Dynamics of Energy Use in UK Households: End-use monitoring of Electric Cookers

Iman Mansouri
Marcus Newborough
Cranfield University, School of Mechanical Engineering, Bedfordshire,

1 - SUMMARY

This study was funded by DGXVII of the EC and the UK DETR. It commenced in January 1997 and was completed in January 1999. The general context of the research was that of reducing the energy consumption of the existing stock of domestic cooking appliances by influencing consumer behaviour at the points of use.

The energy consumptions of electric cookers in 36 UK homes were measured in detail and three methods for influencing end users to reduce their cooking energy consumptions were developed and assessed in 32 households. These "information-transfer methods" involved providing householders with: (a) an energy-saving information pack; (b) appropriate electronic energy-consumption feedback indicators (ECIs) to display the in-use consumptions; or (c) information-pack plus ECI.

2 - INTRODUCTION

This project aimed to promote the adoption of more efficient practices by users of the existing stock of cooking appliances. The main objectives were (i) to collect detailed energy consumption data and (ii) to develop and assess three methods of influencing end users, namely:

1) an appropriate «Information Pack»;
2) electronic «Energy-Consumption Indicators»; and
3) methods (1) and (2) simultaneously.

The sample set of houses was split into four groups. Group 1 (the control group) was monitored across a period of 12 months, while the three other groups (associated with methods (1), (2) and (3) above) were monitored for a minimum period of 16 weeks (ie 8 weeks before and 8 weeks after introducing (1), (2) or (3) to the household). This time-scale was considered long enough to assess any changes and to ensure that users had had sufficient time to use and experiment with the Information Pack and/or Energy Consumption Indicator.

The energy savings for each of the three methods of promoting more efficient appliance use were quantified and a set of recommendations composed based on these findings.

3 - DATA COLLECTION

It was essential to consider the composition of each monitoring group carefully in order to maximise the effectiveness of the study. Two main factors were considered. Firstly the national distribution of households in Great Britain, and secondly the available data on electricity consumptions for cooking appliances (both in general and also related to household-type in particular). The latest published data on the composition of households in Great Britain are given in Table 1.

Table 1 : - Composition of Households in Great Britain 1995/96

Number of Persons in the Household	1	2	3	4	5	6 or more
Proportion of Households with the Specified Number of People	28%	35%	16%	15%	5%	2%

Source : Social Trends 27, 1997, HMSO, p 40

A previous Cranfield survey (carried out in South East England in 1994) revealed that, on average, an electric hob and oven were used for approximately 60 and 30 minutes/day respectively, corresponding to a predicted annual electricity consumption of approximately 670 kWh per household [Mansouri et al.1996]. However, the usage of hobs and ovens varied enormously between different households, indicating that consumption ranged from 260 to 1800 kWh/year per household. Further analysis indicated that the number of persons in a household was the clearest indicator of usage for all appliances including that of cooking appliances [Mansouri and Newborough, 1996] (see Table 2). A more recent Cranfield survey of more than 500 households in Peterborough (UK) in 1997 [Bennett, 1998] indicated similar overall usage patterns for cooking appliances: hobs and ovens being used on average for approximately 58 and 36 minutes /day per household.

Table 2 : - Cooking Appliances: Usage-Patterns by Household-Type

Number of Persons in the Household	1	2	3	4	5	6
Electric Hob + Electric Oven Usage (minutes per day)	45	81	99	85	122	109
Electric Hob Component Usage (minutes per day)	23	49	63	56	88	66
Number of responses in the sample Electric Hob +Electric Oven	*15*	*47*	*31*	*67*	*19*	*7*

Source : Mansouri and Newborough, October 1996
Behavioural Aspects of Household Electricity Consumption

A study by NUTEK of 66 Swedish detached houses (located in central and northern Sweden) between 1991 and 1993 [NUTEK, 1995] reported measured consumption data for food preparation (cookers, microwave ovens and coffee makers) in these households. The total electricity consumptions for these households (which varied between 1630 and 9540 kWh/year with a mean value of 5068 kWh/year) depended upon the number of persons in the household, and even more significantly upon the composition of that household (ie whether the family had only young children, children and teenagers, only teenagers, or retired people). The electricity consumption for the cooker ranged from 150 to 1150 kWh/year per household, with the specific consumption per person ranging from 50 to 500 kWh/year.

