tea.

■ None of the stated attitudes about environmental or climate change had any significant impact on overall energy use when household age was taken into account.

■ Households that say they pay attention to water tend to use less electricity overall than households that do not pay attention to water. However, although the trend was consistent, there was insufficient data to determine if the difference between groups was significantly different.

[15] Franzen, A., & Meyer, R. (2010). Environmental attitudes in cross-national perspective: A multilevel analysis of the ISSP 1993 and 2000. European Sociological Review, 26(2), 219-234.

[16] DECC (2014) DECC Public Attitudes Tracker – Wave 8. London: DECC. https://www.gov.uk/government/collections/public-attitudes-tracking-survey (accessed 31.03.14)

[17] NatCen (2014) British Social Attitudes 29. London: NatCen. http://www.bsa-29.natcen.ac.uk/read-the-report/transport/belief-in-climate-change.aspx (accessed 31.03.14)

How do potential energy savings differ between social groups?

The Departments wanted to compare the potential energy savings for households divided into socio-economic groups. This work builds on our earlier analysis, and allows us to carry out more detailed investigation of the savings from:

- turning appliances off instead of leaving them on standby
- buying appliances that are no larger than necessary
- replacing inefficient appliances with more efficient ones.

Approach

We calculated the potential savings for each household by each of the three methods listed above. Then we grouped these into National Readership Survey socio-economic groups and found the average. As for the previous section, we merged the socio-economic groups into three – A/B, C1/C2 and D/E – in order to obtain larger groups and more significant results. The table below shows the size of sample for each of socio-economic group: reasonable samples for C1/C2 and A/B, but rather small for D/E social grades.

Group	Description	Sample Size
A/B	Professional and managerial	81
C1/C2	Supervisory, clerical and skilled manual	135
D/E	Semi-skilled, unskilled, pensioner and non-working	33

Switching appliances off instead of leaving them on standby

In our earlier work[18] we calculated standby power consumption for a large number of individual appliances, and worked out the proportion of time each appliance was left in that mode. We used this data to compute the daily energy use for each of the appliances and added together those for each household to get a total for the potential standby saving of the household.

For this analysis we selected appliance types that typically used at least 10 Wh per day, and where there were at least 10 examples. We excluded modems, routers, sky boxes and set

[18] Palmer J, Terry N, Kane T (2013) Further Analysis of the Household Electricity Use Survey: Early findings – demand side management. London: DECC/DEFRA

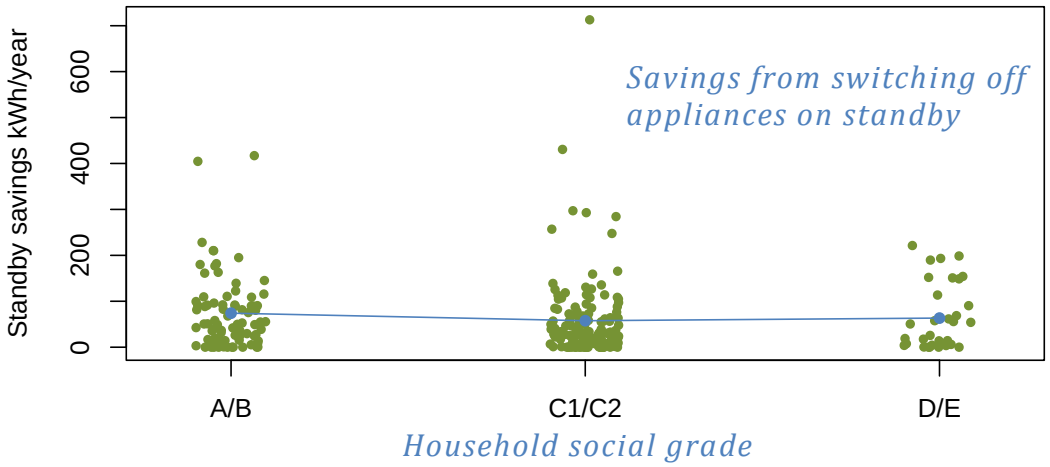
top boxes, dvd recorders and VCRs because they are often required to be on all day. This left us with:

- Audiovisual: tvs, hi-fi's, wii's, dvds, and other audiovisual appliances
- ICT: desktop computers, printers, multi-function printers, computer sites (comprising several computer related appliances on one socket), monitors
- Kitchen: microwaves, ovens, cookers, hobs

Since audiovisual sites (where several AV devices are all plugged into the same socket and monitored together) may include set top boxes, and computer sites may include modems and routers, our analysis gives an overestimate. Also, kitchen equipment may not have an easily accessible switch, so turning off kitchen appliances may not be possible. However, the savings for kitchen equipment were small: only the microwave had an average saving of more than 20Wh/day.

The overall mean saving was 64 kWh/year from standby and the inter-quartile range was 23 kWh/year to 245 kWh/year. From the strip-chart it can be seen that the savings we identified were similar between socio-economic groups. There was no significant difference between the groups.

	Sample size	Mean potential standby savings kWh/year	p-value
A/B	81	78	0.14
C1/C2	135	61	0.57
D/E	33	54	0.33



There were four households with potential savings above 400 kWh/year. In one case the total was almost entirely due to a desktop computer, in another it was a computer site and in the other two it was a variety of equipment but mainly audio equipment.

Since this study took place in 2010/2011 most of the appliances monitored were purchased before EU Directive 1275/2008 17/12/2008 came into effect in 2009. All of them were purchased before the Tier 2 regulations, including appliances with displays, came into force in 2012. Therefore it is likely that standby savings will reduce over time as appliances are replaced.

Switching to smaller appliances

Our earlier work[19] found potential savings from TVs, fridges and fridge-freezers, where newer appliances (bought since 2004) tend to be larger and these tend to use more energy. For example, we found that the average size of TVs bought before 2004 was just over 22.2" but from 2004 to 2009 it was 29.5". We also determined that newer TVs of small size (20 – 24") consume only 55 W on average, compared to 110 W average for all sizes.

It is difficult to say how large appliances need to be, since it varies with household habits and social norms. For this analysis we have assumed appliances could be the same average size as appliances bought prior to 2004. (We accept that this is a moot point, and hard to prove or disprove.)

Since we do not have full information about all appliances, we computed the savings for households where we know the size of at least one appliance. To get an average across all households we adjusted the mean by the fraction of households owning the appliance. We did this calculation for each social group.

For TVs we had size information for 281 appliances from 190 households. Of these, 79 were 22" or less in size. For the other TVs we determined savings by calculating the excess Watts over 55 W (average for new TVs 20"- 24") times the hours in the day when the TV was typically used. Ignoring homes with no TVs of known size, summing the Watts x hours of use for each dwelling gave an overall potential saving. These values are shown in the chart below. The overall mean was 161 kWh/year, but the A/B group had significantly lower savings than the average (p=0.02), only 121 kWh/year. The inter-quartile range over all groups was 15 kWh/year to 220 kWh/year.

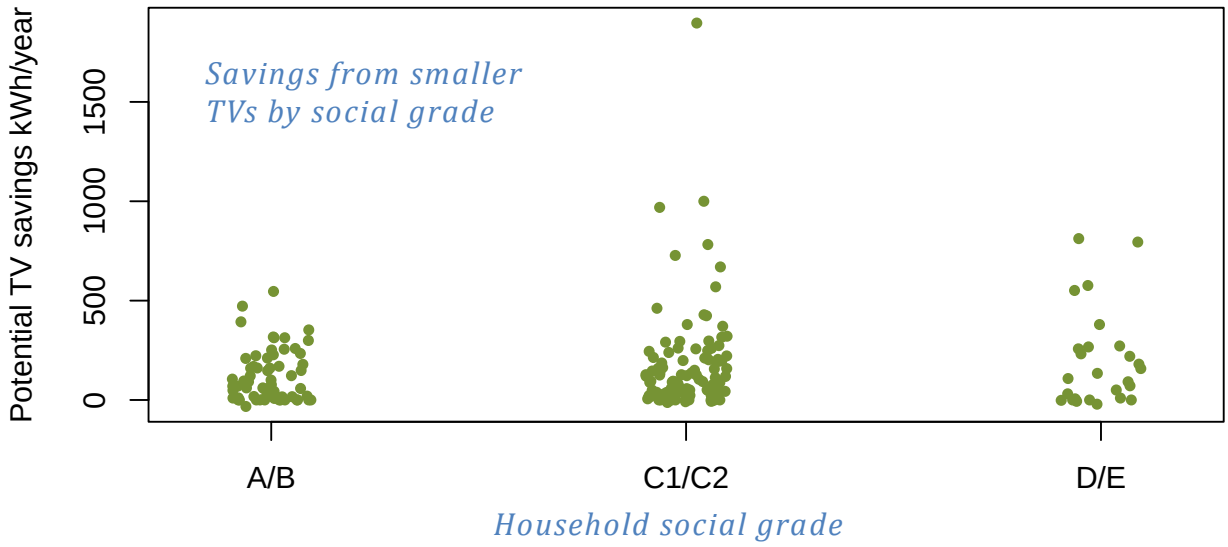
There are six households with potential savings of more than 750kWh/year. Three of these were due to large plasma TVs (two of 42" and one of 46"). There were also some high-consuming 50" LCD TVs. In three of these households the TV was on more than 12 hours per day. None of these six households were in the A/B group.

The TVs monitored in this study were purchased before the EU Eco-Design Directive on TV energy efficiency came into force in 2012[20]. This aimed to improve the reduce energy use by setting a limit for the power consumption on any TV that is sold. The on-power limit now

[19] Palmer J, et al (2013) Electrical Appliances at Home: Tuning in to energy saving. London: DECC/DEFRA.

[20] European Commission (EC) (2009) No 642/2009 of 22 July 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for televisions. Brussels: EC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:191:0042:0052:EN:PDF

depends on the area of the screen: the maximum for TV sets should be (Area+16) x 3.4579 W, where Area is in dm^2. In the HES, 121 of the 281 TVs in the study were over this limit. Over time, this will reduce the effect of savings from smaller appliances presented here – when all TVs are replaced with compliant sets, by around 13%.

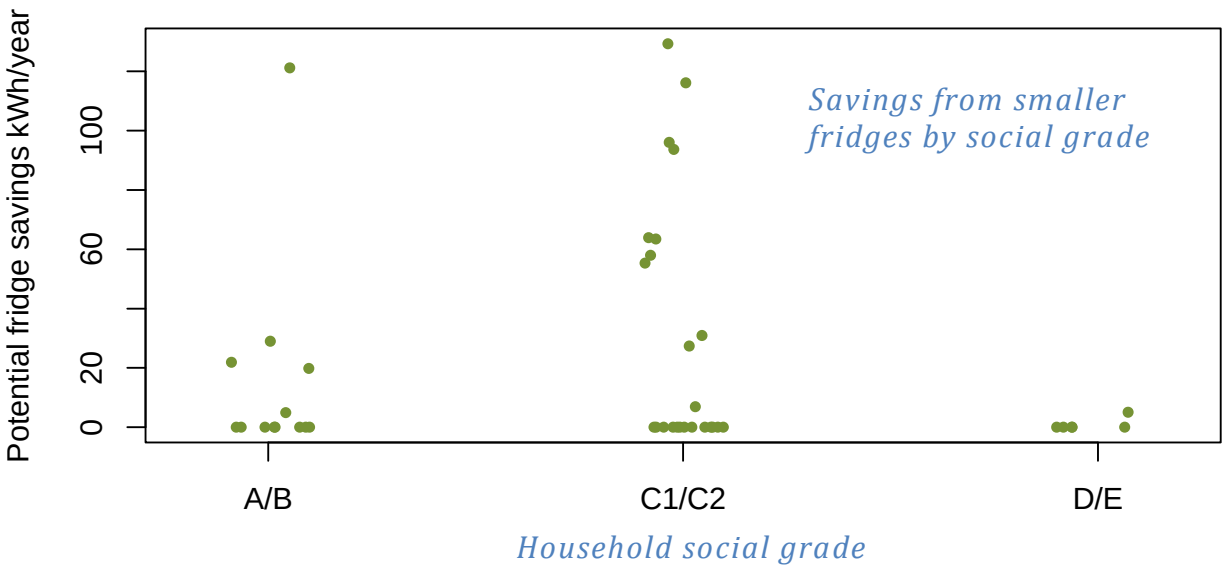


The following table shows adjusted (for the fraction of homes owning each appliance, see previous page) and unadjusted mean savings for households if they substituted a smaller TV. Almost all households had a TV so there is little adjustment to apply.

Social Grade	Sample size	Unadjusted mean savings kWh/year	p-value for unadjusted mean	Fraction of households owning TVs	Adjusted mean savings kWh/year
A/B	62	121	0.02	0.99	119
C1/C2	103	177	0.54	0.99	176
D/E	27	193	0.48	1.00	193

Households in social groups A and B had significantly less potential savings from smaller TVs.

We used a similar rationale to compute potential savings from smaller fridges and fridge freezers. For fridges, out of 113 appliances monitored, only 74 had the size recorded in the HES. The mean size for fridges purchased up to 2004 was 137 litres, while for those bought in 2004 onwards it was 187 litres. The average energy consumption of newer fridges between 117 and 157 litres was 134 kWh/year. We found 18 fridges larger than 137 litres consuming more than 134 kWh/year. These fridges came from 17 households, with potential savings up to 130 kWh/year.



The next table shows the mean savings from substituting smaller fridges by group. The D/E group has significantly lower savings potential (though the sample size is very small).

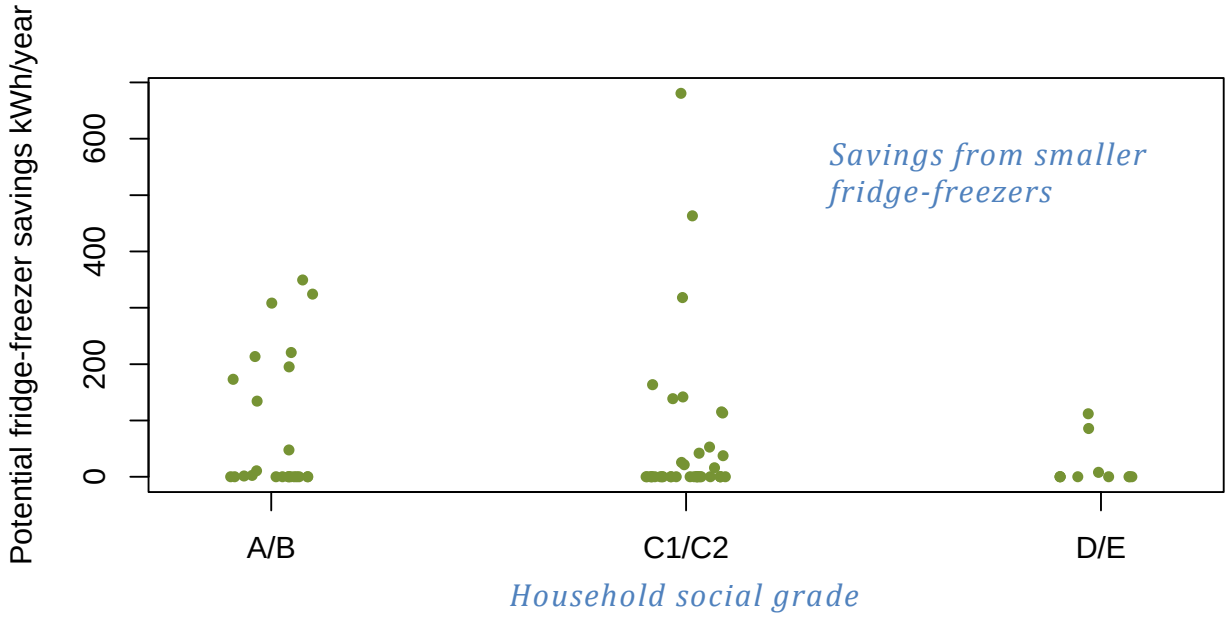
Social Grade	Sample size	Unadjusted mean savings kWh/year	p-value for unadjusted mean	Fraction of households owning a fridge	Adjusted mean savings kWh/year
A/B	13	15	0.48	0.56	8
C1/C2	24	31	0.31	0.52	16
D/E	6	1	< 0.001	0.36	0

For fridge-freezers, our earlier work showed that up to 2004 the average size was 260 litres (total of the fresh and frozen compartments), and from 2004 onwards it was 310 litres. Fridge freezers with capacities of 240-280 litres consumed an average of 344 kWh/year. We selected fridge freezers larger than 260 litres and consuming more than 344 kWh/year, and estimated the savings from replacing them. There were 30 cases where savings were possible and the results are shown in the strip chart below. Of the two cases with highest savings, one is actually a moderate size fridge-freezer, size 265 litres, which appears to have failed because it has very high consumption and never seems to switch the compressor off. The savings are therefore due less to size than to correct functioning. The other is a large fridge freezer, total 557 litres.

