Electricity use by domestic appliances in English households

Dr. Penny Dunbabin (C.Eng)
Department of Energy & Climate Change
3-8 Whitehall Place
London SW1A 2AW
UK
penny.dunbabin@decc.gsi.gov.uk
+44 (0) 300 068 5575

Dr. Jason Palmer
Cambridge Architectural Research
Gwydir St,
Cambridge CB1 2LG
UK
jason.palmer@carltd.com
+44 (0) 1223 460475

Nicola Terry
Cambridge Architectural Research
Gwydir St,
Cambridge CB1 2LG
UK
nicola.terry@carltd.com
+44 (0) 1223 460475

Keywords

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Abstract

The Household Electricity Survey was funded by the UK Department of Energy & Climate Change (DECC) and the Department for the Environment, Food and Rural Affairs (Defra). The main aim was to produce an evidence base to inform energy efficiency policy. Specifically, the aims were:

- To update estimates of residential electricity use by appliance type.
- To investigate the potential for electricity savings in the home.
- To investigate the potential for reducing peak electricity demand.

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. An inventory was made of all lights and appliances in each home. Where possible, each appliance was monitored separately. The overall electricity demand was also monitored. Initial analysis of the data was published in 2012[1]. DECC and Defra commissioned CAR to carry out further, more detailed analysis, which was divided into five parts:

- Appliances: What are the ages and sizes of appliances? How does their actual electricity consumption compare with consumption estimated from EU energy labels?
- Potential for savings: what are the potential savings from replacing appliances with the most efficient ones on the market? What are the potential savings from fuel switching away from electric supplementary heating?
- Peak electricity demand: What scope is there for reducing electricity demand at peak times? (18:00–19:00 in the winter)
- Building Models: Can the results inform or improve our models of lighting and appliances in the household sector?
- Social Studies: Which households use most electricity? Which households have the greatest potential for efficiency savings? Does actual behaviour match stated environmental values? What might be the effect of future demographic changes?

Sample selection

This study focusses on owner-occupiers only; in England and Wales in 2011, owner-occupiers represented 64 % of all households[2]. Owner-occupier properties are generally a little larger than rented ones, and the average household size is also larger.

1. "Household Electricity Survey", Department of Energy & Climate Change, London, (2012) https://www.gov.uk/government/publications/household-electricity-survey-2

2. "Home Ownership and Renting in England and Wales – Detailed Characteristics", Office for National Statistics, London, 28 June 2013 http://www.ons.gov.uk/ons/rel/census/2011-census/detailed-characteristics-on-housing-for-local-authorities-in-england-and-wales/short-story-on-detailed-characteristics.html

Figure 1. Location of participating households.

Households were identified and interviewed by social science specialists at Ipsos Mori to ensure that the sample was representative of the population in terms of life-stage (for example, families or pensioners), number of people in the household, social grade and age of the property. The study included a wide range of dwellings: detached houses, semi-detached, terraced houses, and flats; however, flats were under-represented (4 % against 20 % nationally). The location of households that participated was spread approximately evenly across England, see Figure 1.

It is important to note that virtually all the households (241) had gas central heating, but 24 used top up electric heaters in cold weather and 9 households used electricity as their primary heating fuel. Figures from the Office for National Statistics indicate that around 87 % of English households use gas as their primary fuel[3], while around 8 % use electricity as their primary fuel.

The study is representative of English owner-occupier households only. However, for some purposes we have scaled to either GB (for estimating peak electricity demand) or to the UK (for estimating potential electricity savings through efficiency).

Monitoring and data cleaning

IDENTIFYING APPLIANCES AND LIGHTING

Ipsos Mori staff noted all the appliances and classified each in terms of its priority for monitoring. Appliances were photographed and models and energy labels noted, where available. The appliances were categorized by priority for monitoring; appliances which are left on much or most of the time were classified as priority 1 (for example, cold appliances, wet appliances, electric cookers and ovens, TV's and set-top boxes), while appliances used intermittently, such as radios, toasters and irons were categorized as priority 2. Rarely used appliances were categorized as priority 3. The electricians installed monitoring equipment on as many appliances as possible, working down the list of priority for each house. In addition, the overall household electricity consumption was monitored. Where possible, individual circuits (such as lighting, cooking, electric showers or electric water heating) were also monitored. The electricians also noted the number, type and rating of light bulbs in each room.

MONITORING EQUIPMENT

The power of most of the individual appliances was monitored using serial watt meters. These meters were battery powered, with a resolution of 0.1 Wh and were suitable for single-phase appliances with a power rating of up to 3 kW. Some appliances, mainly heating, water heating, cooking appliances, and lighting were monitored directly from the individual circuits in the switchboard using a "multivoies" system with an estimated accuracy of ±2 %. The internal and external temperatures of the house were monitored using thermometers with a range of 50 to +120 degrees C. Typically, 3–4 temperature sensors were installed indoors, with one in the main room, one in the hall and one in the bedroom(s). Temperature sensors installed outside were installed in such a way as to be representative of the surroundings. The sampling rate of electrical readings was 2 minutes in winter and 10 in summer, while temperature data was sampled at a rate of once per 10 minutes.

DATA CHECKS AND QUALITY ASSURANCE

All appliances were photographed and the photos cross referenced with a spreadsheet supplied by the electricians. At the end of November 2010, the electricians visited the "annual" houses again to download the recorded data, to check that the serial watt meters were still attached to the same appliances and to add monitoring equipment to any new products that had been purchased.

The data were assembled into a database. The signals from each appliance were analyzed individually using a visualization tool which allowed checking for out-of-range consumption and peaks. Records that were doubtful or unreliable were removed. In some cases, the pattern of electricity consumption was not as expected for the appliance in question; in this case, the data was either re-classified as another type of appliance or labeled as "other" if reclassification was not possible. Fewer than ten appliances were included in the 'Other' category or renamed to an appropriate category.