It appears that, in general, a household with a small number of people will have a lower consumption than a larger family. However, because of the complex nature of consumption patterns in households (with factors such as age of the children as well as their numbers affecting consumption) it was probable that monitoring groups of only 10 households would exhibit widely varying consumption patterns. Also, considering the impact of any savings that may result from this study in a national context, it was decided that the composition of the control group should be similar to that of the distribution of household-types in Great Britain, but that the other groups should comprise of 2 to 5-person households.

Suitable households were identified from a survey of over 1000 homes. Altogether 36 households participated in the study with the respective groups consisting of 12, 12, 10, 10 houses (see Table 3). The electrical power demand of the free-standing cooker (or oven and hob arrangement) was measured, the average power recorded and energy consumptions were calculated from this raw data subsequent to downloading. The monitoring phase commenced 30 June 1997 and finished on 4 December 1998.

Table 3 : - Household Types and Study Groups

Household Type	One Person	Two or more unrelated adults	One Family: Couple + no Children	One Family: Couple + Children	One Parent + Children	Two or more Families	Total Number of Households
1995/96 GB Distribution	28%	2%	29%	29%	10%	1%	23.5 million
•••••••••• •••••••••	3	0	5	4	0	0	12
•••••••••••••••••• •••••• •••••••••	0	0	*5*	*7*	0	0	12
••••••••••••	0	1	6	3	0	0	10
•••••••••• •••••••••••••• ••••••	0	0	5	5	0	0	10

4 - THE INFORMATION PACK AND ENERGY CONSUMPTION INDICATOR

A significant feature of this study was that it undertook the detailed design, development and testing of an Information Pack and an electronic Energy Consumption Indicator (ECI).

a) Information-pack - The Information Pack was developed from (i) "energy saving" information obtained from the published literature; (ii) discussions concerning meal preparation and cooking methods held between Cranfield and TTS, Finland; (iii) a questionnaire-based survey addressing cooking behaviour; and (iv) in-depth cooking tests in a Home Economics laboratory. It was considered important that the Information Pack was well structured and supported where feasible with quantitative evidence, not least because this was often lacking in previously published energy-saving information.

In the UK, some advice on cooking practices was available from the published literature, but the information was mainly general in nature. Published literature was also reviewed to assess food consumption habits of households in Great Britain. In general, consumption of food in the home has declined over the 20 years to 1995 [National Food Survey, 1995], as more food and drink has been eaten out. Furthermore, there are significant seasonal variations in the amount of food consumed within the home [National Food Survey, 1995], which implies variations in cooking habits, with associated but unreported energy-use implications. In order to be able to estimate the seasonal variations in the energy consumption of home-cooking, this study was designed to monitor a group of 12 households (Group 1) for a continuous period of 12 months.

Information about the types of meal prepared at home is not well documented. There is some evidence from a small number of studies (some regional and some national) [Charles and Kerr, 1988; Nicolaas, 1995; Warde and Hetherington, 1994] of a conventional behaviour pattern with respect to food preparation and meal preferences.

To provide quantitative data, which could be interpreted easily and clearly by the end-users, and to compare different methods of preparing similar dishes, a series of cooking tests were devised. The dishes included certain traditional meals (such as roast meals) and some commonly purchased ready-made dishes as indicated by the MINTEL marketing database. The tests were undertaken with the help of a Home Economics laboratory. A selection of the results was included in the Information Pack.