This table shows the mean savings for smaller fridge-freezers by group. Once again, the D/E group has significantly lower savings potential.

Social Grade	Sample size	Unadjusted mean savings kWh/year	p-value for unadjusted mean	Fraction of households owning a fridge freezer	Adjusted mean savings kWh/year
A/B	24	83	0.40	0.72	59
C1/C2	39	60	0.95	0.73	44
D/E	**11**	**19**	**0.006**	**0.82**	**15**

The chart below shows potential savings from substituting a smaller fridge-freezer in households from different social grades. There is a much greater range among A/B or C1/C2 social groups, with six households indicating a potential saving of more than 300kWh/year. However, this may be affected by the smaller sample of households in social grades D/E.



Replacing inefficient appliances with efficient ones

For appliances such as fridges and freezers, washing machines and so on, we have already seen that many households own items that are not as efficient as they could be. For example, 75% of the cold appliances monitored were rated A, whereas A+ appliances and better are now available. In some cases the top-rated appliances are only available at a much higher price, for example A-rated tumble dryers are currently around £650 more expensive than a C-rated model (partly because they use heat pumps or gas technologies)[21].

[21] Which, Tumble Dryer Energy Costs. See http://www.which.co.uk/home-and-garden/laundry-and-cleaning/guides/tumble-dryer-energy-costs/

This high cost of energy efficient appliances is discussed in a later section of this report.

We calculated the energy savings that were possible in each household by assessing the likely energy savings for four groups of appliances: cold appliances, washing machines, tumble dryers and dishwashers. We then compared the total potential savings for households grouped by socio-economic group.

The savings for each group relates to both the overall ownership of the appliance in the group, and the energy ratings of appliances in the group. The HES does not have energy ratings for all appliances. For example, the survey for ownership reported 228 washing machines, but only 206 were monitored, and the energy rating is known for just 140. As with the analysis of smaller appliances, we calculated the savings for each household based on the appliances where we have enough information, and adjusted for the proportion of households not owning the appliance. In the case of cold appliances, this means we underestimate the savings because many households have more than one appliance, but we have data for only some of them.

The following table shows the rating we chose as being the best that is readily available now, and the proportion of appliances below this rating, for each appliance group. The A/B household group was little different from other households.

	Best available rating	Most common rating	Efficiency improvement from most common to best available	Proportion of appliances which can be upgraded: all households (A/B households)
Cold appliances	A+	A	24%	98% (92%)
Washing machine	A++	A	23%	99% (100%)
Tumble dryer	A	C	39%	98% (96%)
Dishwasher	A++	A	21%	100% (100%)

The grey box below shows how we estimated the savings in each household.

Estimating potential savings for each appliance

Energy ratings of appliances are set by directives from the EU. They stipulate how the typical annual energy use is calculated, then this is compared with a reference value to get the Energy Efficiency Index (EEI), and from this the rating is determined from a table of cutoff points. For example, washing machines cutoff points are as shown in the table below. The cutoff points suggest that, for example, an A+ machine uses roughly 87% (59/68) of the energy use of an A-rated machine.

This method does not require information about how each appliance is used, such as how often a washing machine is run, or whether the fridge is in a cold or a warm place. It does assume that if an A+ machine uses 13% less energy for the typical annual energy use, then it will also do so for other use patterns. This assumption is questionable in some cases, particularly for washing machines, as the 'typical energy use' is calculated based on a rather unusual pattern of use, with 5 out of 7 washes at 60°C, whereas in fact the HES households rarely washed at more than 40°C.

Washing machine Rating	Energy Efficiency Index Cutoff
A+++ (defined but not yet available)	EEI < 46
A++	46 <= EEI < 52
A+	52 <= EEI < 59
A	59 <= EEI < 68
B	68 <= EEI < 77

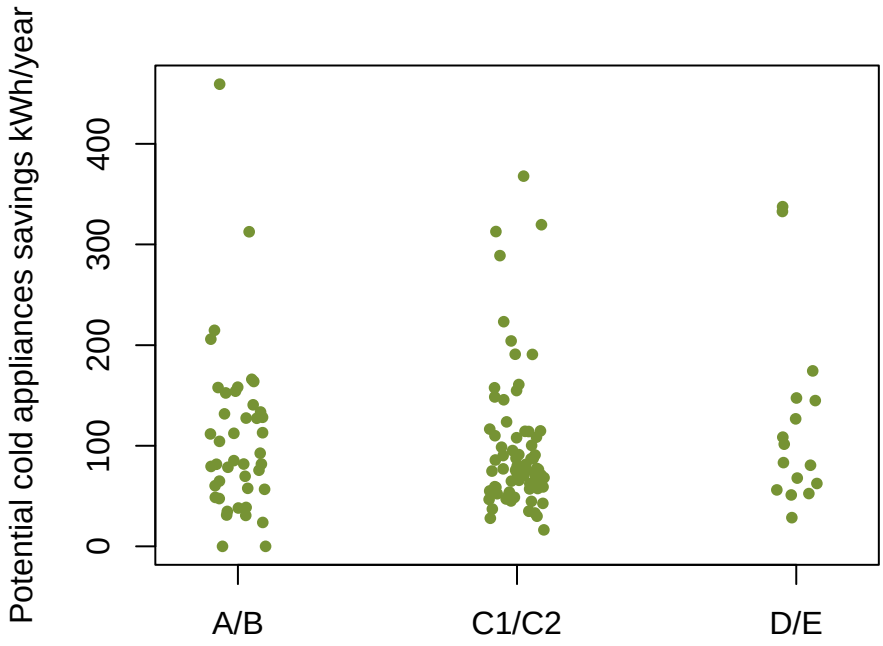
We multiplied the annual energy use for the appliance by this efficiency ratio to determine the likely improvement.

The next table shows the mean potential savings across all households, per year, for each appliance by socio-economic group. None of the differences between social groups was significant.

	Social Grade	Sample size	Unadjusted mean savings kWh/year	P-value for unadjusted mean	Fraction of households owning appliance	Adjusted mean savings kWh/year
Cold appliances	A/B	43	108	0.76	1	108
	C1/C2	74	98	0.44	1	98
	D/E	16	122	0.44	1	122
Washing machine	A/B	44	21	0.90	0.88	18
	C1/C2	73	20	0.97	0.92	18
	D/E	18	20	0.94	0.94	18
Tumble dryer	A/B	28	182	0.88	0.53	97
	C1/C2	29	199	0.78	0.54	108

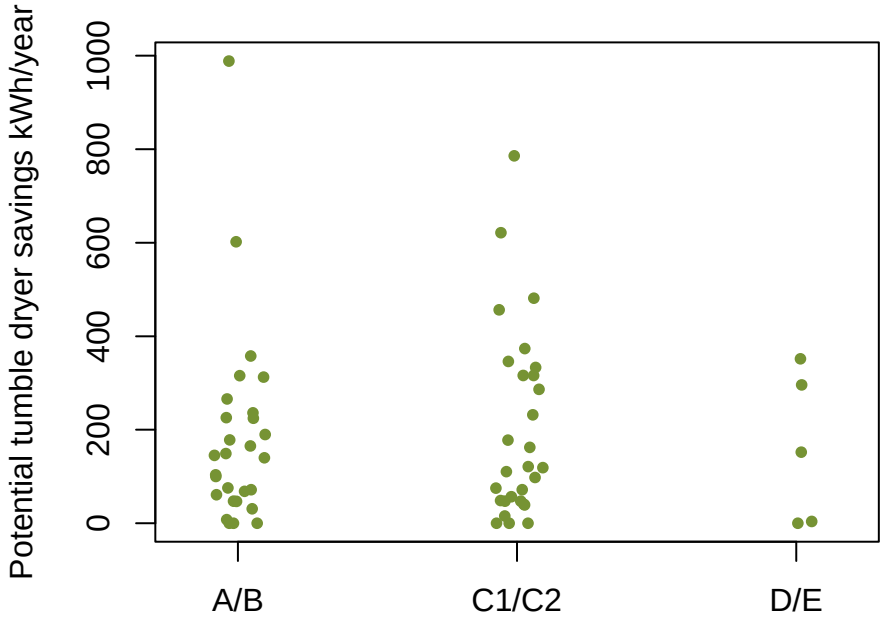
	D/E	5	161	0.72	0.48	78
Dishwasher	A/B	19	48	0.43	0.74	36
	C1/C2	27	39	0.42	0.55	21
	D/E	3	48	-	0.33	16

The large potential savings for cold appliances reflects high levels of ownership, with nearly two units per household compared to only around half of households having a tumble dryer or a dishwasher. The average saving for cold appliances across all households was 104 kWh/year, and the inter-quartile range was 57 kWh/year to 127 kWh/year.



Savings from more efficient cold appliances

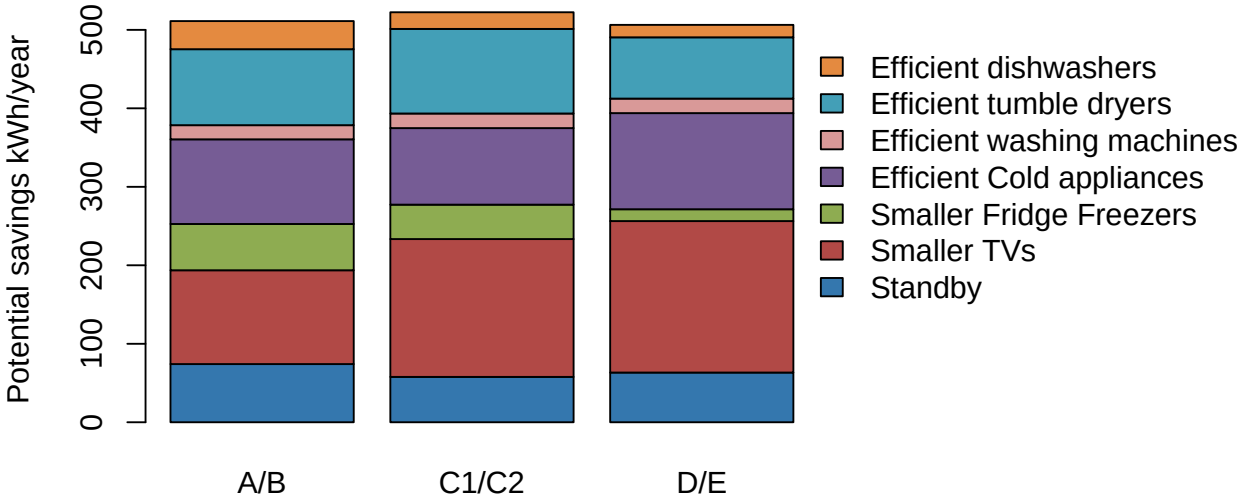
The tumble dryers have the next highest expected savings, due to the large improvement between C and A ratings, and the high annual consumption of tumble dryers generally. These are shown in the chart below. The average saving is 189 kWh/year for households that have a tumble dryer.



Savings from more efficient tumble dryers by social grade

Summary

This final chart shows the overall savings we have identified, by socio-economic group. Overall, the savings potential is similar across all three groups, although the A/B households have more savings from smaller fridge freezers, whereas the D/E households save more from smaller TVs. In fact for all groups the single largest potential saving is from smaller TVs.



The other point to emerge from the strip-charts in this section, and the high inter-quartile ranges, is the wide variation in energy use *within* social groups. This suggests there are limits to the effectiveness of using social group as a focus in policy.

Observations and recommendations

■ There are only minor differences between the potential energy savings for different socio-economic groups. Groups A and B had lower potential savings from smaller TVs, and Groups D and E had lower potential savings from smaller fridges and fridge-freezers.

■ For all groups the largest savings would be from smaller TVs, approximately 160 kWh/year from limiting the size to 22", which was the norm prior to 2004. The inter-quartile range was 15 kWh/year to 220 kWh/year. However, since large TVs are now so prevalent it may not be acceptable for households to return to their previous habits. New TVs had to have energy ratings from 2011 onwards so consumers who consider energy consumption important can make informed choices when they buy new appliances. Since 2012, TVs also had to use less energy.

■ There are also very considerable savings for some households from upgrading to a more efficient tumble dryer: an average of 189 kWh/year for households that have them, and 400kWh or more in some cases where the appliance is heavily used.

Other work on savings from different socio-economic groups

Other evidence about energy use differences in socio economic group shows that income group is an important factor in energy use, but that within each group there is still a high level of variation.

Analysis[22] of data from the 1996 English House Condition Survey showed that median domestic energy consumption rose fairly steadily though deciles of income in the UK, with a correlation coefficient of 17.1%. However, the median masked huge variation within each of the income deciles: in the lowest decile, the energy use of the 80th percentile was nine times higher than the 20th percentile. When income was adjusted for household size and composition (to produce the 'equivalent income'), the correlation between energy and income fell to 8.1%.

A UK domestic energy model considering energy use in different segments of the UK population reached similar conclusions[23]. This showed that energy use was '…strongly, but not solely, related to income levels'. The research also identified dwelling type, tenure, household composition, and rural/urban location as important.

■ Almost all households could make savings from more efficient cold appliances: an average of 104 kWh/year across all households, or 58 to 127 kWh/year for the inter-quartile range.

[22] Dresner, S., Ekins, P., 2004. Economic Instruments for a Socially Neutral National Home Energy Efficiency Programme. London: Policy Studies Institute.

[23] Druckman, A., & Jackson, T. (2008). Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. Energy Policy, 36(8), 3177-3192.

Examining electricity use of pensioners by socio-economic group

The Departments wished to compare energy use by wealthy and low income pensioners. Unfortunately the HES dataset did not include income, so we used socio-economic group as a proxy for this.

Approach

We merged the socio economic group classification down from six groups to three, in order to obtain sufficient numbers in each group to obtain significant results. Then we compared the three groups for total energy use and by appliance type. We have excluded heating as there were only four cases of pensioners using electricity for primary heating and 10 for secondary heating – not enough cases to show significant trends. Further, there were only 10 pensioner households using electricity for water heating and 18 with electric showers, so these categories were excluded.

We also compared the trends we found among pensioners with the corresponding data for parallel non-pensioner households: households with up to two people but no children.

Analysis

First we compared the total electricity use of the three pensioner groups. We found the A-B group used nearly 50% more energy than the C1-C2 group, and the D-E group used less again, on average. There were also significant differences for ICT, and the Washing, drying and dishwasher category. However, there was little difference between the groups' average use for Audiovisual, Cooking or Cold appliances.

	A-B kWh/year (n=15)	C kWh/year (n=31)	D-E kWh/year (n=8)	p-value for trend
Total (excluding heating)*	**3510**	**2390**	**2300**	**0.008**
Cold appliances	670	500	660	0.70
Lighting	**510**	**210**	**290**	**0.03**
Cooking	390	370	460	0.70
Washing, drying dishwasher	**390**	**120**	**100**	**0.02**
ICT	**230**	**84**	**47**	**0.005**
Audiovisual	440	420	390	0.65
Other	236	47	83	0.07
Unknown	580	450	250	0.08

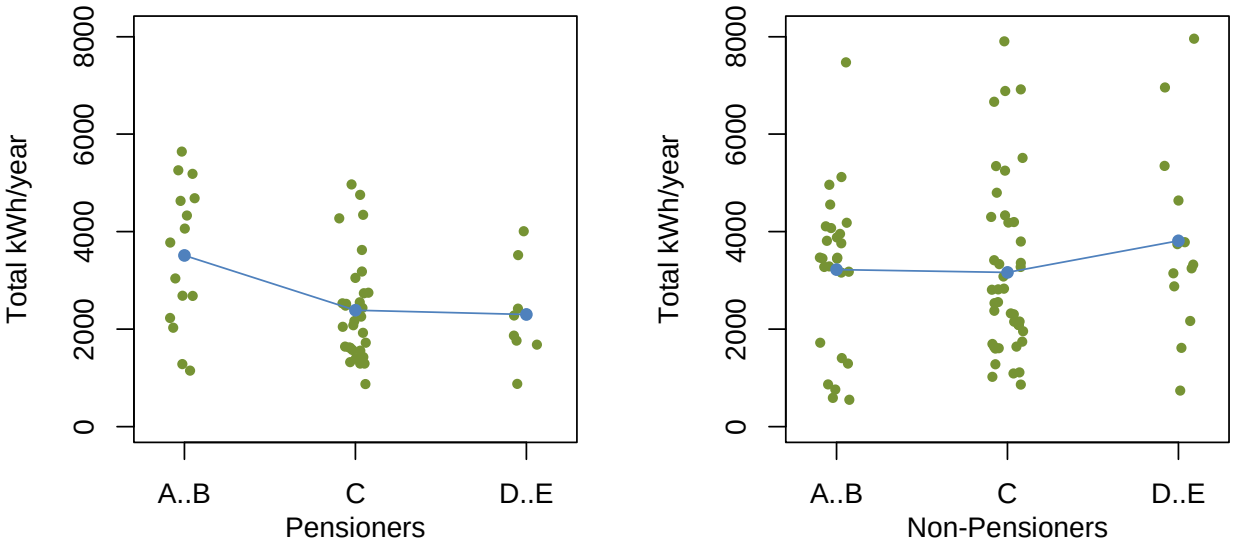
(*Total includes all energy use except heating. Blue text indicates significant differences at 5%.)

