How Trends in Appliances Affect Domestic CO₂ Emissions: A Review of Home and Garden Appliances
Summary Report, April 2010

Project Summary

The Climate Change Act (2008) sets a legally binding target of an 80% reduction in national CO₂ emissions by 2050 compared to 1990 levels. In order to achieve these targets, it is important to understand how energy is being used currently, and to take targeted actions that will reduce future energy use and hence carbon emissions. Domestic energy use contributes 29% of the total energy use in the UK, with cooking, lighting and appliances making up 18% of the domestic total in 2007 (DECC 2008). Whilst there is a growing understanding of measures to reduce space and water heating in the domestic sector, appliance use in this context is less well researched. As the building stock becomes more efficient, the use of energy by appliances will become relatively more significant. This, coupled with the recent growth of the use of domestic appliances, means that attention must be focused on appliances to ensure carbon budgets set by the Government are realistic.

Defra’s Market Transformation Programme currently models the energy consumption for a number of domestic appliances, using market intelligence data, supported by expert assumption where data are not available. Whilst this provides a view of stock and sales, there is currently less information on the real usage of the appliances and actual energy consumption in situ. Additionally, not all household appliances are covered and so it is not fully able to take an holistic approach to understanding domestic energy consumption.

The Department for Energy and Climate Change commissioned a multi-disciplinary team led by Loughborough University to review data on domestic appliances in order to identify where the priority areas for future policy should be. The project aimed to draw together information about the energy demands of current domestic appliance use at a household level, and explore trends in future use, in order to predicting future demands. This information could then be used to inform future household models that include an element of appliance modelling.

Key Findings

- There are approximately 26m households in the UK and this number is set to increase over the next twenty years. In 2008, the average number of persons per household was 2.37, a number that has been declining over the past 40 years. One person households are increasing, and this trend is expected to continue - by 2031, 18 per cent of the total population of England is projected to live alone, compared with 13 per cent in 2006.

- Other changes to the UK demographic include: the average age of the UK population is expected to increase and this ageing population will result in an increased number of retired people, spending more time at home. The socio-economic group forecast shows an increased number of people in the ‘AB’ category, based on occupation of the head of the household. UK household spending has also been increasing steadily and is significantly more than would be accounted for by population increases.
• Current building stock energy models do not include sophisticated appliance sub-models. BREDEM is at the core of most UK domestic energy endeavours and calculates appliance energy demand based on floor area (or floor area and number of people in the household) alone. Such an approach cannot reproduce the large variations in appliance energy use that are observed in practice. Other more sophisticated models are emerging but they are operationally constrained by the availability of data on appliances and their use and the relationship of these to occupancy characteristics particularly with regard to actual appliance use in situ.

• More generally, the data requirements for physically based bottom-up modelling fall in three key categories:
  o **Ownership of appliances by households.** This is informed by numbers of sales of new products, but also requires an understanding of multiple ownership, how long people keep old appliances and what they do with old ones when they buy new.
  o **Usage of the appliances in the household.** Some appliances are in constant use, others are used intermittently (daily, weekly, seasonally) and some are rarely or never used. Even with similar appliances, use patterns vary widely. Quantification of this, even of averages, is difficult using currently available data as behaviour and interaction with an appliance is complex.
  o **Power consumption of the appliance.** The power consumption of individual appliances depends heavily on the appliance in question, and some appliances have much greater power demands than others. Variations though, are more complex, with different average power demands during the period of active use depending on the ‘setting’ chosen. Many appliances consume power when in the ‘off’ mode as well as in stand-by mode. Manufacturer’s nameplate power ratings are often misleading due to internal thermostatic cycling for example. Even field-measurements can be significantly affected by user settings and usage, which are rarely recorded.

Thus, the ‘average power demand’ of many electrical items has much more to do with the way they are used than their nominal power rating.

• During the review, it became apparent that significant studies of appliance ownership, usage and measured power consumption did not exist, although pockets of data were available. In some cases these applied to only one product type, or one consumer group. As a result, a ‘patchwork’ of information was built up, rich and robust in some cases, threadbare in others. Where little information was found, assumptions based on the expertise of the project team were used to inform a household overview.