The final design was a bound 23-page document comprising of 4 sections as well as an introduction and contact details for further information. The individual sections included were (i) information about the electricity consumption of cooking appliances and how they work, (ii) electricity saving tips, (iii) electricity consumption values and comparisons for cooking certain common foods/meals, (iv) a table to enable the Information Pack user to estimate the electricity consumption of cooking appliances in their home.

b) Energy Consumption Indicator - Appliance users are generally unaware of the relative implications of their various interactions with a cooking appliance upon energy consumption. One means of providing them with an improved understanding is that of indicating energy consumptions in (quasi) real-time. An electronic energy consumption indicator could provide feedback to the user in a manner, which is informative and encourages them to experiment in order to identify good/bad practice. Our intention here was to research, develop and use such a unit in the field not to design a commercial product.

Initially, a prototype unit was designed and constructed at Cranfield. The unit indicated via a liquid crystal display (LCD) the cumulative operational energy cost with the last digit representing one pence. The unit also featured 10 light emitting diodes (LEDs) (depicting 1 kW each) which were lit in proportion to the instantaneous power demand. Presenting the cumulative cooking cost is informative. However, it was considered that the effectiveness of the display unit would be improved if the unit displayed certain historical data for comparison.

It was also conceived that further improvement could be obtained by incorporating a facility enabling end-users to verify the energy implications of individual cooking operations and micro-level practices. It was envisaged that this feature would encourage energy-saving experimentation by the user and hence help to maximise the impact of the information provided by the ECI.

Based on the specification required and by considering the preferred features, a design specification outline was distributed to a number of British companies specialising in the development and production of such equipment and 10 identical units were manufactured for the purpose of this project. The ECI may be placed either on the top of the upright section (where the dials are located) or on the worktop next to the cooker. The units are battery-operated by 4 AA size, 1.5V batteries, sufficient for approximately 2 months of field-testing.

The ECI received the signal from a current transformer, which was fitted around the supply cable to the cooker. The ECI has 5 LCD displays (i) «This Event» which incorporates a reset button enables the end-user to zero the display prior to a cooking operation and is updated every 15 seconds, (ii) «Today», (iii) «Yesterday», (iv) «This Week», and (v) «Last Week». All display indicated the cooker's consumption in kWh to 2 decimal places (see Figure 1).

5 - RESULTS

The monitoring programme measured, in detail, the electricity consumptions of cooking activities in 36 UK homes and utilised 32 of the participating households to test three information-transfer methods, which were devised specifically to facilitate energy saving. Unfortunately the data downloaded from one household was found to be corrupted and so results can only be reported for 31 households (ie 12, 12, 10 and 9 households for Groups 1,2, 3 and 4 respectively). A quantitative understanding has been obtained of daily and seasonal variations, the variations in consumption that occur between households, and of the prospective savings that end users of existing cooking equipment can achieve.

5.1. Energy Consumption for Cooking: Trends and Variations

For the Group1 households, which were monitored for a minimum period of 358 days, the electric cooker was used for 295 days per annum with an average daily consumption of 1.30kWh. However, the average consumption per household varied considerably ranging from 0.58kWh to 2.26kWh. It is clear that the daily average value is much less for single person households and also that they use cooking equipment on fewer days per annum (see Table 4). For these reasons, the three single-person households were excluded from the Group 1 data set that was used to determine the seasonal adjustment factors for analysing the raw data from Groups 2, 3 and 4.

Table 4 : - Cooker Usage Pattern - Single and Non-Single Person Households

	Average number of days the cooker is not used per year	Average daily cooker consumption, kWh
3 single-person households	156	0.40
9 non-single person households	41	1.36
12 Control Group Houses	70	1.30

For a given household, the average daily consumption varies across both short and long timescales (see Figs 2 and 3). Considerably more cooking was observed to take place on Sundays and the annual peak value usually occurred on Christmas Day. On average, consumption was 18% and 93% higher on Saturdays and Sundays than during an average weekday.