These differences were more pronounced than those between different socio-economic groups for non-pensioner households. The following strip charts show the variation and mean values for total energy use, lighting, ICT, and washing appliances. The A-B pensioner group has similar electricity use to the mean for non-pensioners.

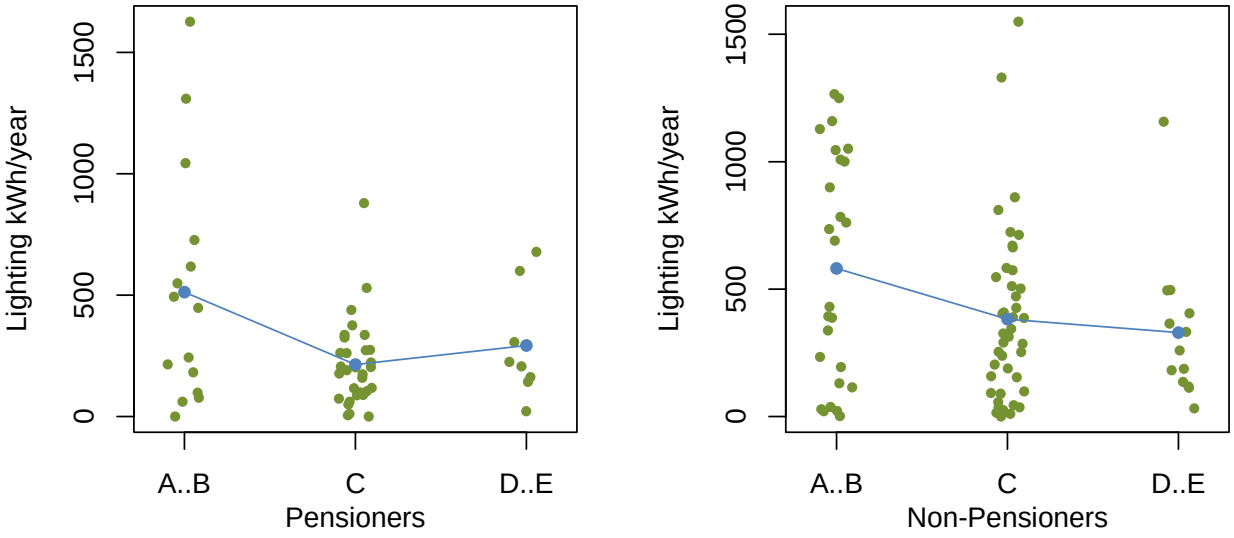
Annual electricity use by socio-economic group for pensioners and non-pensioners

Blue lines mark the mean values for each group

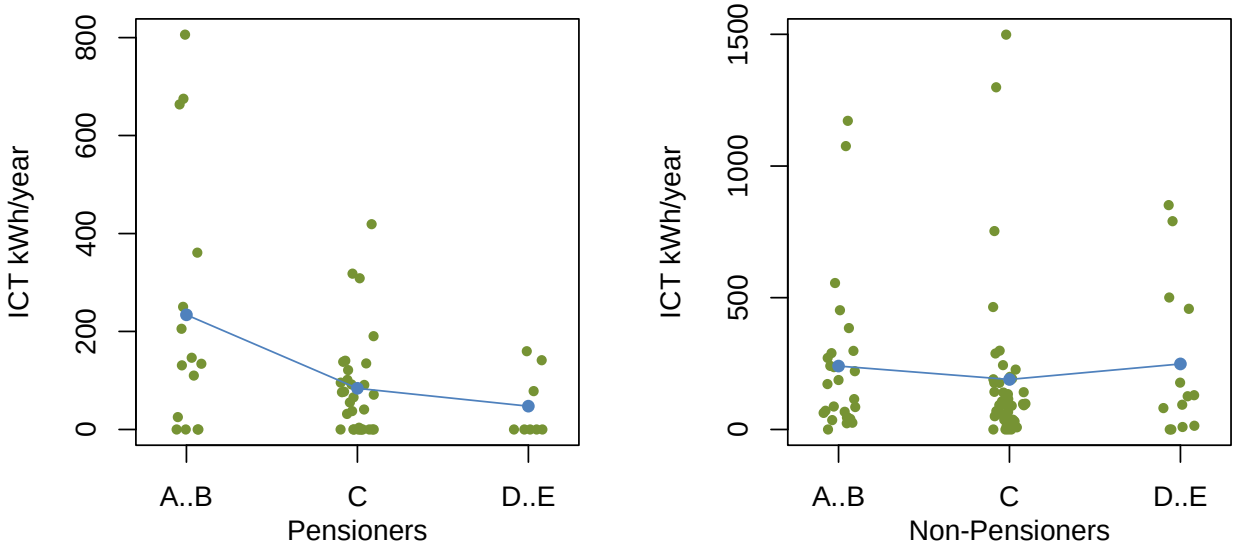
Total electricity consumption



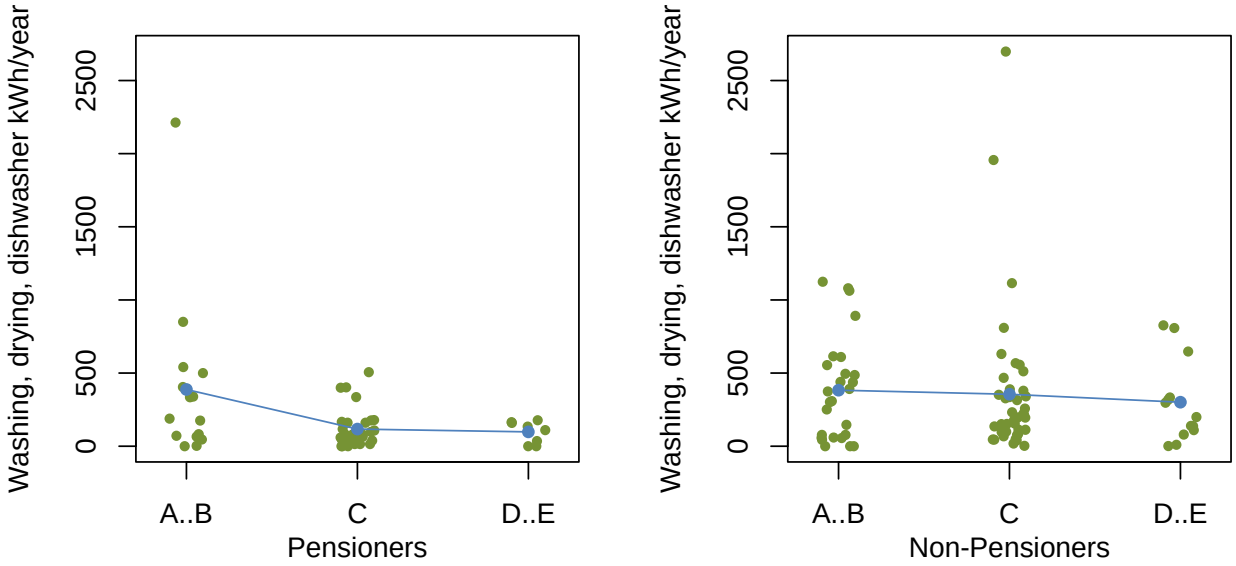
Lighting



ICT energy consumption



Washing Drying and Dishwasher



The charts show that pensioners of higher social group have a greater range of energy use for all types of energy use plotted. They also have higher mean energy use for all types of energy use shown – remarkably similar to A-B social groups among non-pensioners. Pensioners with lower social group appear to have more consistent (and lower) energy use for all of these types of appliance, although there are fewer of them, which affects the plots. These patterns may be linked to the higher disposable incomes, on average, of higher social grades, although other factors (such as dwelling size, lifestyle and expectations of appliance-use) may also be relevant.

The table below compares energy use for high social group pensioners against all non-pensioners. This shows that these pensioners have slightly higher energy consumption than non-pensioners, on average, for these types of appliance.

	Pensioners A-B kWh/year	Non-pensioners (all) kWh/year
Total	3510	3280
Lighting	510	440
ICT	230	220
Washing, drying, dishwasher	390	350

Observations and recommendations

■ Socio-economic group is a stronger driver for pensioners than non-pensioners for several categories of appliance use, in particular lighting and ICT. The A and B group pensioners have similar usage to the average for non-pensioners, but the other groups use less electricity.

■ Socio-economic group could be helpful in identifying pensioner households with greater (or less) potential to save energy. Higher grades tend to use more energy, while lower ones tend to use less – much less for ICT and washing appliances (although there were only eight lower grade pensioners in the survey).

Other evidence analysing energy use among older households

While there has been a great deal of research on energy use in older households, this has focused on the low income segments of the population, looking at fuel poverty in particular, and few studies have been carried out looking at the variation *within* the age group.

However, the Output Area Classification[24] Supergroups give an indication of the differences between pensioners from different socio-economic groups. The group most associated with fuel poor pensioners (called 'Constrained by Circumstances') uses least energy per household (21% below the national average)[25] while two other groups also associated with older consumers (called 'Prospering Suburbs' and 'Countryside') are the top two consumers of energy per household, with 'Prospering Suburbs' 21% above the national mean consumption. This means that while pensioners make up some of the most vulnerable consumers, they appear to account for some of the highest emissions per household as well.

[24] Vickers, D., Rees, P., & Birkin, M. (2005) Creating the national classification of census output areas: data, methods and results. Leeds: University of Leeds.

[25] Druckman, A., & Jackson, T. (2008) Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. Energy Policy, 36(8) 3177-3192.

What impact will demographic changes have on energy use?

It appears that some electricity consumption patterns are linked to demographic characteristics. For example, pensioners are less likely to own and use dishwashers, whereas households with children are more likely to own and use games consoles. The Departments wished to find out how electricity use relates to demographic factors such as household size and composition, to see how changes in these factors over time will lead to changes in electricity consumption.

Approach

Table 418 of the DCLG Live Tables on household projections[26] includes estimates of the number of people of different ages in households, and the number of dependent children. The table gives figures for 2011 and 2021, for England only. We can work out from the HES data mean electricity use for each combination of age and number of children, and project this forward to 2021 to see what affect the expected demographic changes alone would have on electricity use.

A simplified version of Table 418 is shown below (this removes the breakdown of households with different numbers of children).

	Households in 2011 (thousands)		Households in 2021 (thousands)	
	With children	No children	With children	No children
ENGLAND	**15,941**	**6,161**	**17,409**	**6,898**
Under 25	573	237	553	232
25-34	1,825	1,269	1,970	1,354
35-44	1,560	2,635	1,558	2,786
45-54	2,674	1,649	2,534	1,963
55-64	3,431	302	3,777	451
65-74	2,927	46	3,359	70
75-84	2,126	17	2,515	29
85+	826	6	1,144	13

Data analysis

We categorised households into groups consistent with the reported figures in Table 418: those with and without children, and those with different ages of the 'household reference person' (typically the head of household). Then we calculated the mean energy consumption for each category from the HES sample and highlighted statistically significant differences between the energy use in different categories, using the student t-test.

[26] DCLG (2013) Table 418 Household projections: by age and number of dependent children, England, 2011 & 2021. London: DCLG. https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections (last accessed 5 February 2014)

Results are shown in the tables below. In summary, middle-age households (reference person from 35 to 74) tend to use more electricity, on average. Conversely, households aged 25-34 without children, and households aged 75 and over use less, on average. There are statistically significant differences between some of the age bands in households with no children.

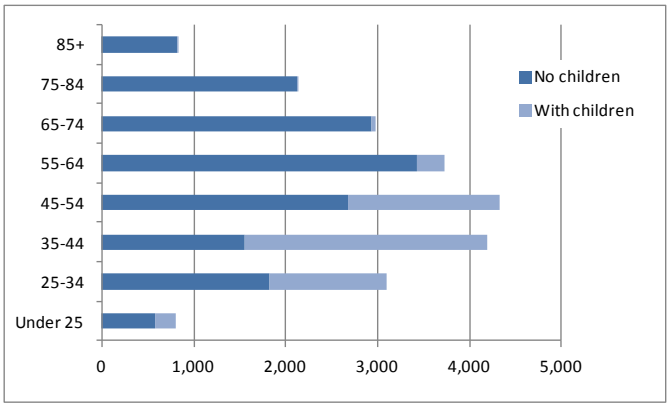
With Children	Sample	Mean total electricity use (kWh)	P-values
19-24	0	N/A	N/A
25-34	11	4285	0.209
35-44	42	4706	0.473
45-54	17	5558	0.432
55-64	8	5593	0.308
65-74	0	N/A	N/A
75+	0	N/A	N/A

No Children	Sample	Mean total electricity use (kWh)	P-values
19-24	2	3848	N/A
25-34	**7***	**1970**	**0.0185**
35-44	12	4142	0.6627
45-54	**33**	**4831**	**0.0359**
55-64	46	3652	0.8072
65-74	47	3670	0.9201
75+	**25**	**2730**	**0.0002**

*Blue text indicates a significant difference

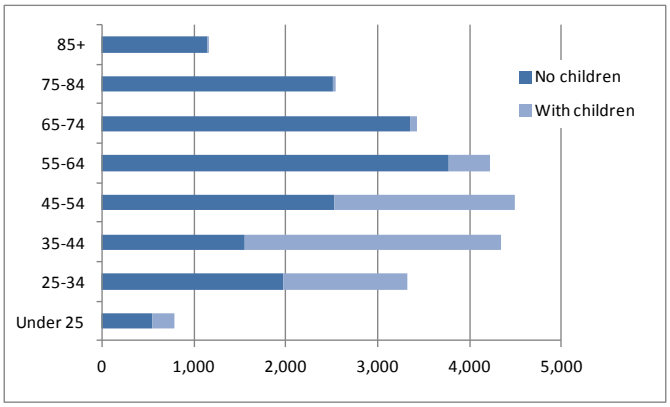
The charts below illustrate DCLG's demographic breakdown for 2011, and the projection for 2021 graphically. Readers will notice that DCLG anticipates increases in all four of the oldest age bands, with the largest increases in the three age bands from 65 and above. What effect would this aging of English households have on electricity use?

Households in different age bands: 2011



Number of households (thousands)

2021



Number of households (thousands)

Source: DCLG (2013)

We factored up the energy use in each age and with/without children category from the HES data to reflect DCLG's projection of the number of households in each category. Our results are shown in the table below. (Figures show total electricity use for all homes in England, broken down by category. Where data was missing, such as 'with children/19-24', we used the mean energy use for homes with children.). The figures are only indicative, because the sample of 250 households becomes very small when it is sub-divided like this. Moreover, the projections assume that today's links between household age/having or not having children and electricity use do not change over the next 10 years, which is a naïve assumption.

Leaving aside these major caveats, the data shows that aging and population rise alone will increase electricity use. Other things being equal, households with children might see electricity use rise by close to 13%, and households without children might see a rise of getting on for 8% in 10 years as a result of an aging population. Across the whole of England, this is a net increase of 9%.

With Children	2011 consumption (MWh)	Projected 2021 consumption
19-24	1,166,672	1,143,872
25-34	5,439,772	5,801,939
35-44	12,398,624	13,110,391
45-54	9,162,979	10,908,561
55-64	1,687,528	2,524,902
65-74	228,343	347,034
75+	113,817	204,480
TOTAL	30,197,736	34,041,180
Increase		**12.7%**

No Children	2011 consumption (MWh)	Projected 2021 consumption
19-24	2,205,273	2,127,865
25-34	3,594,080	3,880,026
35-44	6,462,309	6,451,982
45-54	12,917,656	12,241,303
55-64	12,529,271	13,795,165
65-74	10,742,173	12,325,453
75+	8,060,373	9,991,304
TOTAL	56,511,135	60,813,099
Increase		**7.6%**

Conclusions and recommendations

■ There are significant differences between total electricity use and the age of the household representative person for some age bands among households with no children. Broadly, middle-age households tend to use more electricity, while older households (aged 75+) and younger households (aged up to 34) tend to use less.