• Statistics indicate that the average domestic annual electricity consumption in 2006 was 4457 kWh. Calculations for an ‘average’ household were made using review data or best estimates using a list of 120 different appliances categorised into major end-use categories. The sum of the electricity demand for all the appliances in the calculation totalled 4847 kWh when household ownership was taken into account. Given the uncertainty of the data in some cases, this was considered a close result.

• The estimated proportion of the total appliance energy use, split by appliance category, is shown below. Heating forms the largest component, but detailed analysis of this was outside the scope of this review, as the majority of heating provision is integral to the building fabric.

• Information, communication and entertainment appliances are estimated to have the highest energy demand as a group, although this includes a wide variety of appliances (computers, TVs, telephones, etc).
- Environmental control, including dehumidifiers and air conditioning formed the next largest estimated energy consumption category.

- Garden and DIY appliances are a relatively small category in terms of energy use and hence carbon emissions.

![Pie chart showing estimated proportion of total appliance energy split by appliance category.](chart)

**Figure 1: Estimated proportion of total appliance energy split by appliance category**

- By reviewing the detail within these categories, based on our estimates and calculations, the following domestic appliances appear to use the most energy, given the numbers in use across the UK. Policies relating to the usage of these appliances might usefully be targeted at the whole population.

<table>
<thead>
<tr>
<th>Appliance type</th>
<th>Estimated total annual energy demand per household (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fridge-freezer</td>
<td>325</td>
</tr>
<tr>
<td>TV (CRT)</td>
<td>254</td>
</tr>
<tr>
<td>TV (LCD)</td>
<td>218</td>
</tr>
<tr>
<td>Freezer (various types)</td>
<td>184</td>
</tr>
<tr>
<td>Washing machine</td>
<td>170</td>
</tr>
<tr>
<td>Kettle</td>
<td>161</td>
</tr>
<tr>
<td>Tumble dryer</td>
<td>146</td>
</tr>
<tr>
<td>Electric Hob</td>
<td>141</td>
</tr>
<tr>
<td>Outdoor/garden lighting</td>
<td>140</td>
</tr>
<tr>
<td>TV (Plasma)</td>
<td>136</td>
</tr>
</tbody>
</table>

**Figure 2: Total annual energy demand per household – priority areas**
From the estimates and calculations presented in this report, the following domestic appliances appear to use the most energy on an appliance basis, although their market penetration may not be high. Policies relating to the consumer usage and availability of these appliances could be targeted to specific sectors of the population who use them most.

**Figure 3: Total annual energy demand per appliance – priority areas**

<table>
<thead>
<tr>
<th>Appliance type</th>
<th>Estimated total annual energy use per appliance (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swimming pool heater / filter / pump</td>
<td>9000</td>
</tr>
<tr>
<td>Hot tub / Jacuzzi</td>
<td>2190</td>
</tr>
<tr>
<td>TV (Plasma)</td>
<td>999</td>
</tr>
<tr>
<td>Dehumidifier</td>
<td>657</td>
</tr>
<tr>
<td>Fridge-freezer</td>
<td>500</td>
</tr>
<tr>
<td>Green house heater</td>
<td>500</td>
</tr>
<tr>
<td>Pond maintenance equipment</td>
<td>438</td>
</tr>
<tr>
<td>Freezer (various types)</td>
<td>400</td>
</tr>
<tr>
<td>Electric hob</td>
<td>381</td>
</tr>
<tr>
<td>TV (LCD)</td>
<td>335</td>
</tr>
</tbody>
</table>

Many of these appliances have been the subject of Defra’s Market Transformation Programme modelling and the focus of EuP preparatory studies, however the available research on detailed usage is limited and so the quality of this information is uncertain. Some of these appliances have already been tackled through the setting of EU minimum standards and energy labels, in particular freezers, fridge-freezers and plasma and LCD televisions. However, there are very few behavioural studies to understand the real and complex issues of use; nearly all are self-reported questionnaire surveys of ownership and daily usage. Whilst these provide insight, such studies may be inaccurate (as they usually rely on recollection of household behaviour, often from only one household member). Neither do they provide enough understanding of the underlying behavioural issues in order for effective intervention strategies to be implemented.

A note of caution is appropriate here, whilst an estimate of the priority areas has been attempted within the short time scale of this project, the lack of appropriate information means that much greater understanding is needed before these findings can be verified and effective policies implemented.