For the purposes of this study, the seasons were defined as follows; Spring (March, April and May), Summer (June, July and August), Autumn (September, October and November) and Winter (December, January and February). For the non single-person households, taking summer consumption as the base line, the average daily consumption (*for days that cooker was used*) is 11%, 9% and 22% higher in spring, autumn winter respectively. The relative change in consumption with season varied among the participating homes, but 8 of the 9 non single-person households showed a significant increase in winter. Clearly, it is difficult to define exactly when the seasons change and how this influences users of cooking appliances, but the average number of days per season when the cooker was not used varied only slightly; eg 10 days (~11%) in winter and 14 days (~16%) in summer. Overall, it appears that the average daily energy consumption falls into three broad categories «low» (July and August), «intermediate» (February until June, October and November) and «high» (December and January). For the intermediate level, the average daily consumption was very consistent lying in the range 1.52-1.56 kWh for 7 of the 12 months (see Figure 5).

The number of households in Group 1 is small and so it is important to regard the minimum, mean and maximum daily average consumption values with caution.
However, from this investigation it appears that the variations in annual energy consumption are functions mainly of a household's size, the degree to which it utilises a microwave oven for cooking, how frequently individuals engage in long-duration cooking processes (eg traditional roast meals), and the actual number of days per annum that they cook food at home.

5.2. The Effectiveness of the Information-Transfer Methods

The ECI and Information Pack were well received by the participating households. In most cases, positive feedback was received regarding the ease of utilising the ECI and/or the Information Pack. A small minority of households reported that they had not used or interacted with the ECI/Information-Pack, but no one indicated that they had tried to save energy but found the process irksome. Several households were certain they had saved energy while others were unsure; their expectations did not always match the measured results. It appears that a majority of those who received the Information Pack read it once, and then returned to it subsequently for specific information/advice. In general, it would seem that individuals soon established the level at which they wished to use or interact with the ECI or Information Pack and then proceeded to do so. This is an interesting finding, not least because we had intentionally offered the householder no financial inducement to participate in this study and no instruction/request to save energy.

Overall, 14 out of 31 households achieved savings of >10%, and six of these achieved savings of >20%. In Group 2, three out of 12 households achieved savings of >10% and feedback from these participants indicated that this was done mainly by adjusting certain micro-level practices and increasing their use of microwave ovens (see Table 5). The ECI appears to have been much more effective than the Information Pack. In Group 3, seven out of 10 households achieved energy savings of >10% and half of the group accomplished reductions of >20% (see Table 6). This is considered to be an excellent result from an energy-efficiency standpoint. In Group 4, four out of 10 households achieved energy savings of >10% (see Table 7).

Comparisons between the results from Groups 3 and 4 suggest that there was no compound benefit from providing a household with both an Information Pack and an ECI. The reasons for this are not entirely clear from the feedback comments obtained from the participating households. Overall, 11 out of 19 households which were provided with the ECIs achieved energy savings of >10%. Therefore, it is reasonable to expect a majority of households to achieve energy savings of 10 to 30% if provided with the tested ECIs.

In general, it is clear that the three tested information-transfer methods were able to influence large proportions (25% to 70%) of consumers in the respective test groups to reduce significantly (by >10%) their energy expenditures on cooking. The magnitude of the savings achieved by households equipped with ECIs is particularly encouraging. It should also be remembered that the general context here is one of enabling such savings to be achieved without requiring households to invest in a new (ie more energy-efficient) cooking appliance.