SEASONAL VARIABILITY OF APPLIANCE USE

Seasonal patterns of consumption from the 26 households that were monitored all year were used to scale the monthly electricity consumption figures from the households monitored only for one month. CAR calculated separate seasonal factors for each category of appliance, i.e. for lighting, cold appliances, wet appliances, space heating, water heating (including electric showers), IT, audio-visual appliances and cooking.

ENERGY PERFORMANCE CERTIFICATES

Each dwelling was surveyed by a registered surveyor and an energy performance certificate was produced. This certificate describes the heating load and the expected electricity demand from lighting. The surveys were undertaken by members of the National Home Energy Rating (NHER) Accreditation scheme. As members of the scheme, the surveyors are required to work to national standards and are regularly audited.

3. "English Housing Survey: Energy Efficiency, Table DA6103", Department for Communities and Local Government, London, July 2014 https://www.gov.uk/government/statistical-data-sets/energy-performance

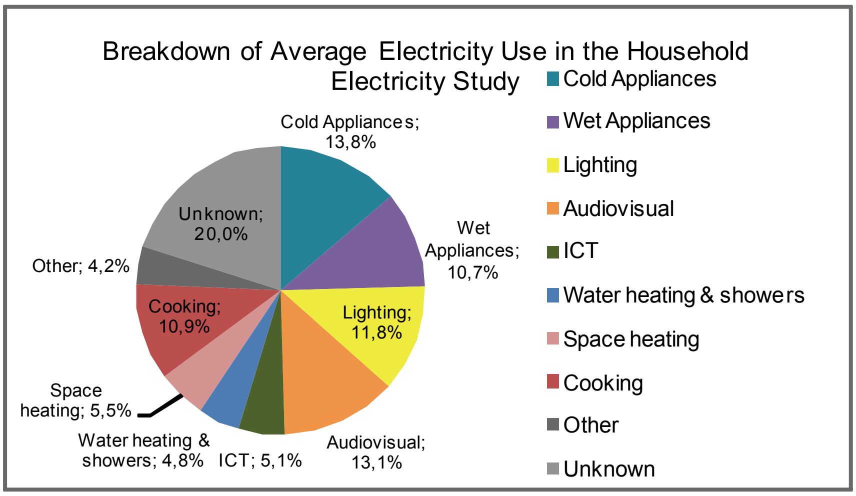

Figure 2. Breakdown of average electricity use in the Household Electricity Study.

Table 1. Comparison of the electricity use by different categories of equipment in three household electricity studies

	English Household study (2010–11)	**Remodece (2006–2008)**	**Swedish study (typical family) (2009)**
Cold Appliances	20 %	29 %	17 %
Wet Appliances	15 %	16 %	15 %
Lighting	17 %	18 %	26 %
Audiovisual	19 %	10 %	12 %
ICT	7 %	12 %	11 %
Cooking	16 %	11 %	10 %
Other	6 %	3 %	9 %
Overall kWh (excluding space heating, cooling and water heating)	**2,851**	**2,646**	**8,416**

Results: Overall consumption

The average electricity consumption of households in the sample was 4,093 kWh. Figure 2 shows the breakdown by category of appliance. Nine households in the sample used electricity as their primary heating source. Out of the 241 households that used gas as their primary fuel, 24 used supplementary electric heating in cold weather.

The households had between 13 and 85 appliances in their homes, with about a third of households owning between 30 and 40 appliances. Approximately 20 % of the electricity use in the sample was not identifiable. This is a larger percentage than expected and requires explanation. In some households, several key appliances could not be monitored (for example, some built-in fridges and electric showers were inaccessible. Furthermore, the electricity used by items such as gas central heating circulation pumps, or smoke alarms, burglar alarms and electric doorbells was not monitored. It is likely that a proportion of the unidentified load was due to plug in electric heaters, since the unidentified load rose, in real terms, in cold weather. These heaters should have been monitored, but householders may have removed the meters.

Cold and wet appliances accounted for around 25 % of the demand, with audio-visual and ICT at 18 % and lighting at 11.8 %. Although most homes in the sample had gas, many used electricity for cooking and for showers or immersion water heaters. Collectively, cooking, space heating and water heating made up 21 % of demand.

Table 1 compares these results to results from the REMODECE[4] program, which monitored household electricity demand in 12 countries in Europe in 2006–2008 and with a Swedish study by Zimmerman[5], which monitored 400 households in Sweden in 2009. *Electricity used for space heating, water heating, showers and air-conditioning has been removed, to ensure comparability.*

The English Household Study agrees quite well with the Remodece one in terms of overall level of consumption; cold ap-

4. "Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe", de Almeida et al, (2008), Coimbra, Portugal

5. "End Use Metering Campaign in 400 Households in Sweden: Assessment of the potential electricity savings", Zimmermann JP (2009), Swedish Energy Agency, Eskilstuna, Sweden

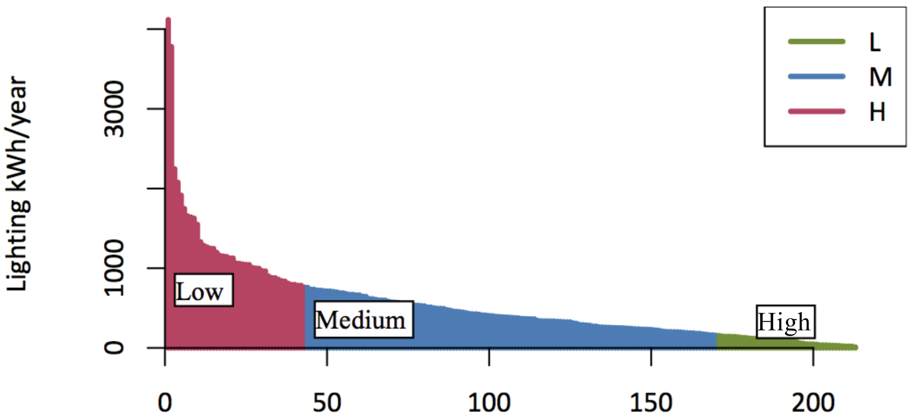

Figure 3. Variability of annual lighting demand for the sample.

pliance demand is lower (partly due to more efficient products coming on the market and partly due to the cooler climate of the UK relative to some of the other countries). Audiovisual demand was high in the English study. The figures shown here from the Swedish study are for a typical family with children, so are not directly comparable to the other studies. The overall consumption from the Swedish study is much higher (8,416 kWh). Within this, the share for lighting is high, for a variety of reasons. Firstly, lighting demand increases with latitude; secondly because of the high number of lights installed (42 per household, on average) and finally because the study was undertaken at a time when relatively few low energy bulbs were installed in residential houses (only 5.5 low energy lamps out of a total of 42). If the Swedish study were repeated now, the lighting demand would be expected to be considerably lower.