■ The number of households in England is forecast to grow by 10% from 2011 to 2021. However, if current trends of energy use according to household age endure (notably older households using less electricity), demographic changes will lead to a slightly smaller increase in electricity use: up by 9% over 10 years. (The increase

Other research on the effect of demographic changes

The key demographic trends in the UK are a growing population, an ageing population, and a growing number of households[27]. Population distribution is also changing, with particular increases in the South East, and smaller increases and in some cases declines in the rest of the country.

According to the Energy Saving Trust[28], key demographic factors tending to increase energy use include: falling average household occupancy, increased use of appliances and consumer electronics, greater affluence, longer life expectancy, and heating homes to a higher temperature. Factors tending to reduce energy use include using energy sources other than fossil fuels, improved building standards,

[27] Royal Commission on Environmental Pollution. (2011). Demographic Change and the Environment (Vol. 8001). London: The Stationery Office.

[28] Hamza, N., & Gilroy, R. (2011). The challenge to UK energy policy: An ageing population perspective on energy saving measures and consumption. Energy Policy, 39(2), 782-789.

looks set to be a little higher for households with children and a little lower for households without children.)

■ Without improvements in energy efficiency and/or demand management, electricity generators need to prepare for increased demand for electricity arising from demographic effects alone. They should be ready for annual rises of around 1% a year until 2021.

energy efficiency programmes, rising fuel prices, and greater awareness of energy efficiency.

For example, data collected as part of the integrated impact assessment of the London Housing Strategy illustrated the effect of household size on energy use, showing that a five-person household will on average consume less than twice the electricity and gas of a single-person household (see table below).

Occupants	Consumption per household (normalised)	
	Electricity	Gas
1	1.0	1.0
2	1.4	1.3
3	1.6	1.4
4	1.8	1.6
5	1.9	1.7

Investigating high and low use households

The Departments wished to know as much as possible about households with very high or very low electricity use. This was to supplement what we found out by interviewing high and low use households for our lighting report[29]. It seems likely that there is more potential to achieve savings among households with higher-than-average electricity consumption. This is a strong motive for learning more about these households – what is it that causes them to use more electricity than other households? Are there social or demographic factors that help to explain high use? Is there any evidence that specific interventions might be more successful in these households than in other households?

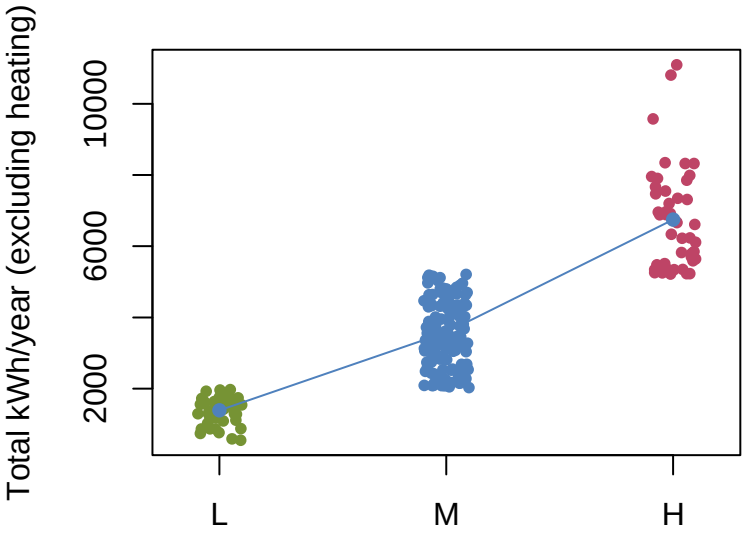
Conversely, other things being equal it seems likely that there is more limited potential for savings among low-use households. It would be useful to know if it is possible to identify such households from afar – without monitoring their electricity use – and to avoid intervening where there is less potential for savings. There is another line of questioning about what motivates low-use households to consume less electricity than their peers (which could include spending more time away from home), and whether any insights we can draw from low users could be applied to save electricity in higher consumption households.

Approach

For this analysis we looked at all non-heating appliances and we selected households where we could identify appliance types for least 60% of the energy used. This means we have 228 households from the original 250.

We classified the households as low (bottom 20%), high (top 20%) and medium (the rest). The strip chart below shows the ranges in each category. There are 46 households in the top and bottom categories, and 136 in the medium category.

[29] Terry N et al (2013) Final Lighting Report. London: DECC.



Overall consumption for non-heating appliances

Low – less than 1970 kWh/year
High – more than 5,220 kWh/year
Mean – 3,780kWh/year

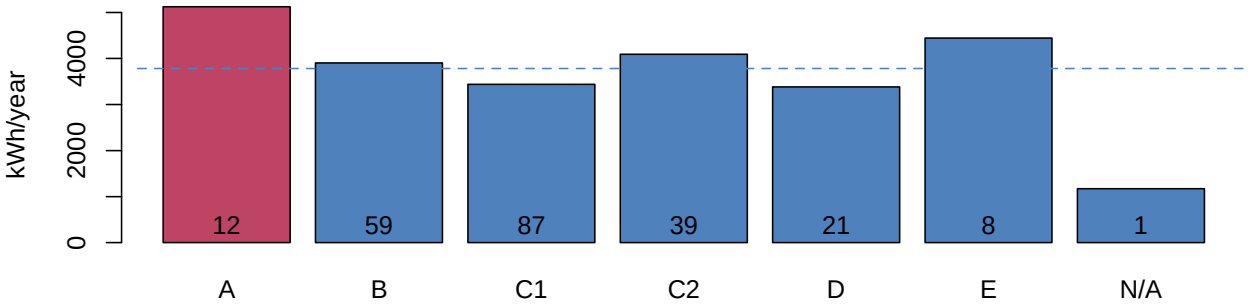
The overall mean for these households (excluding heating) is 3,780 kWh/year and the cut-off for high use is 5,220 kWh/year, so a household has to use 1,440 kWh/year more than average to qualify as a 'high user'. The low use cut-off is at 1,970 kWh/year, which is 1,820 kWh/year below the average.

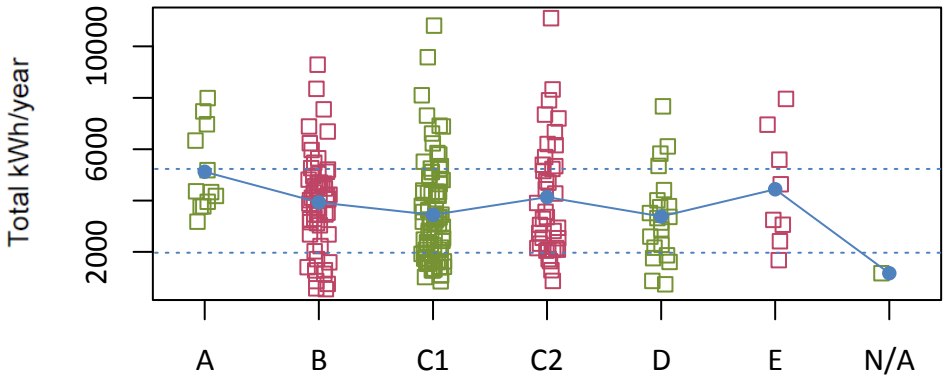
We looked at a number of factors to see if they related to high or low use.

Analysis – Demographics

Social grade made little difference except for A grade households (p=0.02), see charts below (red bars indicate significant results). The mean total use for A-grade households was 5,125 kWh/year, which is 1,330 kWh more than average. This is not quite enough alone to put a household into the high use category. In fact only four of the A-grade households were in the top category.

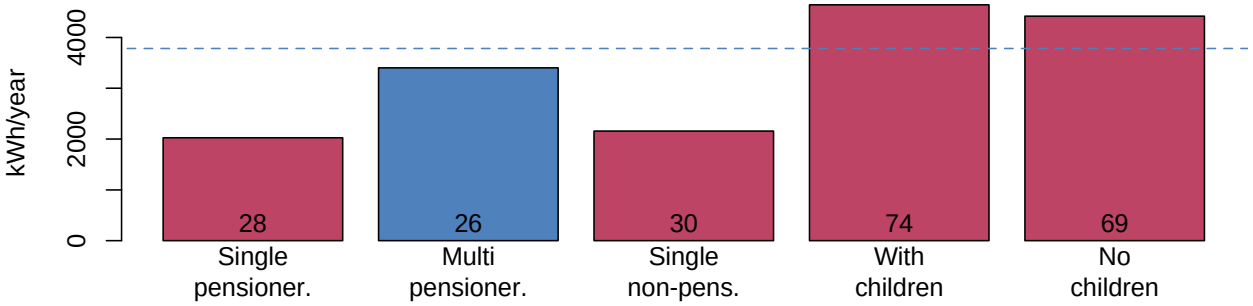
Overall consumption by Social Grade





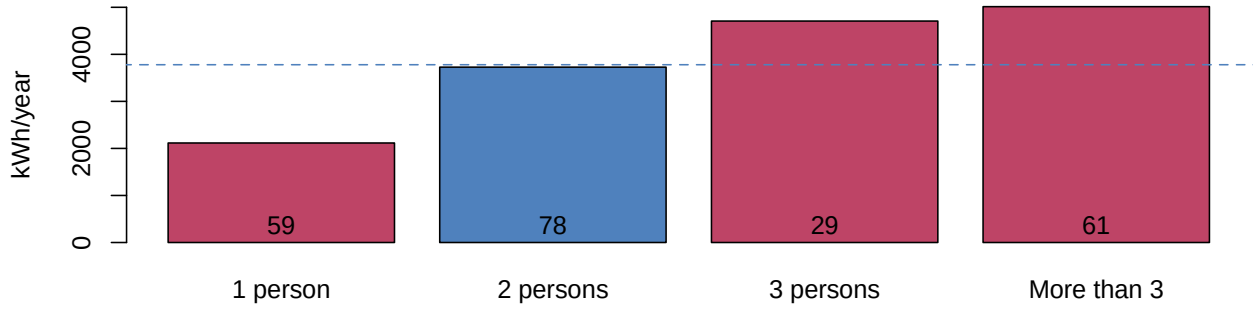
We found that single-person households use less than the mean, while multi-person households tend to use more.

Overall consumption by Household Type

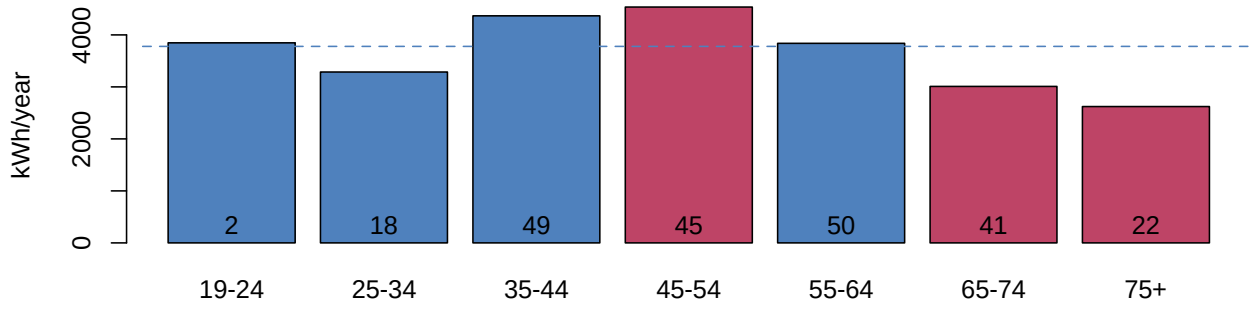


The effect of adding persons to a household decreases as the household gets larger: for households with three or more people, each person uses barely more than half the single person household use. (See table and chart below.)

Household size	Mean household kWh/year	Mean per person kWh/year	Sample size	P-value for difference
1 person	2,117	2,117	59	< 0.0001
2 persons	3,728	1,864	78	0.76
3 persons	4,708	1,569	29	0.0027
>3 persons	5,015	1,179	61	<0.0001

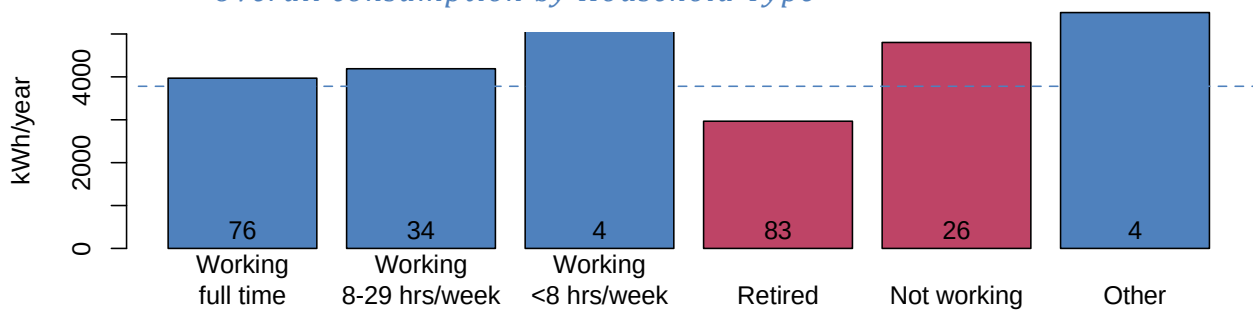


Age was significant not just for the retired groups: the 45-54 age group used 757 kWh/year more than the overall mean. (See graph below.)

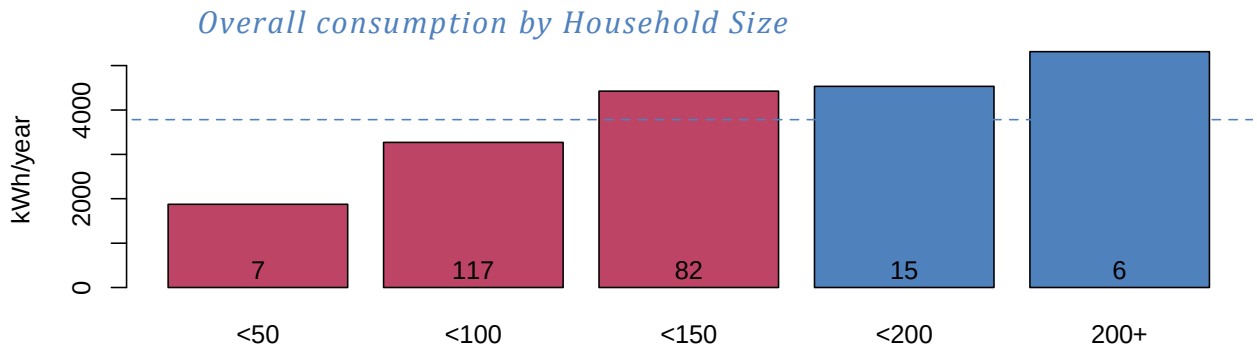


Gender was not a significant factor. However, working status was important, with retired people using 812 kWh/year less than average, and otherwise not working people using 1,025 kWh/year more: the category shown in the chart below merges those seeking work and not, but both groups used more electricity than the average.

Overall consumption by Household Type



The size of the house was also significant, especially at the low end. Dwellings with a floor area over 130 m^2 (the top 20%) had a mean electricity use of 4,480 kWh/year, which is 690 kWh/year more than the average. Conversely, dwellings with a floor area less than 75 m^2 (the bottom 20%) averaged only 2,500 kWh/year.



Of the 46 high-use households, 39 had at least one of the main high use contributing factors: Social Grade A, 3 or more people, age 45-54, not working (but not retired), and/or dwelling larger than 130 m^2. However, seven of the high users had none of these factors. Also 13 of the 46 low-use households scored on one or two of these factors, though none were Social Grade A.

Factor	Consumption above the mean for all homes kWh/year	Sample Size	P-value	% of high scoring households
Social Grade A	1,344	12	0.016	33
3 or more persons	1,136	90	< 0.0001	37
Not working (but not retired)	1,025	26	0.026	31
Age 45-54	757	45	0.042	33
Floor area >= 130 m^2	671	44	0.027	32

All significant results for high use

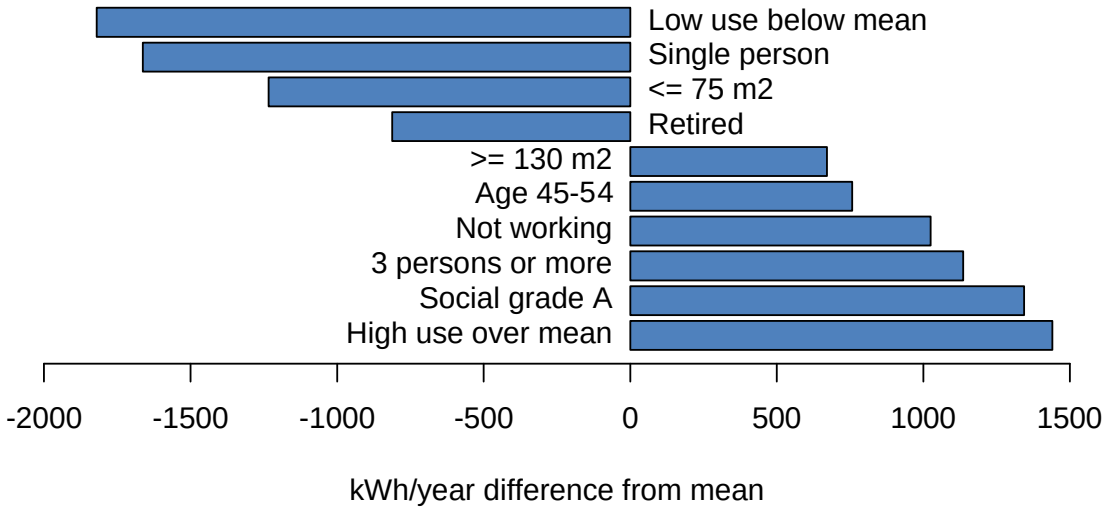
Of the 46 low-use households, 39 had at least one of the main low use contributing factors: living alone, being retired and/or living in small house. However, eight of the high use households also scored on one of these: six were retired, one was single, and one lived in a small home.

