A short review of energy information in domestic refrigeration and cooking

Cooking I Refrigeration I Cooking and coolingI

References

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Introduction

There has been a dramatic transformation in the last decade in consumer uptake of energy efficient white goods such as fridges, freezers, washing machines 1. Figures published by DEFRA shows that in the UK, domestic energy use produces approximately 1.9 tonnes of Carbon per annum per household 2. Recent studies 3, 4, 5, 6 investigated the annual rates of CO2 emission associated with energy use and have suggested changes in usage in order to decrease these emissions.

The UK has amongst the highest annual electricity consumption of ovens in Europe 7. The Department of the Environment data in 2001 8, showed that around half of UK households own an electric oven and hob and accounted for an estimated 3.4 TWh and 3.0 TWh per annum, respectively 9. This figure has risen to approximately 21.2 TWh (Table 1) per year, according to latest estimated data from MTP (2007) and is expected to rise to 22.0 TWh per year by 2020 10.

Table 1. Annual total energy consumption by domestic cooking products in 2006 (from BNCK01 10).

Product	Annual total energy consumption (TWh)
Electric hobs	3.364
Electric ovens	3.304
Gas hobs	3.364
Electric hobs	4.910
Gas ovens	2.970
Microwave ovens	2.390
Kettles	4.256

Domestic Cooking

Personnel at the Food Refrigeration and Process Engineering Research Centre (FRPERC) at the University of Bristol have a long history of working on white goods. James and Rhodes (1978) 11 looked at energy consumption when cooking meat joints from frozen compared to fresh joints. Their findings were that energy consumption when cooking meat joints from frozen was 2.3 times higher from that of thawed. More importantly only between 72 and 84 % of the total energy used was spent in keeping the oven at the required temperature. Recently pilot work has been carried out to look at at energy consumption and efficiency of electric and induction hobs. Results showed that induction hobs consumed 20% less energy and were 15% more efficient than electric hobs.

Detailed energy-consumption data for domestic appliance, particularly for cooking activities in real situation (by type of meal or by appliance) are very scarce. The only recent study found was carried out by Wood and Newborough (2003) 12 who looked at ways of saving energy on cooking appliances in 44 households in UK. They monitored these households for a period of 12 months and found that the average daily energy consumption for electric cooking was 1.30kWh. Wood and Augood (1999) 13 showed that a cooking event can produce a peak of up to 10kW while kettles, ovens and tumble dryers creating an individual peak demand of only 2-2.5kW (Figure 1). Slider et al. (2000) 14 carried out an experimental investigation on domestic appliances in 100 households in France. They found that the combined cooking-related energy consumption accounted for 14 % of the total electricity-specific energy consumption of the households surveyed. The average annual energy consumption of all electric cooking appliances was 568kWh/year. They also found a monthly variation over the year in cooking-related electricity consumption, with the energy consumption in January being 1.25 times the annual average monthly value and 0.72 times in June 14.

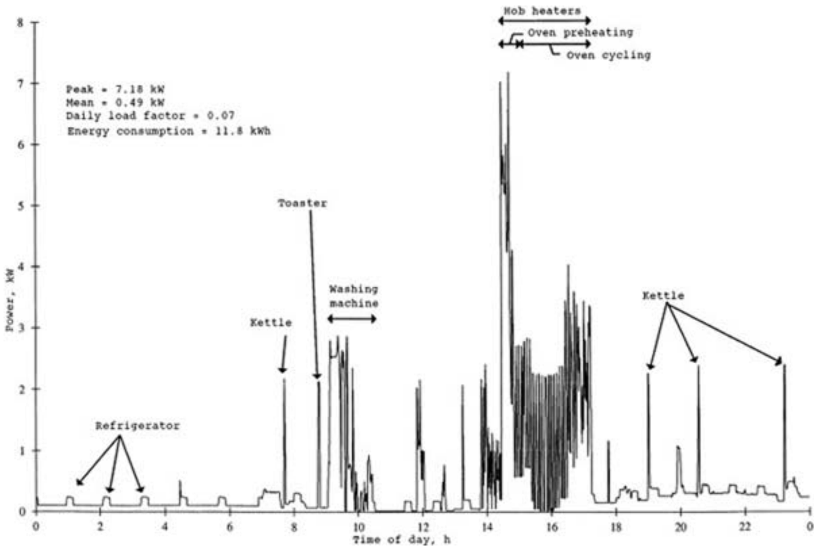
The market transformation programme commissioned a work in 2006 15 to look at the energy efficiency of traditional versus microwave cooking. Results of their work indicated that there is potential to save energy by changing cooking methods from traditional to cooking with microwave oven. This saving has being estimated as 10% however, further work is necessary to identify how much of the cooking could be transferred and what real savings could be made. This would provide a better understanding of fan-oven use, user habits with fan ovens such as oven preheating and its effect on energy consumption.

Domestic Refrigeration

When considering cold appliances James et al. 2007 17 have carried out a concise review of published data available on the performance of domestic refrigerators. In there they list a number of UK surveys of consumer handling of domestic storage of refrigerated goods dating back to 1990 with the latest been carried out in 2006. It also lists the publish data available on air temperature distribution in domestic refrigerators. However, none of these surveys seem to cover energy consumption in real situation.

There have been various design changes in the last decade, in particular general improvements to increase energy efficiency. Improved compressor efficiency has lowered energy consumption in some models. Recently, the use of Vacuum insulating panels (VIPs) for wall insulation in domestic refrigerators has been used to achieve better energy efficiency 18, 19, 20. Blomberg CT1300A won the 2004 European Energy+ award for a two-door refrigerator, this had an Energy Efficiency Index of 19.81 and annual energy consumption of 137 kWh 20. However, there are several issues regarding their suitability for domestic appliances which must be addressed such as vulnerability, handling problems, weakness of insulation at the edges and costs of the panels. There may also be other environmental issues, such as production and disposal impacts.