VARIABILITY OF APPLIANCE USE BETWEEN HOUSEHOLDS

It important to underline that there is a large variability in use for every appliance type within the sample; this is particularly pronounced for lighting, for which the lowest 20 % of the sample averaged 82 kWh/year, while the highest 20 % used 1,300 kWh/year (nearly 16 times as much), see Figure 3.

A similar result was found for the 24 homes that used supplementary electric heating; the average was 4 kWh per day during the heating season, with a range from well under 1 kWh per day up to 16 kWh per day. Backup heating used an average of 20 % of the total electricity use during the heating season for these households, rising to 30 % during the peak period from 18:00–19:00. On particularly cold days, it was very much higher.

No single household was found to have high demand for all appliance types.

Results: Appliances

We investigated the following aspects:

- Age and energy labeling of appliances
- Actual consumption versus modeled consumption
- Trends in size of appliances
- Excess consumption of a small percentage of cold appliances.

AGE AND LABELING OF APPLIANCES

Age information was not available for all appliances, but where it was available, there was again significant variability between appliances of the same type. The average appliance age across all households varied from 3.8 years for kettles to 8.4 years for fridge-freezers.

Many of the appliances did not have EU Energy Labels; in some cases, this was because the appliances were very old (labels were introduced between 1994 and 1999), while in other cases, the labels had been mislaid. For the cold appliances in the sample that did have labels, the most common label was A, followed by B, with very few A+ appliances. The most common energy label for washing machines in the sample was B, followed by A, while for tumble dryers the most common label was C, followed by D.

ACTUAL VERSUS ESTIMATED ELECTRICITY CONSUMPTION OF APPLIANCES

The energy use of many appliances varies according to how they are used. Dishwashers and washing machines, for example, use more or less energy per cycle depending on the temperature setting and program selected – and overall consumption also depends on how often they are used. Manufacturers publish estimates of actual electricity use for many appliances, based on lab experiments and simple assumptions about usage. A comparison of actual and estimated annual energy use for the major appliance types is shown in Figure 4; the project did not include a similar analysis for audiovisual or IT equipment.

For dishwashers, refrigerators, freezers and fridge-freezers, the average calculated annual electricity use (based on manufacturers' estimates) was closely matched to the average measured electricity use, suggesting that these appliances were operating as expected according to Energy Label assumptions. However, for washing machines and tumble dryers, the mean measured annual electricity consumption was found to be lower than the mean estimated annual energy consumption (29 % lower in both cases). This was due to much lower average energy use per cycle, seemingly the result of lower temperature washing programs (30 or 40 °C washes rather than 60 °C washes which form part of the rated annual electricity use calculations). In fact there were more washing cycles a year in the HES households than assumed in Energy Labels

Table 2. Energy labels of household appliances in the sample

Appliance type	Number of appliances in HES sample	Number of appliances with an energy rating	Percentage of appliances according to energy label					
			A+	A	B	C	D	E
All cold appliances	398	167	2 %	**75 %**	18 %	4 %	–	–
Fridge-freezers	149	77	1 %	**79 %**	14 %	5 %	–	–
Freezers	143	46	2 %	**65 %**	17 %	9 %	2 %	4 %
Refrigerators	106	44	5 %	**70 %**	23 %	2 %	–	–
Dishwashers	111	61	3 %	**74 %**	7 %	13 %	3 %	–
Washing machines	227	149	1 %	15 %	**68 %**	9 %	7 %	–
Tumble dryers	111	64	–	2 %	8 %	**75 %**	13 %	3 %

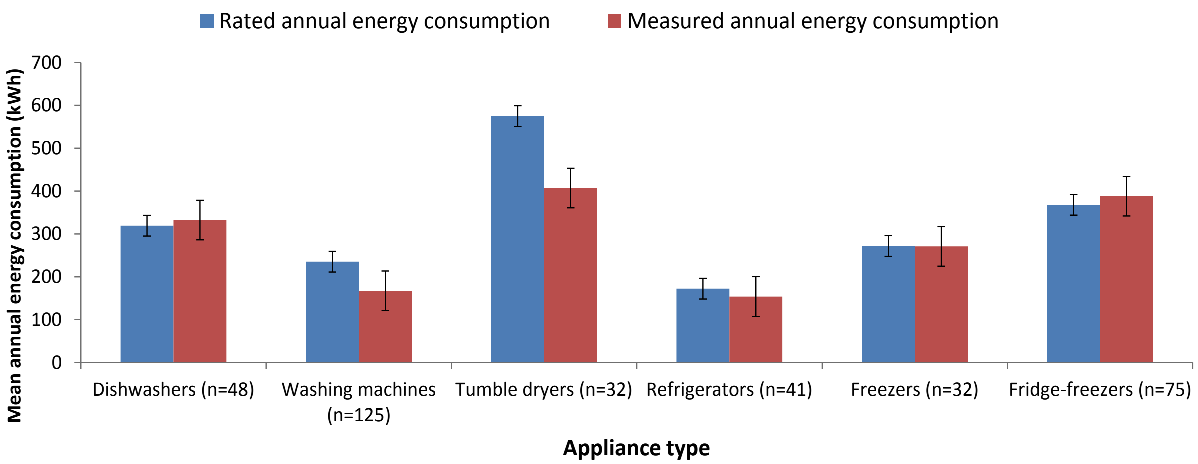

Figure 4. Comparison of rated and measured annual energy consumption.