Factor	Consumption below the mean for all homes kWh/year	Sample Size	P-value	% of low scoring households
Single person	1,663	59	< 0.0001	58
Floor area < 75 m^2	1,234	52	< 0.0001	46
Retired	812	83	< 0.0001	29

All significant results for low use

These factors are summarised in the following chart, which shows how much difference each factor makes relative to the low and high user cut-off values.

Demographic factors for high/low consumption



Stated behaviours

The households were asked to fill in a survey, including questions about their behaviour. The table below shows the questions, and how we scored the answers. We gave higher scores to behaviours and attitudes contributing to high energy use. However, since the answers are not scalar values, and the differences between the answers are not necessarily equal, we simply scored each one +1, 0 or -1. We scored each part of Question 6 separately, so that there were nine questions in all. We then performed a linear regression relating the answers to each to the total energy use of the household.

Number	Question	Answers (score)
Q5	Which of these statements would you say best describes your current lifestyle?	I don't really do anything that is environmentally friendly (1) I do one or two things that are environmentally friendly (1) I do quite a few things that are environmentally friendly (0) I'm environmentally friendly in most things I do (-1) I'm environmentally friendly in everything I do (-1)
Q6	How often, if at all, do you do the following? 1 Leave the heating on when you go out for a few hours 2 Leave your TV or PC on at home when you are not using them 3 Cut down on the use of hot water at home* 4 Wash clothes at 40 degrees or less* 5 Leave the lights on when you are not in the room 6 Leave a mobile phone charger switched on at the socket when not in use 7 Boil the kettle with more water than you are going to use	Always (1) Very often (1) Quite often (0) Sometimes (0) Occasionally (-1) Never (-1) Don't know (0)
Q7	Which of these statements applies to you personally at the moment with regard to buying energy efficient ('A' rated or better) appliances, excluding energy saving light bulbs. NB. This question was not very discriminating as 70% of respondents gave the same answer ' I've bought energy efficient appliances and intend to do it again')	I don't really want to buy energy efficient appliances (0) I haven't really thought about buying energy efficient appliances (0) I've thought about buying energy efficient appliances, but probably won't do it (0) I'm thinking about buying energy efficient appliances (0) I've bought energy efficient appliances, but I probably won't do it again (0) I've bought energy efficient appliances and intend to do it again (-1) I've tried buying energy efficient appliances, but I've given up (0) I haven't heard of energy efficient appliances (0) Don't know (0)

** The scores for these questions were reversed so that the high values would relate to high energy use*

We found that only three of these questions were significant in relation to total energy use, as shown in the table below. Taken together these factors still only accounted for a small part of the overall variation (R-squared = 0.16).

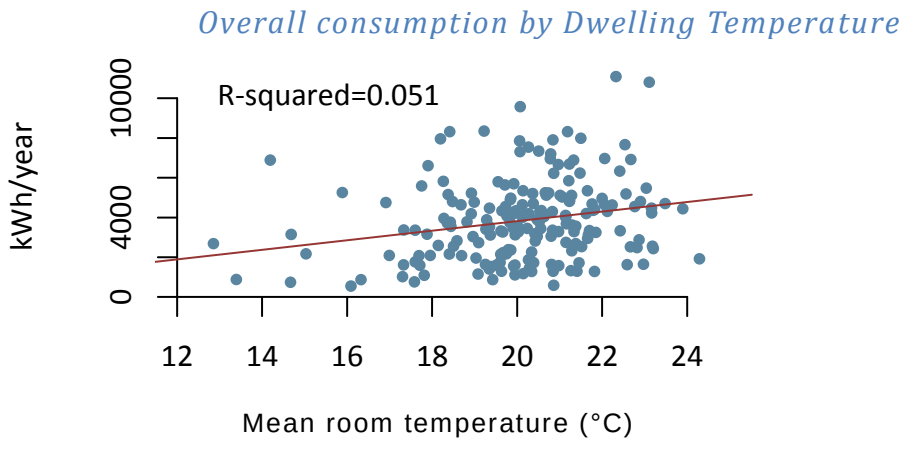
Question	Increase in mean annual use (kWh/year	Significance (p-value)
How often do you leave your TV or PC on at home when you are not using them	853	0.00014
How often do you leave a mobile phone charger switched on at the socket when not in use	668	0.00054
Do you buy energy efficient ('A' rated or better) appliances	727	0.0075

We also looked at the survey answers to Question 3, which asked the household to indicate their agreement or not with statements about resource management and environmental responsibility. Only one of these had a significant correlation with total energy usage – this was the statement 'I don't pay much attention to the amount of water I use at home'. However, this only explained a tiny fraction of the variation in the answers: R-squared = 0.03.

Dwelling temperature

To test whether high-use households also used more heating than average, we looked at the average internal temperature of the dwellings. We used only readings taken in the autumn, winter and spring, and used the temperature between 8 and 9pm, when the heating is likely to be active.

We found a significant correlation (p = 0.002), but it only accounted for a small part of the variation (shown by the low R-squared).



Appliances types

We classified each household as high, medium or low use for each of the seven appliance types (using the same criteria: top and bottom 20%). Since only a few households used

electricity for water heating, and only 80 used an electric shower, it was not possible for households to score 'low' in those categories: the 20% cut-off level was zero energy use.

Number of high use categories	0	1	2	3	4	5	6	7
Low	78%	20%	2%	0	0	0	0	0
Medium	13%	24%	30%	24%	8%	1%	1%	0
High	0	0	11%	22%	33%	22%	11%	2%

All of the high-use households scored high in at least two categories, and the average score was four – suggesting that high-use households typically have high use for a number of different appliance types (say, washing appliances, lights, cooking and audio-visual) rather than just one.

There was more consistency at the low use end, with two households scoring low in 7 out of 8 possible categories (ignoring the 'Unknown' category). This indicates that households cannot achieve low energy use overall without having low use for a number of different appliance types.

Number of low use categories	0	1	2	3	4	5	6	7
Low	0%	2%	22%	22%	22%	20%	9%	4%
Medium	27%	40%	22%	8%	1%	1%	0	0
High	46%	39%	11%	4%	0	0	0	0

The next table shows how many high-use households scored high for each category, and what this means in terms of energy use. No particular category dominates, and there is very little correlation between categories. We ranked the households for each category and found the highest correlation was 0.4 for washing with lighting.

Relatively few high use households score high for water heating or showers, and there is relatively little difference between the high and low cut-offs.

Category	Number of low use households with low use in category	Number of high use households with high use in category	Difference between high and low cut-offs (kWh/year)
Unknown	39%	61%	1,102
Washing, drying and dishwashing	56%	50%	677
Lighting	61%	41%	609
Audiovisual	57%	41%	566
Refrigeration	43%	43%	543
Cooking	57%	35%	494
ICT	37%	41%	281
Showers	0	30%	140
Other	30%	39%	129
Water heating	0	20%	0.4

A majority of high-use households had high electricity use for unknown appliances. These were appliances that were not metered separately in the survey. (There are records of all appliances owned by each household, sometimes much more numerous than the metered appliances. However, there is no information recording why some appliances were metered and others were not. Not all of the unmetered appliances were unusual appliances, and sometimes washing machines and/or cold appliances were omitted.) We cannot be sure from the data available, but there are three possible explanations:

1. high-use households owned more appliances, so the monitoring installers were more likely to miss some
2. they owned more appliances that were not in use when the installers fitted monitoring equipment – say electric fan heaters, for example
3. they had more inaccessible equipment that was hard to meter separately – like fans and pumps.

In reality, all three factors probably contribute to the high unknown usage for high-consumption households, and this may merit further research.

Apart from the Unknown category, the largest variation is in Washing, drying and dishwashing. There are also large differences for Lighting, Audiovisual and Refrigeration. Lighting is discussed in a separate report[30], but we investigated the other categories further, to see what factors contribute to high and low use.

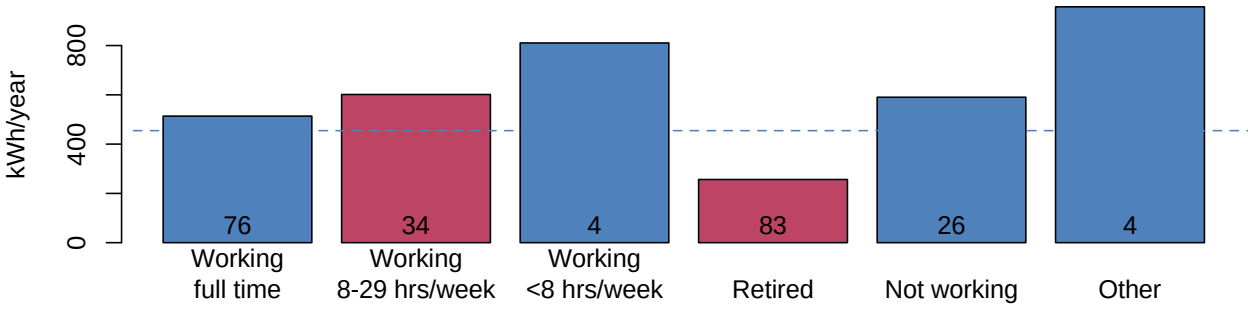
Washing, drying and dishwashing

We looked for correlations between washing energy use and demographic factors, and found some of the same factors that affect overall use level also applied to washing: a strong correlation with household size, and Social Grade A households used more, while retired households used less. The highest-using age group was again 45-54, but this difference was not significant. There was also significant variation with house size.

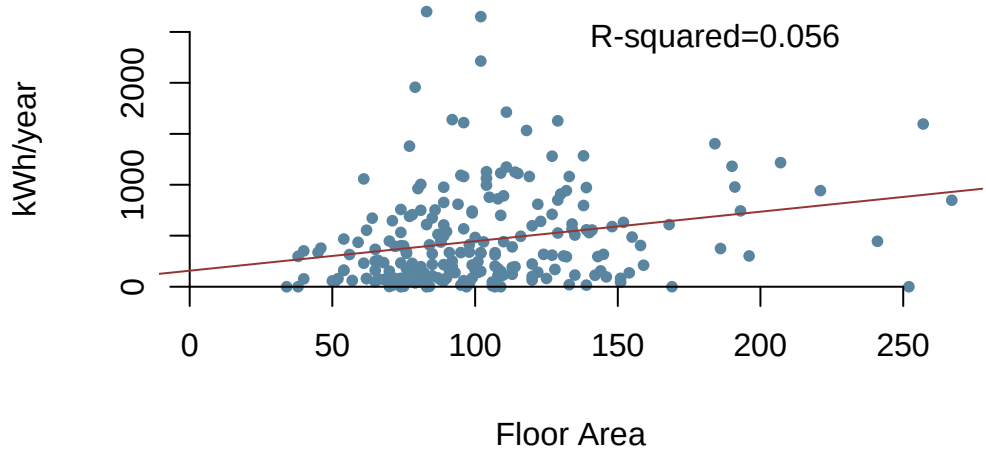
Factor	Washing, drying and dishwasher over-consumption compared to all homes kWh/year	Sample size	P-value	% of high use households
Social Grade A	322	12	0.026	50
3 or more persons	252	90	< 0.0001	38
Retired	-198	83	<0.0001	10
House Size	145 /50m^2	227	0.0003	-

[30] Terry N et al (2013) Final Lighting Report. London: DECC.

Washing/drying/dishwasher consumption by Household Type



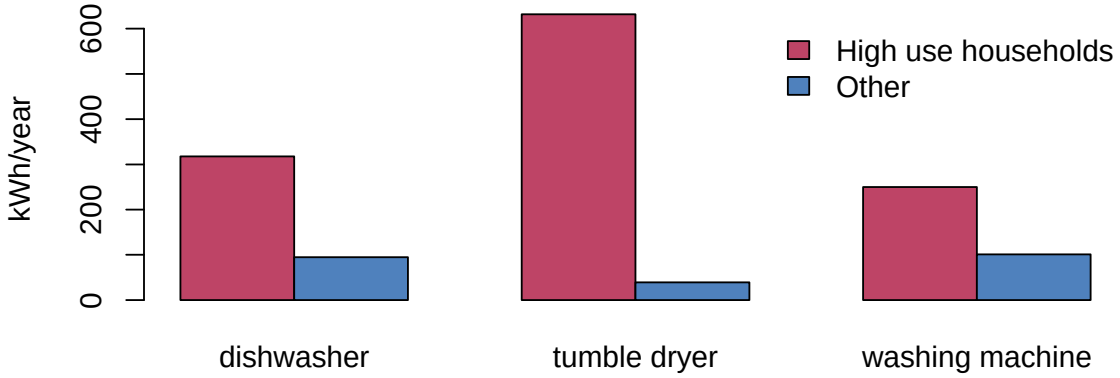
Washing/drying/dishwasher consumption by Floor Area



Next we looked more deeply into the washing, drying and dishwasher category, considering each appliance separately. Our earlier work[31] has shown that the seasonal adjustments we made to energy use at the category level are too coarse for the appliance level. To allow for seasonal use we split the data by season (winter, spring, summer and autumn) and then took an average for the year. Comparing the households which scored high for washing, we found that although there are significant differences for washing and even more so for dishwasher use, the biggest difference is in the use of tumble dryers.

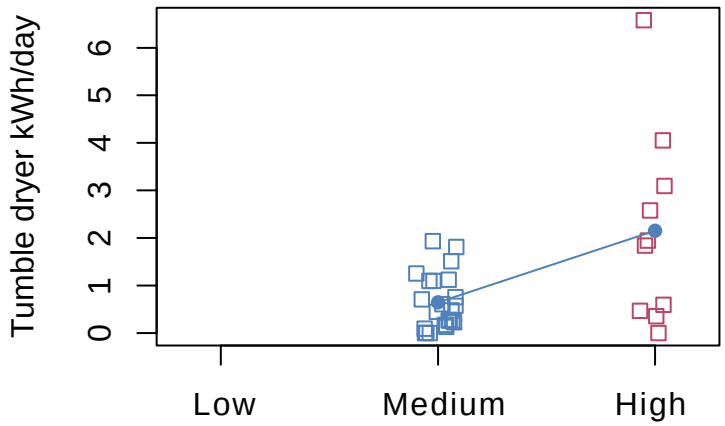
[31] Palmer J. et al (2013) *Electrical appliances at home: tuning in to energy saving*. London: DECC (p140). https://www.gov.uk/government/publications/early-findings-demand-side-management

Difference between high use households and other households for washing/drying/dishwasher appliances

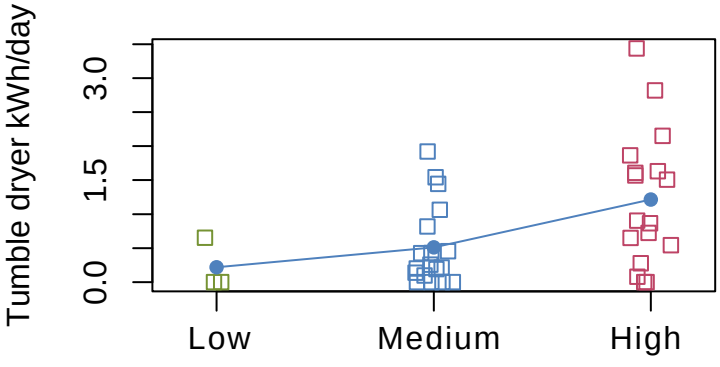


Readers should note that households in Socioeconomic Group A are more likely to own a dishwasher (92% compared to 59% overall), and more likely to own a tumble dryer (69% compared to 53% overall). Also we found increasing ownership of these appliances in larger dwellings.