**Recommendations**

A number of recommendations are made as a result of this review.

- More detailed investigations taking measurements in the home are needed. Recent developments in sensor and wireless sensor technology are beginning to make monitoring of appliance energy use, at frequent time intervals a realistic possibility. Such monitoring would significantly enhance our understanding of what happens in practice. The joint Defra, DECC and Energy Saving Trust Product Usage Study recently commissioned will provide good, initial data in this area, through its 10 minute interval measurement of individual appliances in 200 homes across the UK, which will fill some of the gaps identified in this review. However, the underlying behaviours driving the appliances usage may not be captured; an understanding of these is critical to making effective recommendations.
Rich, qualitative and detailed data are needed on use and behaviour in relation to household activities and practices, particularly in the areas of high energy demand within households or across the UK, e.g. use of the television to watch TV, listen to radio, provide background sound or a visual focal point to a room; understanding of cooking practices; use of lighting in and outside the home and reasons for these; washing practices (clothes and personal) and underlying expectations of hygiene; security and safety requirements and the impact on appliance use. These need to extend to the wider population, not just small samples, in order to ensure appropriate intervention strategies can be targeted at all relevant consumers.

The proposed National Household Model (NHM) needs to include an appliance component in order to predict future domestic energy consumption: as homes are better insulated, appliance energy use is likely to represent a greater fraction of total home energy demand; electric space and water heating, using for example heat-pumps may be more prevalent.

Future models will also require demand profiling to make best use of an energy supply system which has a higher proportion of intermittent generators using renewable sources.

However, the requirements and desirable features of an appliance component are multiple and there is risk of an over-ambitious specification being defeated by lack of data. The immediate priority is to develop a rigorous core of data that can underpin more detailed modelling activities.

Further analysis of existing data sets could help enhance understanding of appliance use. Household appliance surveys and measurement programmes already underway provide the potential for greater understanding. Capitalising on these for the specific purpose of populating the NHM would provide initial data before more extensive behavioural studies could be undertaken, although issues of data protection and confidentiality would need to be addressed.

Data sharing from future studies should be encouraged to enable an open household appliance data archive to be established. It could become a requirement of future research programmes to supply data to a central archive for all to access. The Product Usage Study data collection programme would provide a significant start to this process.

A quantified way of representing behavioural change following intervention strategies could be developed as part of the household model so it can more accurately assess the impact of future policies, from forced changes to consumer driven action.

Better ways are needed to communicate behavioural understating to designers and manufacturers, to ensure they are designing for end user needs. The current focus is on technical performance in standard conditions, rather than covering issues relating to real practice. This may include the use of exemplar design concepts to inspire manufacturers and designers, and to demonstrate value in terms of effective behavioural change and a successful product.

**Methodology and Scope**

Literature relating to domestic appliances was reviewed, to determine data about the key issues of ownership, usage and energy consumption. Additional data were noted where they appeared relevant to understanding the landscape of household domestic appliances. Only standalone appliances were considered, so any devices integral to the fabric of the building were not covered by this review.
Energy consumption for each appliance and appliance group was then calculated using information from the review. The review had a UK focus, so studies from outside the UK were not reviewed in any detail.

Running concurrently with this project, and yielding relevant information, was an EPSRC funded project called, for short, 4M\(^1\). Led by Loughborough University, the project is attempting to model the direct carbon footprint of the city of Leicester. Early sight of the raw data from an appliance survey from 4M allowed a household perspective to be taken, something not often possible from other published data.

**Limitations**

The published data did not always provide sufficiently detailed information to establish accurate ownership levels, detailed usage patterns or real energy use data. As a result, ‘best guess’ estimates had to be made to inform the range of energy consumption calculations. The literature often included very few details of the derivation of data and many apparently new sources seemed, although not explicitly stated, to refer back to the Market Transformation Programme data. Only electrical demand was considered in the whole house calculations, although this covers the majority of domestic appliance energy use.

**Further Information**

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**Contract commissioned by:**
Tina Dallman, Department of Energy and Climate Change

**Further information:**

\(^1\) Measurement, modelling, mapping and management: a methodology for shrinking the urban carbon footprint (EPSRC, SUE2 programme).