(284 cycles per year on average for washing machines and 260 for tumble dryers, compared to 220 and 160 in the Energy Label assumptions).

The prevalence of low temperature washes may reflect the success of the Energy Saving Trust's "Wash at 30" campaign, which ran from 2006–2009 and which was supported by major detergent manufacturers.

SIZE OF APPLIANCES

The analysis found that nearly all appliances are increasing in capacity over time, with the exception of dishwashers, see Table 3, below. Larger size or capacity is usually accompanied by increased energy consumption, see Figure 5. In many cases size is more significant than the energy rating – for example, a large (52") A+ television would typically use more electricity when on than a medium (42") A-rated television.

The average size of all cold appliances purchased by the households in this study increased from 1985 to 2011 (fridges increased in volume by two-fifths, on average, while freezers and fridge-freezers increased in volume by one fifth). This increase in size has partially undermined the efficiency gains made by appliance manufacturers.

This finding underlines the importance of considering overall electricity demand, rather than only considering efficiency. Since this study, the European Commission has set absolute limits on the power of vacuum cleaners[6].

OVER-CONSUMPTION BY SOME COLD APPLIANCES

Most households used between 300 and 840 kWh a year to run cold appliances. However, inspection of the electricity profiles indicated that some of the cold appliances did not cycle on and off as designed, resulting in very high electricity consumption, see Figure 6.

The exact reasons for this are unknown, but may include faulty door seals, compressors or thermostats, or excess frost-

6. "Commission Regulation (EU) No 666/2013 of 8 July 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for vacuum cleaners", European Commission, Brussels, July 2013

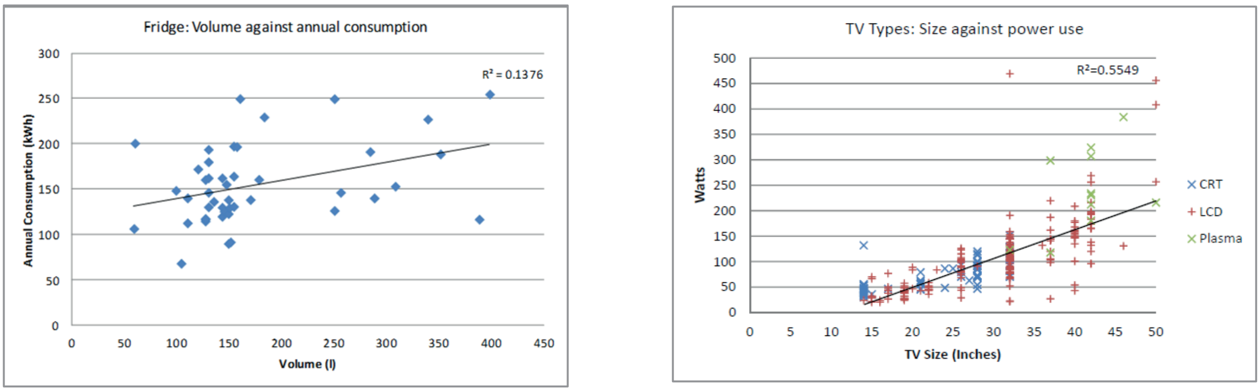

Figure 5. Volume of refrigerator against average annual consumption and TV screen size versus power.

Table 3. Trends in size of household appliances.

Appliance type	Rising trend in size/capacity?	Strength of trend*
TV	Yes	Medium
Washing machine	Yes	Low
Tumble dryer	Yes	Medium
Dishwasher	No	–
Fridge	Yes	Medium
Freezer	Yes	Low
Fridge-freezer	Yes	Low

* *Trend classifications are based on regression coefficients, R^2; "Low" means $R^2 \leq 0.1$; "Medium" is $0.1 < R^2 \leq 0.7$; "High is $R^2 > 0.7$.*

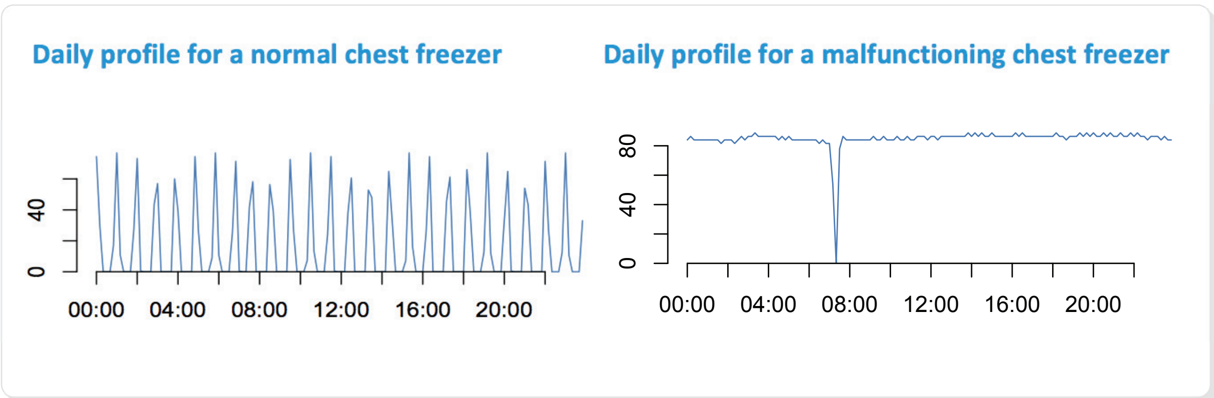

Figure 6. Comparison of the electrical time-series of a normal chest freezer and a malfunctioning chest freezer.