From our earlier work[30], we know that some households use the tumble dryer much less in summer than in winter. However, analysing daily use of the tumble dryer by season, we see that high users overall are likely to make heavy use of the tumble dryer at all times of the year.



Winter time kWh/day for the tumble dryer by household category

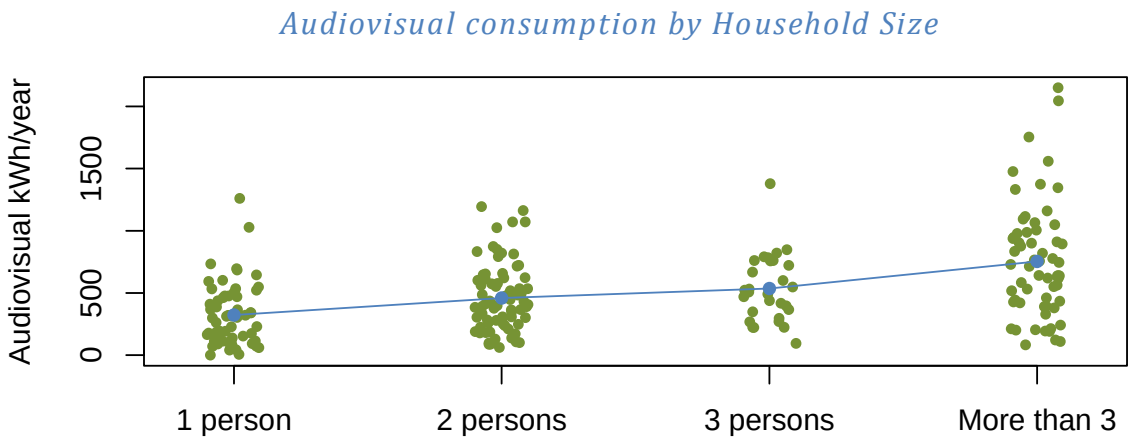


Summer time kWh/day for the tumble dryer by household category

This could be because these high users do not have space to dry clothes[32] other than in a tumble dyer – except that the high users had more space rather than less: 36 of them live in detached or semi detached houses, compared to none in flats and only eight in (smaller) terraced houses. Also smaller dwellings used less electricity than larger ones in this category.

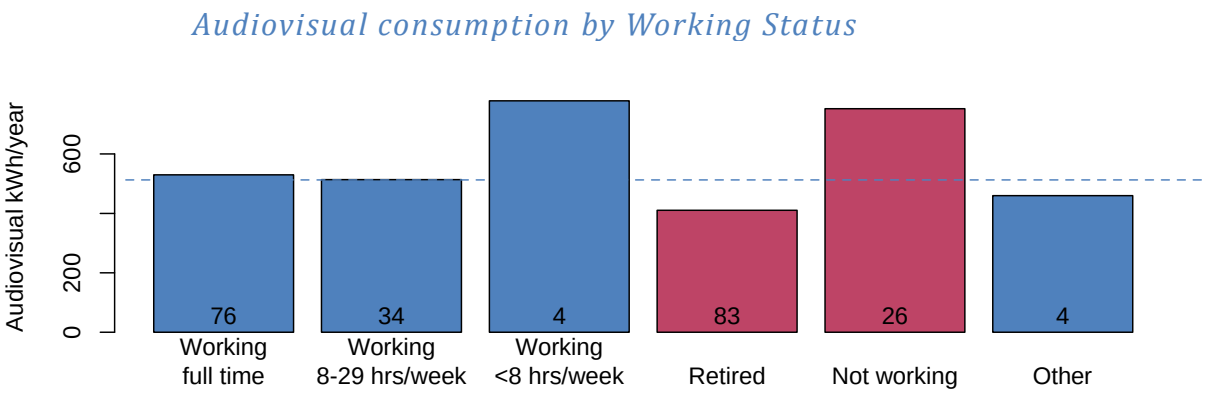
Audiovisual appliances

We looked for correlations between audiovisual energy use and demographics, and found somewhat different patterns compared to overall electricity use (see chart below). As before, there was increasing use with household size. In particular, all the highest users were relatively large households.



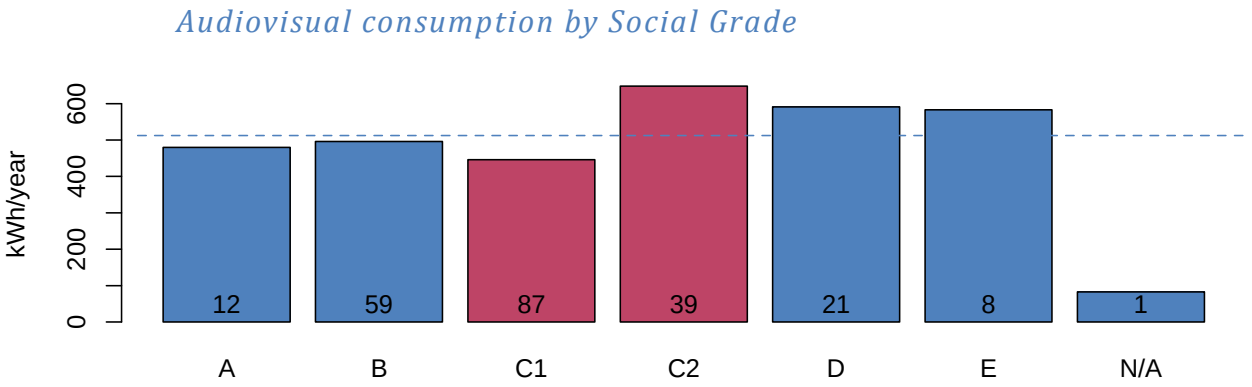
In this chart the blue line links the mean for each group

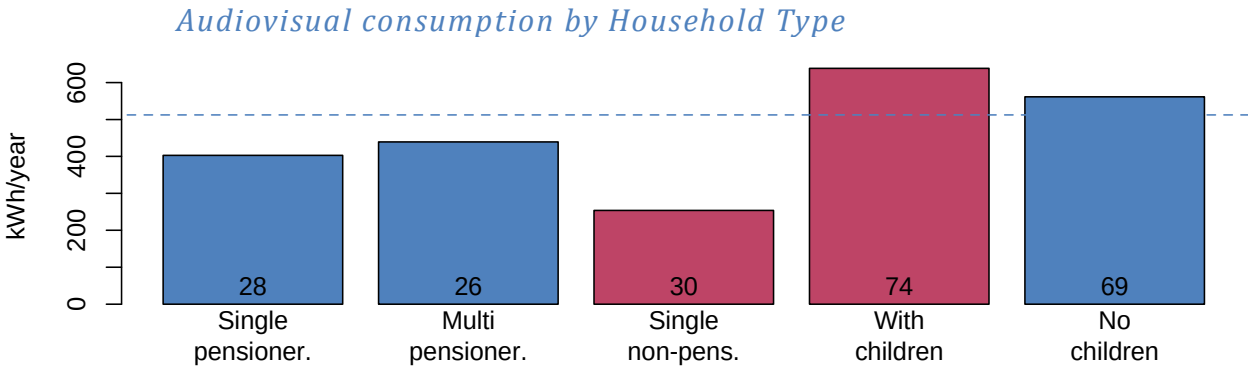
Also retired householders used somewhat less electricity for audio-visual appliances than average, but other non-working households used more.

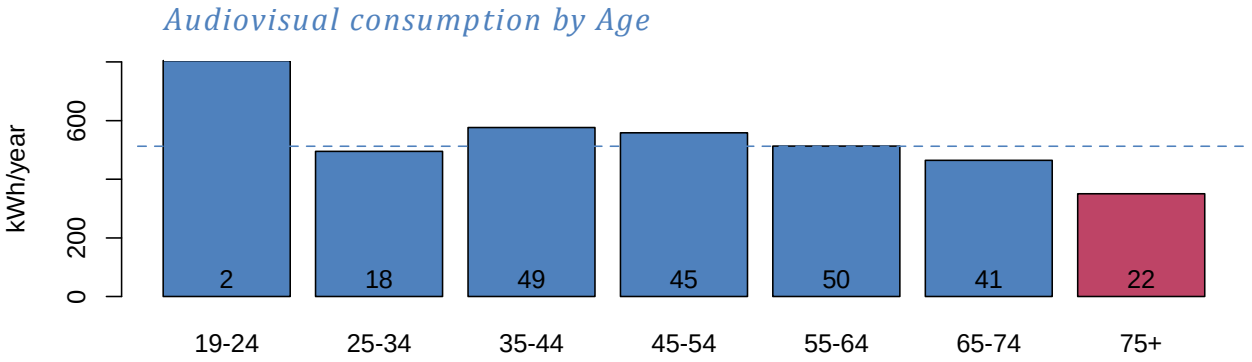


[32] The Code for Sustainable Homes recognised this, by giving points to suitable space allocated to drying clothes. See DCLG (2006) Code for Sustainable Homes: A step-change in sustainable home building practice. London: DCLG.
https://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf (accessed 31.03.14)

In other respects the AV high users were different from the overall high users: there was little difference due to social grade, single pensioners were close to average (though single non-pensioners used much less), and more among those with children. Looking at age, the middle age group 45-54 did not use more than average and only the 75+ group used less.





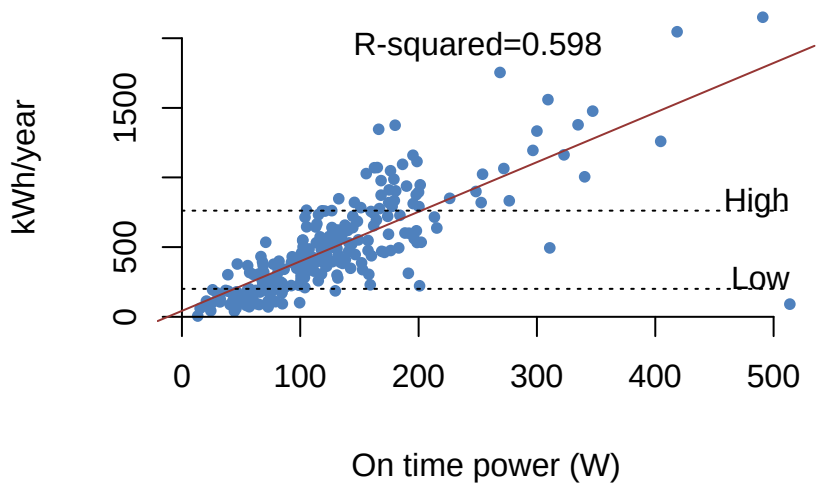


The table below brings together all of the significant factors affecting high electricity use for audio-visual appliances.

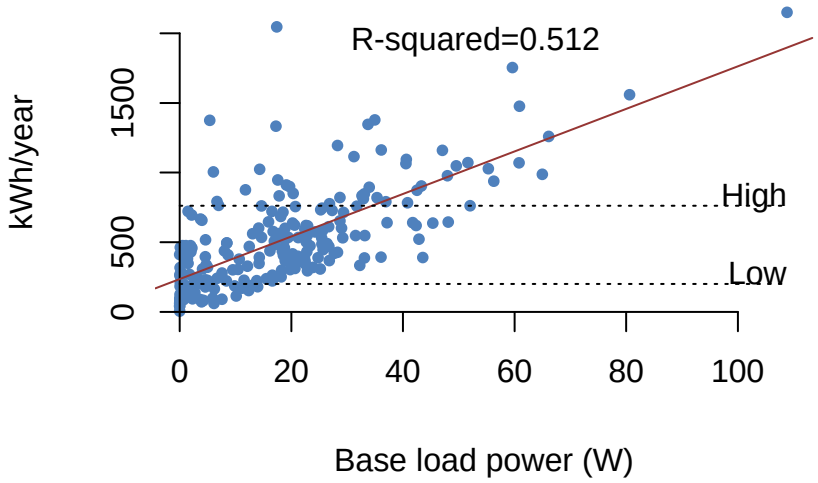
Factor	Audiovisual consumption compared to all homes kWh/year	Sample size	Significance (p-value)	% of high use households
Not working (but not retired)	240	26	0.038	38
Three persons or more	171	90	0.0002	37
Households with children	126	74	0.0056	31
Age 75+	-162	22	0.02	9
Single non-pensioner households	-258	30	< -0.0001	0

There are many different kinds of audiovisual appliance, and there are often several appliances connected to the same socket. This means it was not possible to do a comprehensive analysis at the appliance level. Instead, we looked to see which overall factors contributed most to high audiovisual energy use. We found that the on-time power was slightly more important than base load, as shown in the charts below.

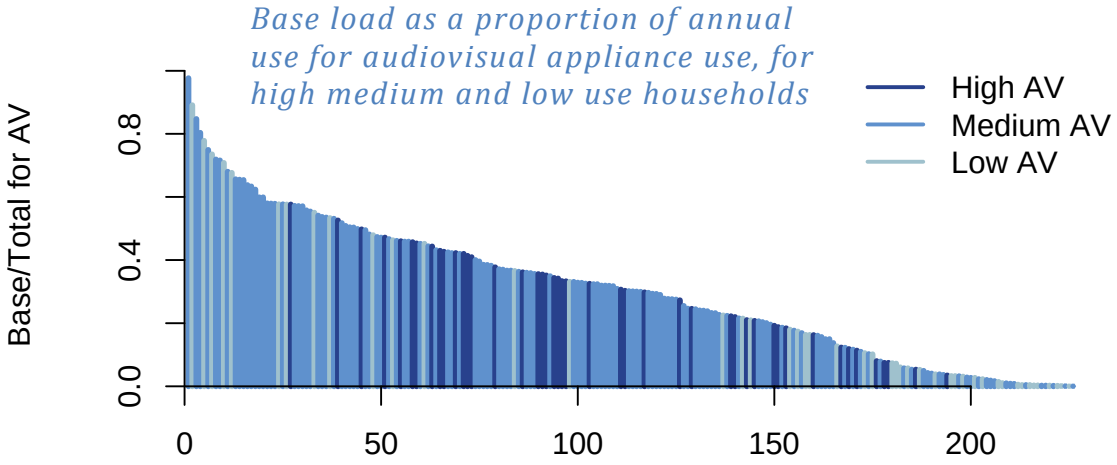
Audiovisual consumption by Mean on-time power and base load Size



For this analysis we determined a threshold for each household that distinguished the on state from base load, then we evaluated the base and on-time power as the average power consumption below and above the threshold. The threshold was determined by analysis of a histogram of overall power – as the trough between the first and second peaks.

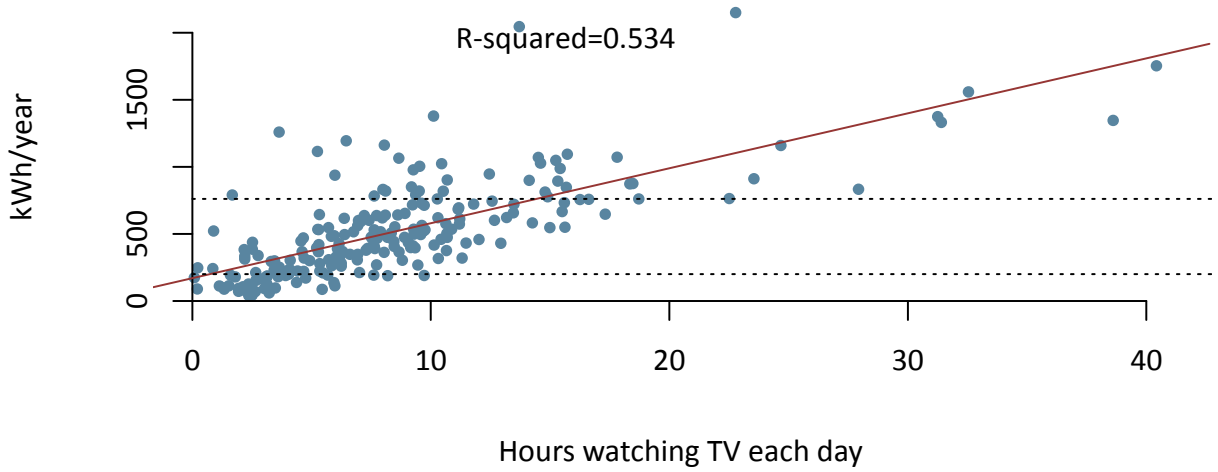


We calculated how much energy consumption was due to base load only, and the proportion of the total audiovisual energy use, for each house. The proportion varied from 80% down to very little – but for households with high AV use the base load was typically medium to low. This shows that high AV use is rarely due to standby alone, and the on-mode power is more important.



We also found that audiovisual energy use correlated faily well with hours of TV use per day, when counting each TV separately. (This analysis may not include all TVs because some of them may be on a general 'Audiovisual site' socket.) However the correlation was better than with base load, and not quite as good as with on-time power.