The demand imposed on the electricity grid by customer's changes continuously throughout the day as domestic, commercial and industrial appliances are switched on and off. Design microcontrollers are fitted to appliances that are sensitive to the power imbalances on the electricity grid and able automatically to alter the timing of their demand requirements accordingly. These are known as dynamic demand control. There are a number of publications 12, 13, 21, 22 on the use of dynamic demand and its impact on energy consumption. A report produced by the Department for Business Enterprise and regulatory reforms (2007) on dynamic demand control (DDC), identifies encouraging evidence as to the potential of such approach to increase the efficient operation of generation, reduce the costs of operating the electricity grid and reduce the emissions of greenhouse gasses. However, the report concludes that further work needs to be carried out to support the further development of the technology to fully quantify the extent to which it can contribute to the Government's energy policy goals 21.



The Market transformation programme 22 has carried out trials on dynamic demand controllers mainly on cold appliances. Their trials on domestic refrigerators in laboratory showed that internal temperatures can remain under control while still responding to high grid load as shown by dips in mains frequency. The UK market is around 3.8 million units per year so if only half of these are DDC appliances (a realistic possibility), market penetration could happen relatively quickly. Since the DDC does not save energy for the domestic consumer, it is recognised that there needs to be a market incentive to help make DDC appliances attractive to manufacturers and their customers. They have plans to carry out a field trial from 2008 - 2009 of more than 400 DDC operated cold appliances. However, in all the work produced to test DDC, there is little if no evidence on its effect on food temperature in fridges.

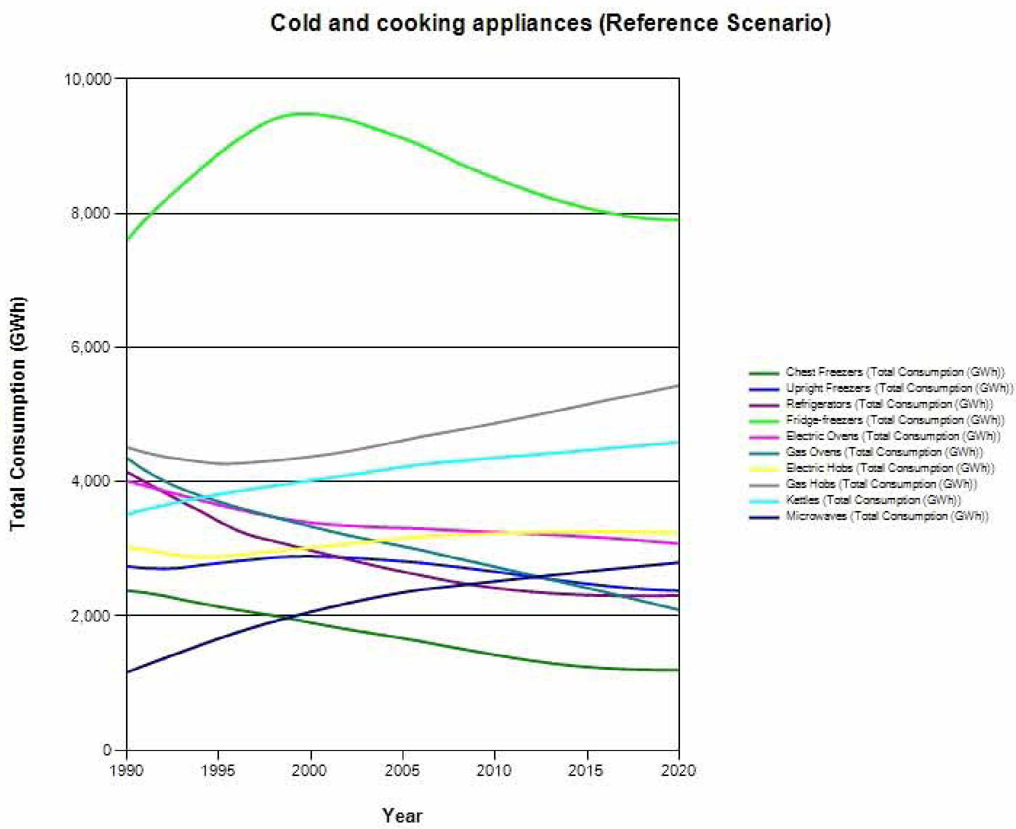


Figure 1. Example of an electricity demand profile from an individual household recorded on a 1-min time base (from Newborough and Augood,1999 13).

Domestic Cooking and Cooling

The market transformation programme designed a web tool 16 to estimate energy consumption of domestic white goods including different scenarios:

Reference Scenario: estimates and aggregates the impact of existing policy measures, superimposed on underlying market trends.

Earliest Best Practice Scenario: indicates what could happen if the market was to adopt the most cost-effective options.

Policy Scenario: estimates the effects of an ambitious but feasible programme of policy measures.

This tool provides helpful energy figures for cold (fridges, freezers and fridge freezers) and cooking (electrical hobs and ovens, gas hobs and ovens, microwaves and kettles) appliances. Figure 2 shows the reference scenario (existing policy) for the total energy consumption for domestic refrigeration and cooking appliances. It shows that the energy consumption of gas hobs, microwave and kettles particularly will increase up to 2020, whereas the other appliances will either remains the same or decrease. In this tool toasters, breadmakers and others small white appliances are not included.

Figure 2. Graph produced from the "What if tool" predictions for the cold and cooking appliances when considering a reference scenario (from 'MTP, 'whatif' tool 16).

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