Table 4. Proportion of malfunctioning cold appliances and excess electricity consumption

Appliance	Sample Size	Proportion malfunctioning	Extra electricity consumption for malfunctioning appliances kWh/year
Fridge	99	2 %	180
Freezer	129	9 %	331
Fridge-freezer	148	4 %	120

Table 5. Standby recorded for a range of appliances.

Appliance	Average standby (W)	10–90 % range (W)	Sample size	% standby identifiable
Sky box	18.9	15.5–24.3	25	96 %
Set-top box	14.1	4.1–24.7	186	84 %
Hi-Fi	6.8	0.5–14.3	23	65 %
VCR	5.4	2.9–9.5	33	73 %
Wii	3.3	0.9–10.2	46	80 %
DVD	3	0.3–6.2	127	70 %
TV	1.4	0.0–5.0	407	42 %

ing, or be a result of poor installation (e.g. limited air flow around the cooling fins). Householders would not normally be aware of these faults. Overall, 21 out of 376 appliances (6 %) appeared to be malfunctioning, resulting in significantly higher electricity consumption.

The sample size was very small, but it appears that older appliances were more likely to malfunction. DECC has commissioned further work to establish the reasons for this malfunction.

STANDBY

There is some uncertainty in the data because of limitations in the monitoring equipment for monitoring appliances in low power states, but our analysis suggests that standby power in this sample accounted for an average of 201 kWh per household per year, or 5.1 % of total electricity use. Table 5 shows the range of standby recorded, where sample sizes were significant.

However, the EU Standby regulation (2008)[7] and its subsequent modification in 2013[8] limited standby to 1 W for appliances entering the EU supply chain in 2010 and to 0.5 W for appliances entering after 2013. We would therefore expect the overall electricity demand from standby to decline as old appliances are replaced.

Results: Potential Savings

We scaled the electricity demand of the households in the sample to the UK level, using data on house and occupancy types. The resulting estimate was 105.5 TWh, close to the UK Government figure of 115.2 TWh for the period 2010–2011[9]. We subsequently examined potential savings from replacing lights and appliances with the most efficient models available.

Starting with lighting, we found that only 30 % of the light bulbs in the sample were low energy bulbs (compact fluorescent, LED or conventional fluorescent tubes). The rest were traditional (incandescent) bulbs, or halogens, which use considerably more power. This was particularly true for outdoor lighting; 58 % of the households had at least one outdoor light, and the vast majority of these used traditional incandescent bulbs (49 %) or halogens (30 %). Households with traditional bulbs had an average installed load for outdoor lighting of 66 W, while those with halogens had much higher installed loads; an average of 350 W, with 1,500 W at one property.

Replacing all inefficient lamps represents a good opportunity to reduce electricity use. Regulations under the EU Eco-Design Directive[10, 11] restrict the entry of these lamps into the European supply chain, so the electricity demand for lighting is predicted to decrease over time. Projections for the UK Government suggest an 80 % take-up of low energy lights by 2024. Using this uptake rate, we estimated the savings across all HES households, and found increasing the proportion of low energy lights from 30 % to 80 % would save an average of 230 kWh a year per household, which scales to 6.2 TWh across the UK.

We also examined the potential savings from four different interventions that could reduce energy use by appliances:

- replacing cold appliances with A+ or A++ energy-rated appliances
- replacing existing washing machines, clothes dryers and dishwashers with energy efficient alternatives (A+, A and A+ respectively).
- replacing desktop PCs with laptops
- reducing standby power for audio-visual and computer sites

7. "Commission Regulation (EC) No 1275/2008 of 17 December 2008 Implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign Requirements for Standby and Off Mode Electric Power Consumption of Electrical and Electronic Household and Office Equipment", European Commission, Brussels, 2008

8. "Comission Regulation (EU) No 801/2013 of 22 August 2013 Amending Regulation (EC) No 1275/2008 with regard to Ecodesign Requirements for Standby, Off Mode Electric Power Consumption of Electrical and Electronic Household and Office equipment, and Amending Regulation (EC) No 642/2009 with Regard to Ecodesign Requirements for Televisions", European Commission, Brussels, 2013

9. "Digest of UK Energy Statistics, Table 5.1", Department of Energy & Climate Change, London, 2014 https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes

10. "European Commission (EC) (2009) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps" European Commission, Brussels, 2009

11. "European Commission (EU) (2012) No 1194/2012 of 12 December 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment" European Commission, Brussels, 2012

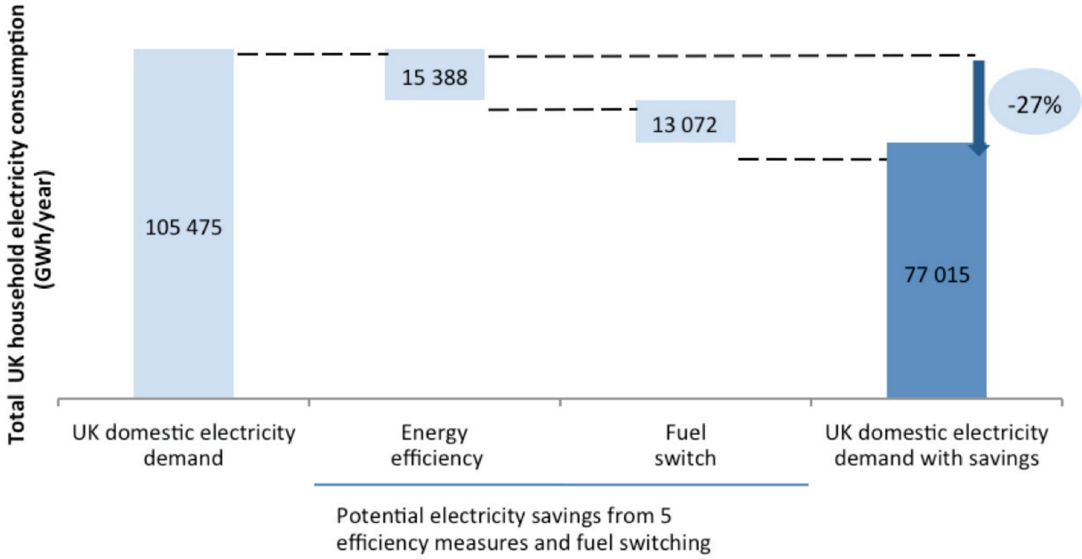

Figure 7. Potential electricity savings from five energy efficiency interventions and fuel switching (scaled to the UK household sector).