Audiovisual consumption by hours watching TV



We also found a significant correlation between the number of AV appliances monitored and the overall AV consumption. However, this accounts for less of the variation: R-squared = 0.26.

We investigated the top five households for audiovisual energy (see table below), all of whom used more than 1400 kWh/year for AV, nearly double the 'high' AV cut-off, which is 760 kWh/year. Three of these are also high energy users overall. Most of them had several TVs in heavy use, but one of them had only one, albeit one drawing 400 W.

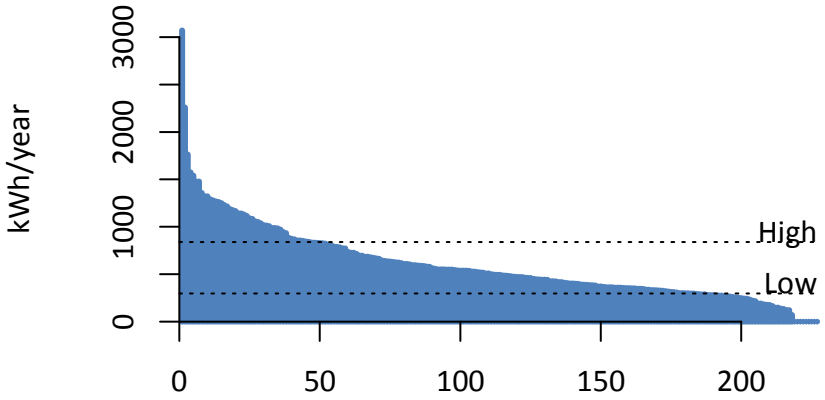
Household	Socio-demographics	Overall use category	Annual AV use	Notes
Multiple adults	No children, seeking work, Social group B	H	2,150 kWh/year	Has at least six TVs, a Sky box and a Play Station 2. Base load is 109 W.
Adults and children	Not working, Social group C2	M	2,046 kWh/year	Only one TV is used, much but it takes 400 W and consumes 1880 kWh through the year.
Adults and children	In part time work, Social group D	H	1,754 kWh/year	Uses three TVs, two of which take 140 W. Base load is only 17 W
Multiple adults	No children, in part time work, Social group B	H	1,560 kWh/year	Three TVs, the main one using 230 W. The AV base load is 81 W
Adults and children	Social group B, in full time work	M	1,477 kWh/year	Has six TVs but uses mainly only two. One set top box takes 27 W, using 246 kWh/year. The overall AV base load is 61 W.

Refrigeration

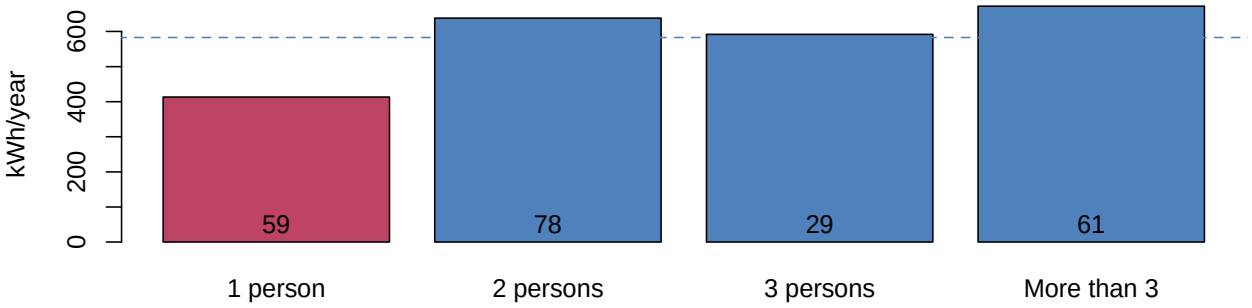
Most households used between 300 and 840 kWh/year on cold appliances, as monitored in the survey (not all appliances were monitored so the low end figures are biased). Single-

person households used 170 kWh/year (29%) less than average. However, 19 households used more than double the average (see charts below).

Refrigeration consumption for all households

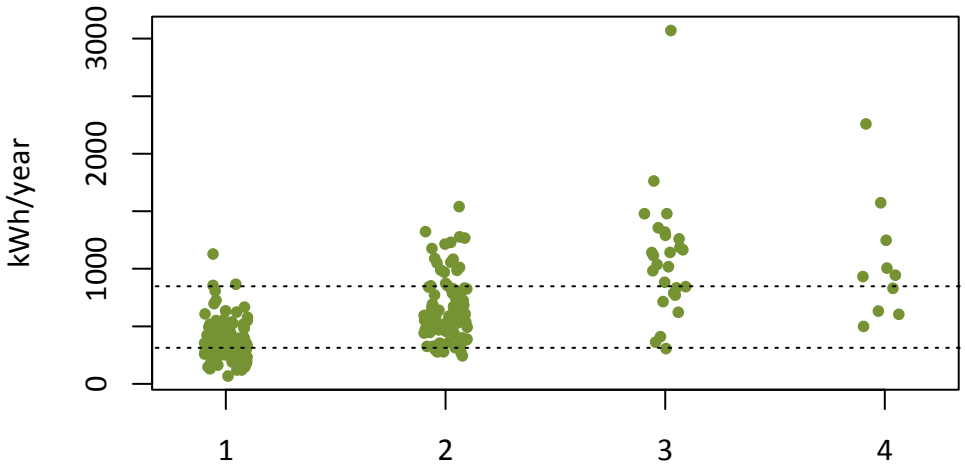


Refrigeration consumption by household size

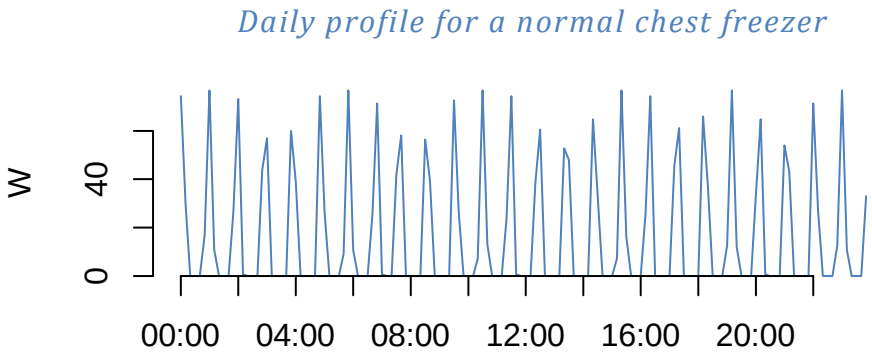


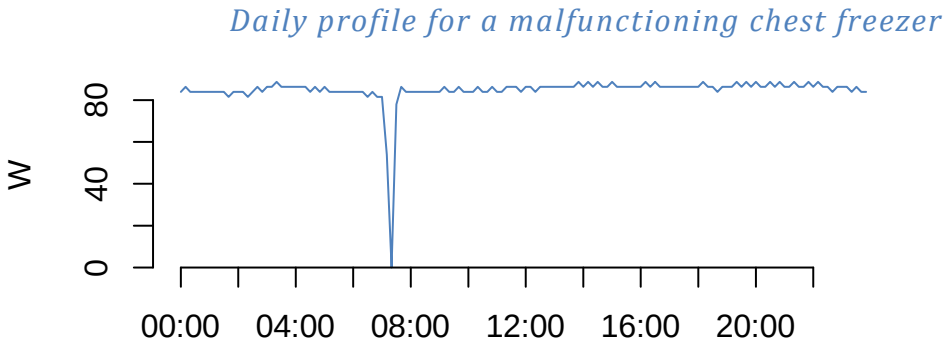
Only part of this variation was due to the number of appliances monitored, as shown in the chart below.

Refrigeration consumption by number of appliances

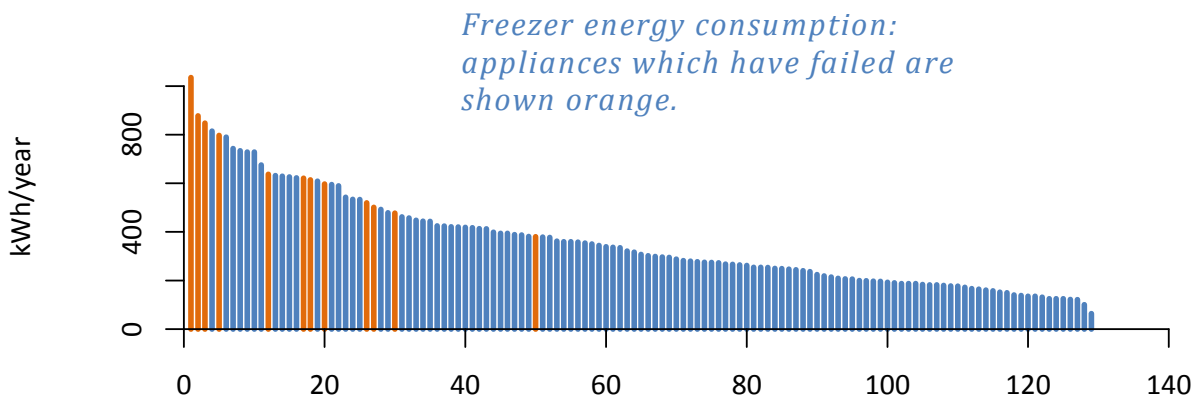


We also know from previous work that size and age of appliance account for only a small part of the variation in fridge and freezer energy consumption. (R^2=0.14 for size, 0.09 for age for fridges, and for freezers even less). We inspected some of the profiles and determined that some of the high consuming fridges and freezers have probably failed – perhaps due to poor seals or a failed thermostat. The appliances do not cycle on and off normally. The following charts show a sample profile from a normal freezer and one that has failed.





We identified malfunctioning cold appliances using a simple heuristic: normally an appliance draws significant power for no more than half the time. If it is drawing a high power for 90% of the time it is likely to have operating problems. We chose the 'high power' cutoff to be half the 90% quantile. By this rule, we found that 21 out of 380 appliances (6%) were probably malfunctioning. However, 12 of the 46 high-refrigeration users had at least one malfunctioning appliance: two of them had two faulty appliances. Malfunctioning appliances tend to draw more power: the 12 faulty freezers drew 300 kWh/year more than the average



Freezer energy consumption: appliances which have failed are shown orange.

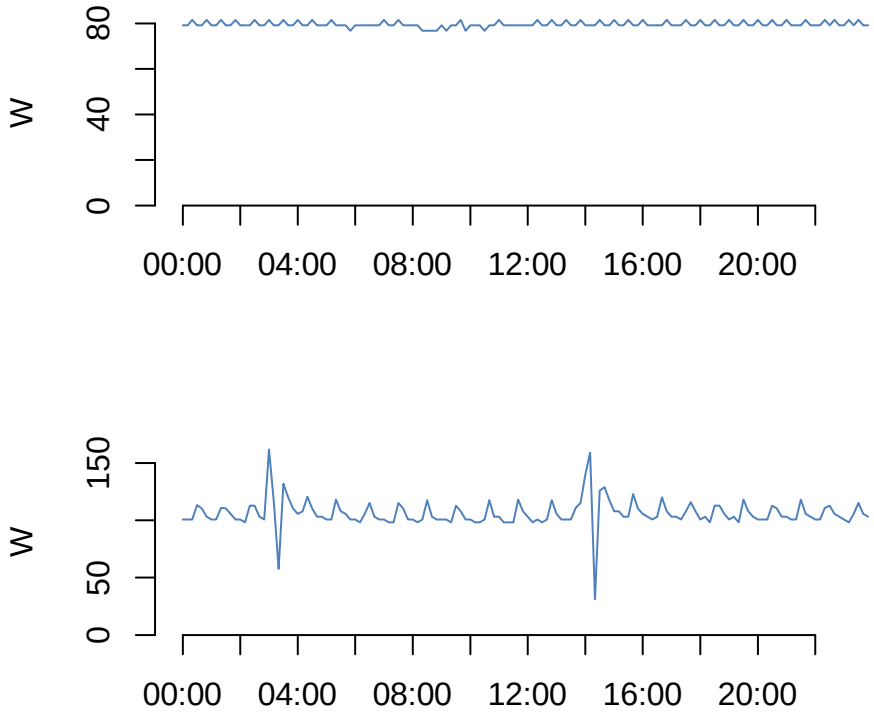
Appliance	Sample Size	Proportion malfunctioning	Extra usage for failed appliances kWh/year	Significance of the difference in energy use (p-value)
Fridge	99	2%	180	Sample too small
Freezer	129	9%	331	0.0002
Fridge-freezer	148	4%	120	0.15

Faulty appliances tend to be older: of the 380 appliances, we know the age of 282 of them. Of these, 20% of appliances bought before 1995 were faulty, compared to 3% of newer appliances.

Age	% malfunctioning	Sample size
> 15 years	20	15
11 to 15 years	3	31
6 to 10 years	3	69
5 years or less	4	167

There were two faulty appliances less than two years old. Their profiles are shown below:

Daily profiles for two appliance less than 2 years old, apparently malfunctioning



There were 34 households with high refrigeration use whose appliances had not failed, two of them had only one appliance monitored: a fridge-freezer. Unfortunately, we have no energy labels or size information for these appliances.

We found no significant differences between energy use for appliances depending on which room they were in: kitchen, utility room conservatory and so on. We also looked for a difference in energy consumption between dwellings dependent on the average internal temperature, but we found nothing significant.

Observations and Recommendations

■ Low use households tend to be single persons living in small dwellings, often retired. High-use households are often Social Grade A, or with three or more persons. (Note that these large households often have higher energy us *per person*.)

■ All high-use households scored high for at least two types of appliance use, and two thirds of them scored high in four or more types. The most common high-use appliance types, which also show the biggest spread between high and low use, were Washing, drying and dishwasher, Lighting, Audiovisual, and Refrigeration. There was very little correlation between use in different categories.

■ High use in the washing category is mainly due to use of the tumble dryer, with high-use householders using 600 kWh/year more than other households for this appliance. Some might argue this is not necessary, since they typically have sufficient space to dry washing outside. High electricity use for washing could also be reduced if households purchased more efficient tumble dryers – or used them less.

■ High audiovisual consumption is associated with larger households, especially those with children, and watching more TV, usually having more than one TV in regular use. Some audiovisual appliances (such as set top boxes) have high base-load consumption, and the average proportion of AV electricity due to base load is 30% overall for high use households. For low use households it is less – only 22%. This suggests that it would be more fruitful to target high consuming on-mode power for appliances such as TVs, than looking at base-load power, though there is potential there too.

■ Some of the high electricity use for refrigeration is due to unusual power demand for the appliances, mainly in older freezers (15 years old or more), suggesting they are faulty and the thermostat does not cycle on and off as normal. These freezers consume 330 kWh/year more than the average. Fridges seem to be less likely to fail in this way, but the sample size may be too small to show a difference. Householders could be encouraged to test and where necessary replace older freezers with more efficient ones – see next section. The simplest test is to listen for the compressor pump running continuously. Equipped with straightforward guidance, any householder could do this.

■ Alternatively (or as a complement), to achieve a reduction in demand, it may be worth subsidising a service to householders to test the efficiency of fridges and freezers.

Exploring opportunities for energy savings from an exchange scheme for inefficient appliances

Replacement schemes for household goods have been used in many countries to encourage the uptake of energy efficient products and remove older inefficient appliances (see blue box, next page). We used the HES data on appliances to estimate approximate savings from such a scheme, and to suggest appropriate rebate levels for old appliances, paid on the condition that the money be used to replace the appliance. The rebate levels were based on the cost of currently available energy efficient products, and assuming that appliances were replaced early – before they start to malfunction.

Although the Departments originally asked us to focus on low income households, the Household Electricity Survey did not include income data *per se*, and our previous findings[33] have shown that there is not a significant difference in terms of energy use or ownership of energy efficient appliances by different social grades. Therefore in this analysis, all of the households in the HES are included, in order to increase the sample size.

The following appliances were investigated:

- Fridges
- Freezers
- Fridge Freezers
- Washing Machines
- Tumble Dryers

Given that households with old appliances have not yet replaced them, we posited that most households need an incentive to replace old, inefficient appliances.

Approach

We compared the energy use of existing appliances with the energy use of new appliances at a range of price points, in order to assess the potential energy savings across the survey group following replacement, for a range of rebate amounts. In order to assess the price and energy use of typical current cold appliances, data was collected from the John Lewis website[34] for the following product categories (number of products shown in brackets):

- Fridges (84)
- Freezers (84)
- Fridge Freezers (201)
- Washing Machines (85)
- Tumble Dryers (39)

[33] Palmer, J. et al (2013) Electrical appliances at home: tuning in to energy saving. London: DECC.
[34] http://www.johnlewis.com/electricals/c500001 (last accessed 15 Jan 2014)

Past and Existing Appliance Replacement Schemes

Landlord Green Appliance scheme

This scheme, run by the Scottish Government, was launched in December 2012, with Phase 2 starting in December 2013. It offers private landlords up to £500 towards the cost of replacing old and inefficient appliances in their properties. To be eligible, a Green Deal Advice Report must be carried out, and if loft insulation and/or cavity wall insulation are required, evidence must be provided to show that these have been implemented. Old appliances must be working, and evidence must also be provided to show that they have been removed by the supplier, to ensure correct disposal.