The combined potential savings, together with the lighting savings, were estimated at around 15.4 TWh for the UK, roughly the equivalent of the output of 2.25 large gas or coal fired power stations*. Since this study was published, some of these savings have already been realized (for example, LEDs are much more common in the household sector than previously and many households have replaced desktop PCs with laptops or tablets). Furthermore, as previously mentioned, the EU Standby regulations have reduced the potential savings from standby (see footnotes 4 and 5). On the other hand, the true potential for savings could be higher; our study did not include an estimate for replacing inefficient TV's or ovens, and more efficient appliances have entered the market. In 2014, A+ is now the minimum standard for cold appliances for example.

Readers should note that there is a substantial price differential for highly efficient tumble dryers.

FUEL SWITCHING

In the UK, it is rare for households to use electricity as their primary heating fuel; only around 8 % of households do so. For these households, we considered the potential electricity savings from switching to non-electric fuels for heating, or more efficient electric heating systems, such as heat pumps, for water heating and space heating. We also considered the possible savings from replacing secondary electric heating by the primary heat source (usually gas or oil). When taken together, these figures accounted for around 13 TWh for the UK as a whole, roughly the output of 2 large gas or coal fired power stations.[12] Figure 7 shows the combined potential reduction in electricity demand from fuel switching and replacing inefficient lights and appliances. *In principle, it would be possible to reduce the current UK household electricity demand by 27 % using these measures, although residential gas and oil consumption would increase.*

12. Based on 1.5 GW capacity, 52 % load factor, resulting in an annual output of 6,837 GWh/year.

Results: Daily electricity profiles and peak demand

The study also provided information about the variation of electricity demand throughout the day. Figure 8 shows a typical example, omitting the houses that use either primary or secondary electric heating. Four aspects are immediately apparent:

- The peak demand in the household sector occurs at around 18:00–19:00
- There is a significant proportion of "unidentified load"
- Cooking peaks at around 18:00–19:30, while lighting peaks at 20:30–22:30 and audio-visual use peaks at around 20:00–22:00.
- Washing and drying appear to take place throughout the day.

Figure 9 shows the components of household electricity demand at peak time, 18:00–19:00.

The peak demand for power in the households in the sample occurred from 18:00–19:00, at an average of 720 W per home, rising to more than 1 kW in cold weather. Nearly 60 % of the identifiable peak electricity demand was used for cooking, lighting and audio-visual appliances. It is difficult to re-schedule these uses, but there is potential for reducing peak load by improving efficiency of these appliances. It is relatively easy for householders to change the time of use of some other appliances, such as washing machines and electric water heating. For the households in the sample, we found these made up 9 % of the peak household load. If all households with washing appliances refrained from using them during the evening peak, this would reduce the peak load by up to 1.3 GW (the equivalent of one fairly large power station). *However, the results indicated that increasing the efficiency of non-switchable appliances would be a more effective way of reducing the peak load than shifting the time of appliance use.*

Time-of-use tariffs are not common in the UK residential sector, except for households who use night storage heating. The study reviewed four time-of-use pilots, covering a total

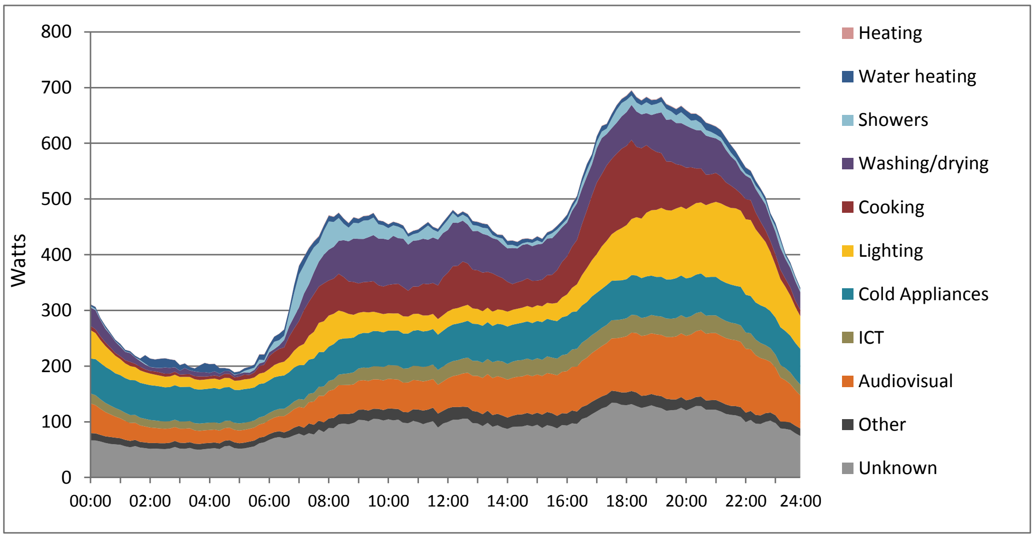

Figure 8. Typical daily electricity demand profile for a household without supplementary electric heating.

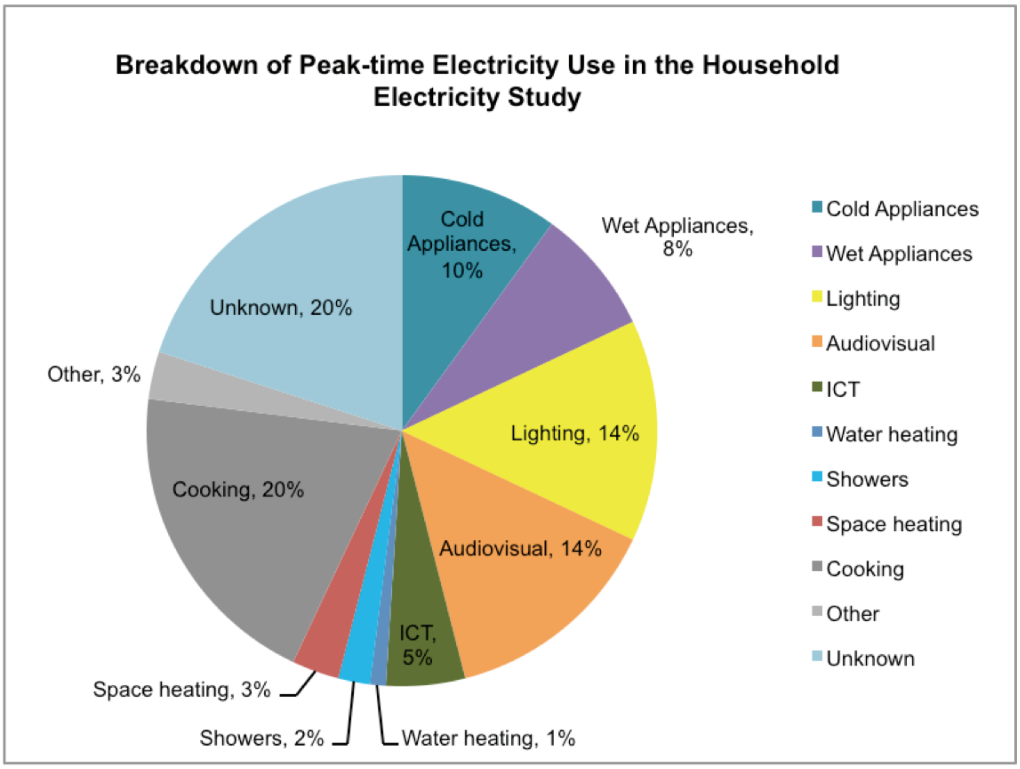

Figure 9. Components of electricity demand at peak times (18:00–19:00) for households without supplementary electric heating.

of 3,177 households and concluded that, in principle, time-of-use tariffs could reduce the evening peak by approximately 2.7 GW.

COMPARING HOUSEHOLD DEMAND TO NATIONAL ELECTRICITY DEMAND

Figure 10, from National Grid, shows overall consumption for GB, which consists of residential, non-domestic and industrial and transport demands. Data from Elexon (the balancing and settlement company) represents an estimate of overall household demand. Data from the Household Electricity Study has been scaled to GB level and compares well with the Elexon data, although it is clear that the Household Electricity sample under-estimates electricity use from 01:00–06:00; this is almost certainly due to the low representation of primary electric storage heating in the Household Electricity Study sample (3 %, as opposed to around 8 %).

December temperatures were particularly low during the study, well below the long term average (see data from the UK Met Office[13]. As a result, households in the Household Electricity Study used supplementary electric heating during par-

13. "Winter 2010 –11 Temperatures", UK Met Office, Bracknell, UK, 2011 http://www.metoffice.gov.uk/climate/uk/summaries/2011/winter

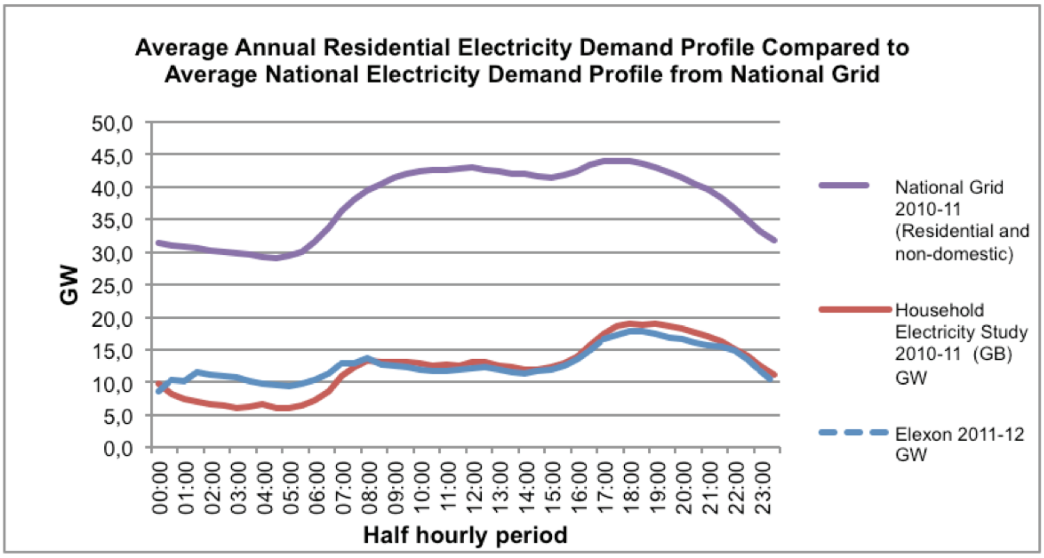

Figure 10. Average annual residential sector electricity demand profile, compared with the average national electricity demand profile for GB from National Grid (note for GB, not for the UK).