The value of the rebate depends on the type and energy rating of the replacement appliance, as shown in the table below[28].

Appliance being replaced	Energy rating of replacement	Rebate value
Fridge freezer	A+++	£400
Fridge freezer	A++	£340
Freezer	A+++	£450
Freezer	A++	£420
Fridge	A+++	£490
Fridge	A++	£400
Dishwasher	A+++	£380
Dishwasher	A++	£280
Washing machine	A+++	£290
Washing machine	A++	£170

Come On Labels

The Come On Labels project was set up to support the implementation, compliance checking and monitoring of energy labelling schemes in a select group of EU member states, in support of the EU Energy Labelling directive. Its purpose was to explore the extra tools and information required to encourage uptake of energy efficient products, accepting that energy labels alone are not sufficient, due to other key barriers (e.g. financial, motivational or informational).

In March 2013, *New Product Replacement Schemes in the Come On Labels Countries* was published[35], giving an overview of existing schemes, and making recommendations for future schemes. The schemes identified in the report are summarised in the table on the next page.

The key recommendations were as follows:

1. Decide whether you wish to support better replacement or early replacement.
2. Choose eligibility criteria wisely.

[35] See http://www.energysavingtrust.org.uk/scotland/Organisations/Technology/Free-resources-for-housing-professionals/Landlord-Green-Appliance-scheme-Phase-2

3. Make sure the old appliance is being disposed of.
4. For financial incentives, design accompanying information measures.
5. Monitor the effects and efficiency of the programme.

A second report was published in 2011: *Instruments for the Replacement of Old Appliances*[36]. This explored the impact of direct financial incentives, of the following forms:

- Direct Subsidies: a direct financial reward to buyers of energy efficiency products. Must be designed carefully with regards to target audience, eligibility, duration of measure etc. May be set up to promote both early or better replacement. Popular, but may not be cost effective due to 'free-riders'.
- Fiscal Incentives: tax incentives such as tax credits, deductions from income tax, enhanced capital allowances, reduced VAT rates [37]
- Indirect Subsidies: non-monetary credits or points, awarded to consumers on purchase. This has the advantage of influencing the products/services bought with the subsidy.
- Bonus/Malus Programmes: price adjustments to products dependent on their performance/efficiency. This promotes better rather than early replacement.
- Micro-Credit Models: an advantageous loan, e.g. with low/no interest or repaid through savings.

[36] http://www.come-on-labels.eu/replacements/summary-of-mechanisms
[37] Note that EU rules restrict the type of products where VAT may be adjusted to building related products, like water heaters.

Country	Name	Period	Cold Appliances	Washing Machines	Tumble Dryers	Dishwashers	Oven/Hob	Monitors/TVs	Lamps	Air Conditioners	Instrument Type	Details and Eligibility Criteria	Allowance Type	Allowance
Austria	Trennungsprämie	2009-2010	x								Financial / information	Exchange of old appliances for new A++ appliances.	Direct payment	€50-100, depending on appliance size.
	Top Energy saving Household	2010		x	x			x			Information / incentive (competition)	Households were encouraged to achieve their energy savings potential, with the chance of winning energy efficient appliances.	-	-
	Foto competition	2009-2011	x	x	x	x		x	x		Information / incentive (competition)	Buy an energy efficient product and take a picture. Enter this into a competition to win an efficient appliance.	-	-
	Summer action	2006-2012	x								Financial / information	Exchange old appliance for A+++ and A++ appliances. The cost of the appliance could be won through a prize draw.	Direct payment	100 prizes of € 100 for A+++; 100 prizes of € 50 for A++
	Energy saving week	2012			x			x			Information / incentive (competition)	Enter to answer a question and win an efficient appliance (one prize per day).	-	-
Belgium	Energy grant - Prime	2013	x		x						Financial / information	A++ and A+++ rated cold appliances; A rated tumble Refrigerating Appliance class A++ and A+++; tumble dryer class A for households in Brussels region	Direct payment	From €50-200 depending on income and in the case of refrigerators on energy class. Additional €100 for large families
Croatia	Pilot incentive scheme on efficient appliances	2013	x	x	x	x	x				Financial	First come first serve (100 households); A+++ appliances	Direct payment	Up to 25% of appliance price.
Germany	Stromspar-Check	2008-2015							x		Information / incentive	Consumers who receive unemployment benefit, social assistance or housing allowance	Free energy saving lamps	Up to €70

	Stromspar-Check - Freiburg Refrigerator exchange campaign	2012	x								Financial	Consumers with incomes below the poverty line. Energy savings of >200kWh/year must be achieved, with A+++ new appliances. Applicant must have a 'power saving check' consultation.	Appliance exchange	n/a (applicant must have a 'power saving check' consultation)
Spain	RENOVE plan (Rebate Program domestic appliances)	2011-2012	x	x	x	x	x				Financial	A+, A++, or A+++ rated appliances.	Rebate	€80-120
	Rebate Program Air conditioners	2011-2012								x	Financial	A-rated appliances.	Rebate	€200-450
UK	DECC & John Lewis energy labelling trial	From 2013	x	x	x	x	x				Information	Include lifetime energy running costs on appliances at the point of sale.	-	-

The key data collected for each product in this HES report was as follows:

- Price (correct in December 2013)
- Energy rating
- Typical energy consumption per year (from the Energy Label)
- Fridge volume (litres)
- Freezer volume (litres)
- Load Capacity (kg, washing machines & tumble dryers)

When replacing a large household appliance such as a fridge or freezer, other factors beyond price and energy rating affect a consumer's decision to buy a particular model. In order to capture this to some extent, we used the volume/capacity of the existing appliance to restrict the range of available products, with the assumption that households would always choose similarly sized replacement appliances (+/- 10%).

The typical energy consumption given for new appliances in Energy Labels is estimated using a standard set of usage assumptions. For the existing appliances, in many cases we have both the estimated typical consumption and the actual surveyed usage, dependent on the specific behaviour of each household. Previous results have indicated that the rebound effect is not significant for household appliances[38], so we took 'typical' energy use from the Energy Labels, then multiplied by actual/Energy Label estimate for existing appliances in the HES. This assumes that new appliances diverge from Energy Label estimates in the same ratio as existing appliances – which we cannot be sure about, but is probably more reliable than using the Energy Label estimate with no adjustment.

(This calculation incorporates the effect of lower-than-expected energy use for washing appliances we found in our earlier report[39] – around 30% less than assumed in Energy Labels. DECC's Energy Efficiency Deployment Office (EEDO) checked the assumptions for this work and found that they were similar to those in EEDO's modelling, although the savings for tumble dryers are conservative.)

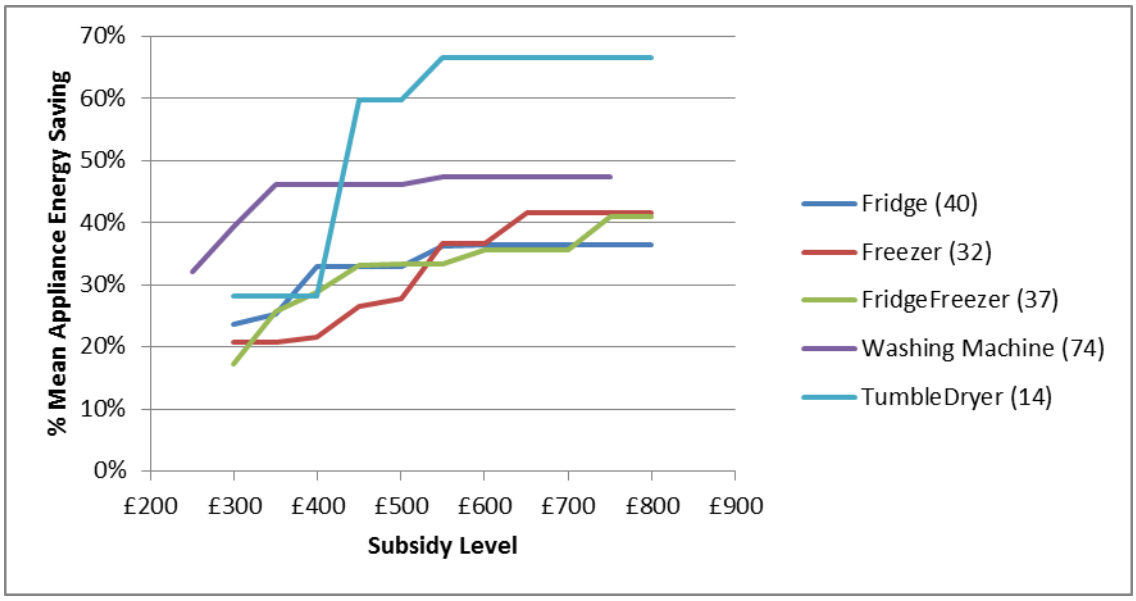
We tested a range of rebate levels, defined in price thresholds, and at each price we selected the lowest energy consumption appliance available that matched the volume each household needed, assuming that the household chooses an appliance under the rebate level (i.e. they do not supplement the rebate with their own money).

At each price threshold, we calculated the potential energy saving, and recorded the energy rating of the new appliance.

[38] Palmer, J. et al (2013) Electrical appliances at home: tuning in to energy saving. London: DECC.
[39] Palmer, J. et al (2013) Energy use at home: models, labels and unusual appliances. London: DECC. Both available here: https://www.gov.uk/government/publications/household-electricity-survey

Analysis

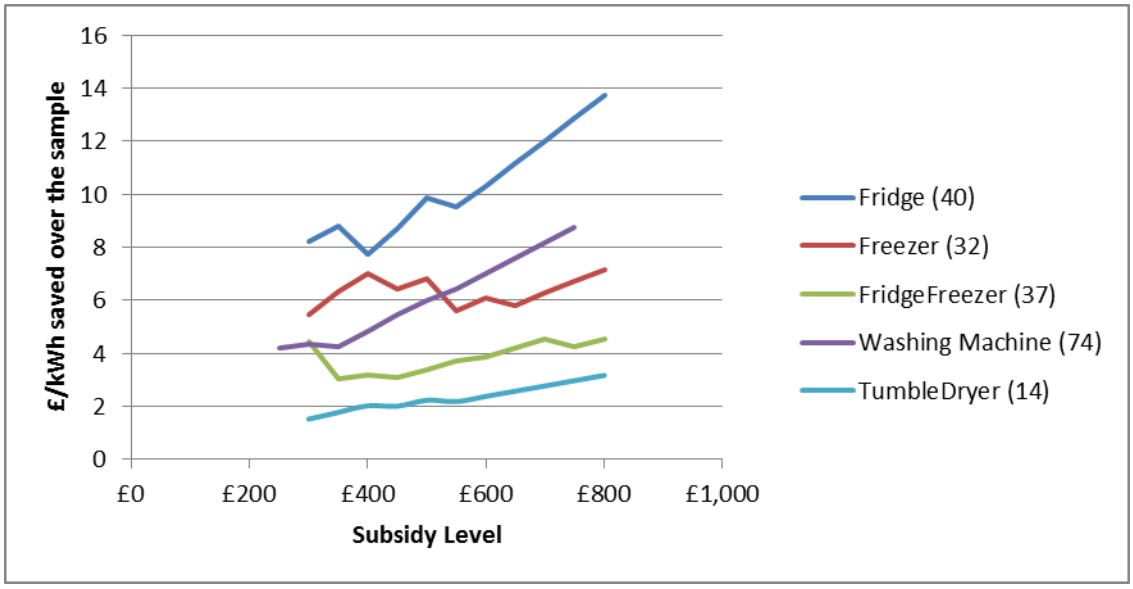
The graph below shows the mean percentage saving in energy use achieved across the households at each rebate level, for each appliance type. The number of replacement appliances included is shown in brackets in the legend.



Mean appliance energy saving per household at different rebate rates (the number of appliances included in the analysis from the survey is shown in brackets)

Savings in all cases increase as the rebate level increases, because increased outlay allows households to purchase more efficient appliances. There are step-changes in energy saving potential for all appliances (e.g. £450 for tumble dryers, or £750 for fridge-freezers). These show the price points where the next level energy rated appliance becomes available, and indicates what rebate would achieve the most cost-effective energy savings. (Where increases in the rebate would achieve lower energy savings.)

The next graph shows the cost per kWh/year saved for households with a saving, for each appliance type, to allow comparisons between the cost-effectiveness of savings of rebates on different appliances. This allows prioritising between appliance types when limited funding is available to pay for subsidies. The calculations assume that the household only qualifies for the rebate if they retire their old, less efficient appliance.



Cost per kWh saved (£/kWh) for households with a saving, with different subsidies

This indicates that a replacement scheme for tumble dryers and fridge-freezers would give the greatest potential energy saving per pound, mainly because existing appliances are so inefficient compared to new appliances – particularly for tumble dryers, where many existing dryers are rated C or below.

Using this data, we estimated the rebate levels that would give the optimum energy savings, along with the energy rating of appliances that could be achieved with the subsidy, see table below. A comparison of these figures with the Landlord Green Appliance Scheme (see blue boxes, above) in Scotland show that they are broadly in line with the rebate values available there.

	Optimum rebate level	Corresponding Energy Rating	Mean Appliance Energy Saving (%)	Mean Annual Household Saving (kWh)
Fridge	£400	A++	33%	51
Freezer	£450	A++	27%	72
Fridge Freezer	£450	A++	33%	146
Washing Machine	£350	A+++	46%	87
Tumble Dryer	£450	A+	60%	225

Subsidy levels to achieve cost-effective energy savings

As the last step in the analysis, we used the Treasury's Green Book[40] approach to calculate the Net Present Value (NPV) of future savings, using DECC's Annex F electricity price projections to 2025, and a 3.5% discount factor – in line with the Green Book recommendations. This is a complex methodology, but the main points are:

- Electricity savings are valued at the long-run variable cost (LRVC) of electricity supply, not the retail price (as this includes fixed costs and transfers between groups in society).
- The CO_2 benefits and air quality benefits of using less electricity are included.
- Appliances are assumed to be replaced in 2014 and to operate for 12 years.
- The subsidy for the appliances was as given in the table above.
- Costs and benefits from recycling the appliances are not included.

The Table below gives the NPV's.

	Upfront cost (rebate offered to householder)	Net benefit of electricity savings	Net benefit of reduced CO_2 emissions	Net benefit of improved air quality	NPV of benefits	NPV of cost minus benefits	Comments
Washing Machine	£350	£86	£3	£1	£90	+£260	Not cost effective
Fridge	£400	£50	£1.60	£0.80	£52.40	+£347.60	Not cost effective
Freezer	£450	£71	£2	£1	£74	+£378	Not cost effective
Fridge Freezer	£450	£145	£5	£2	£152	+£298	Not cost effective
Tumble drier	£450	£222	£7	£4	£233	+£217	Not cost effective

This analysis shows that appliance replacement is not cost effective at the rates of rebates that would make purchase economic for the householder. The analysis does not include any benefits

[40] Treasury (2014) The Green Book: appraisal and evaluation in central government. London: HM Treasury. https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent (accessed 10 February 2014)

from reducing fuel poverty or savings from lower generation capacity resulting from cutting peak demand. Different input data and analyses would be needed to include these.

Observations and Recommendations

■ There is a large difference between the energy consumption of the most efficient appliances now available compared to older appliances now in use in the HES homes. For tumble dryers the energy saving from replacing existing appliances can be more than 60%.

■ Households' use of cold appliances is related to factors that are difficult to control in the short term (such as family size), so use is unlikely to vary after an appliance is replaced. This means that the savings from replacement are largely predictable.

■ These appliances have long service lives (10-20 years) and natural replacement without additional incentives will be slow. Without incentives, householders are unlikely to replace appliances before they start to malfunction unless they have another motive – say, to modernise the appearance of the appliance, or because their family grows.

■ However, cost-benefit calculations in accordance with the Treasury's Green Book indicate that a rebate scheme that meets the full cost of replacing an inefficient appliance would not be justified for financial reasons. Such rebates would have to be justified for other reasons – possibly linked to reducing peak load and/or fuel poverty.

Prepared by Cambridge Architectural Research, Loughborough University and Element Energy under contract to DECC and DEFRA. Views are the authors', not the Departments'. May 2014.