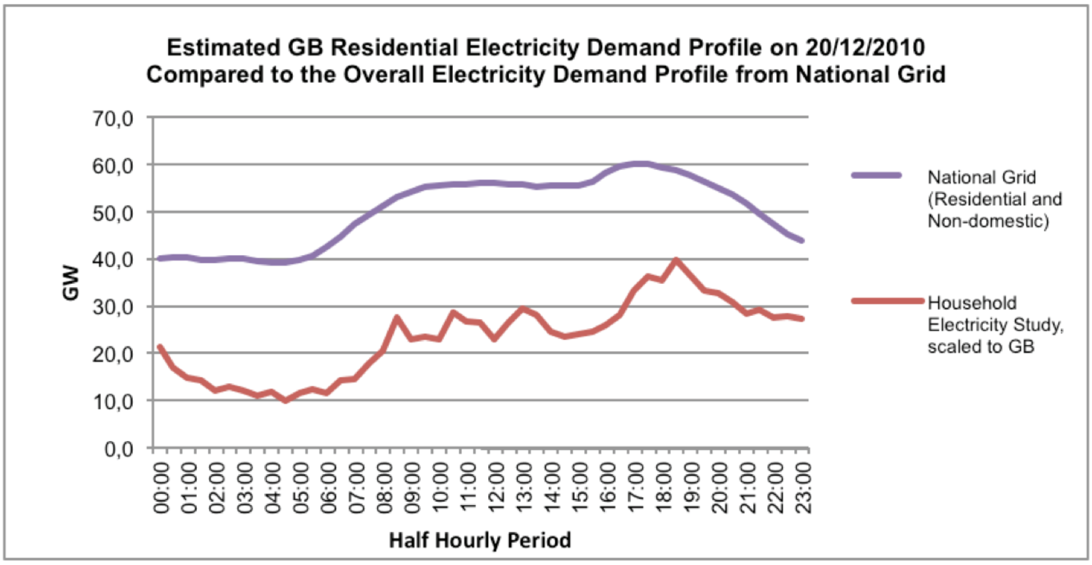

Figure 11. Residential sector electricity demand profile compared with national electricity demand profile on the coldest day (21/12/2011).

ticularly cold days. Figure 11 shows an estimate of the GB residential electricity demand on the coldest day, scaled from the Household Electricity Study sample. The overall national peak demand of 60.2 GW was recorded at around 17:00 (earlier than normal, since snowy conditions and Christmas holidays meant that many people were at home). The scaling method is approximate, but the residential sector was estimated to account for around 33.1 GW at 17:00, rising to 40 GW at 18:30). This was an exceptionally cold day, with a UK average temperature of around -5.5 degrees C, as opposed to the long term average of around +4 degrees at this time of year.

This part of the peak load is avoidable, and the study indicates that *if all 4.2 million UK households with electric secondary heating switched to a different form of heating, the peak load could be reduced by around 2 GW* (this would also result in a small reduction in annual electricity use).

Modeling electricity use by lights and appliances

The "Standard Assessment" Procedure[14] is used to model fuel use for space and water heating, as well as electricity use for lights and appliances in domestic properties in the UK. The algorithms for these models are used in the National Housing Model and the Cambridge Housing Model, which form the basis of DECC statistics on residential energy use. These algorithms are simple and are based on the floor area, number of occupants (for appliance consumption) and floor area, number of occupants, exposure to natural daylight and proportion of low energy lighting (for lighting consumption):

14. "The Government's Standard Assessment Procedure for Energy Rating of Dwellings", Building Research Establishment, Watford, 2012 http://www.bre.co.uk/sap2012/page.jsp?id=2759

For the households in the sample, the Cambridge Housing Model (which is used in DECC statistics) was found to provide a good overall estimate of electricity use for lights and appliances (under-estimating by < 5 %). However, the split between appliances, lights and cooking was different. The model estimate of electricity use for appliances and lighting, averaged across all the homes in the sample, was too high (33 % over for appliances, 25 % for lighting), whereas the model estimate for cooking was 33 % too low. There is a case for revising the models based on this study.

Social studies

In the final section of the report, we examined the reasons for high and low electricity use. We also investigated whether stated environmental beliefs correlated with actual behavior. Finally, we estimated a possible increase in electricity demand of 9 % by 2021, based on demographic factors alone[15]. However, this trend will be influenced by two opposing factors; the tendency of households to use more appliances and the increased efficiency of those appliances.

Comparison with other studies

Zimmerman et al. studied electricity use in 400 homes in Sweden in 2009 (see footnote 5). The methodology was very similar to that adopted here; however, the results are very different. The principal difference is that electric heating is very much more common in Sweden than in England, where 87 % of households use gas as their main heating source. Combined with the colder climate, this means that Swedish households draw much more power from the electricity grid – up to 2.7 kW, on average, with nearly 2 kW even at night. For comparison, the typical demand in the English study was 600 watts, rising to a peak of 1 kW in the evening and falling to around 250 W at night.

Conclusions

The study identified 15.4 TWh of potential electricity savings in the household sector through wider deployment of energy efficient appliances and lighting. This is roughly equivalent to the output of 2.25 large fossil fuel power stations. Ecodesign and Energy Labeling regulations should help realize some of this potential.

The study estimated that around 13 TWh of electricity (the output of around 2 large fossil fuel power stations) could be saved if the 8 % of households that use electricity as a primary heating fuel switched to gas or oil. However, the residential gas and oil demand would increase.

Peak electricity demand could be reduced by 1.3 GW nationally by rescheduling the use of washing machines and immersion water heaters. This is just under the peak output of a large gas or coal fired station (1.5 GW). However, greater reductions in peak demand can be made through improving the overall energy efficiency of appliances. An alternative way to reduce peak demand is to operate time of use tariffs. A review of a range of pilot studies indicated that UK consumers do respond to such tariffs and estimated a potential reduction in peak demand of 2.7 GW nationally.

The analysis found that nearly all appliances are increasing in size or capacity over time, with the exception of dishwashers. Larger size or capacity is usually accompanied by increased energy consumption. There is a risk that the trend to increasing size could partially offset the reduction in consumption caused by improvements in efficiency.

If electricity consumption patterns remain unchanged, then we anticipate that residential electricity use will increase by 9 % by 2021 because of demographic change alone. However, this trend will be influenced by two opposing factors; the tendency of households to use more appliances and the increased efficiency of those appliances.

Further information

The full reports can be found here: https://www.gov.uk/government/collections/household-electricity-survey.

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