Table 5 : - Consumption Change - Information-Pack Group

Household	**«Before» Phase**, Number of Days	**«After» Phase**, Number of Days	**Consumption Change** For days that cooker was used
H-11	72	68	-13%
H-25	89	68	-13%
H-2	74	68	-12%
H-19	83	68	-4%
H-29	78	68	-3%
H-35	68	57	-3%
H-34	56	67	-2%
H-24	72	68	-1%
H-6	73	63	1%
H-1	72	68	2%
H-20	73	68	5%
H-8	73	68	7%

Table 6 : - Consumption Change : Energy-Consumption Indicator (ECI) Group

Household	**«Before» Phase**, Number of Days	**«After» Phase**, Number of Days	**Consumption Change** For days that cooker was used
H-5	82	56	-39%
H-15	73	57	-26%
H-30	69	83	-25%
H-4	82	56	-23%
H-17	70	62	-23%
H-16	92	61	-15%
H-7	71	64	-11%
H-3	81	56	-5%
H-13	72	56	+6%
H-10	58	84	+9%

Table 7 : - Consumption Change : ECI and Information-Pack Group

Household	«**Before» Phase,** Number of Days	**«After» Phase,** Number of Days	**Consumption Change** For days that cooker was used
H-21	68	104	-27%
H-9	74	69	-18%
H-26	60	57	-17%
H-23	68	57	-15%
H-33	56	69	-5%
H-31	57	68	-2%
H-28	109	69	+5%
H-32	58	75	+8%
H-36	68	69	+31%
H-27	61	55	excluded from analysis

6 - CONCLUSIONS

Based on measured data, electric cooking equipment is used (on average across the 12 Group 1 households) for 295 days per annum with an average daily consumption of 1.30kWh. However, the average consumption varies considerably within the Group ranging from 0.58kWh to 2.26kWh. It is clear that this parameter is of low magnitude for single person households, whereas it tends to be high for families with children (and especially so for those who often engage in long-duration or traditional cooking processes, eg cake baking, roast dinners and cooked breakfasts).

The average daily demand varies across short and long timescales. Considerably more cooking was observed to take place on Sundays (typically >2 kWh) and the overall peak value usually occurred on Christmas Day. The average consumptions on Saturdays and Sundays were 18% and 93% greater than on an average weekday. The relative change

in consumption with season varied among the participating homes, but 8 of the 9 non single-person households showed a marked increase in winter. On an average winter day the consumption is 30% greater than on an average summer day for the 9 non single-person households in Group 1. The associated variation in the average number of days per season when the cooker was not used was less pronounced than expected (ie increasing from 10 in winter to 14 in summer).

In most cases, positive feedback was received from the participating households regarding the ECI and/or the Information Pack. No one reported back that they had tried to save energy but found the process irksome. Instead it appears that individuals soon established the level at which they wished to use the ECI and/or Information Pack and then proceeded to do so. This is an encouraging finding for several reasons. We had intentionally not offered a financial inducement to households for their participation in this study and issued no direct instruction or request to save energy when installing the ECIs/Information Packs. Also, it should be remembered that the financial motivation that was potentially influencing end users to reduce cooking energy expenditures was very small (eg on an average day, a 20% reduction would yield a saving of less than 2 pence, which is equivalent to an annual savings of about £6).

The average seasonal effect observed for Group 1 was applied to the downloaded «before» phase consumption data for Groups 2,3 and 4 so as to estimate the expected «after» phase consumptions and then this prediction was compared with the measured after phase consumptions to identify the energy savings associated with the Information Pack and/or ECI. Overall, 14 out of 31 households achieved savings of >10%, and six of these achieved savings of >20%. In Group 2, three out of 12 households achieved savings of >10% and feedback from these indicated that this was done mainly by adjusting certain micro-level practices and increasing the use of microwave ovens. The ECI appears to have been much more effective than the Information Pack. In Group 3, seven out of 10 households achieved energy savings of >10%, of which five accomplished reductions of 23% or greater.

Comparisons between the results from Groups 3 and 4 suggest that there was no compound benefit from providing a household with both an Information Pack and an ECI. The reasons for this are not entirely clear from the feedback comments obtained from the participating households. However, with an information pack (irrespective of its exact design) one needs to find the relevant section and read it, whereas the numbers on the ECI display can be absorbed without any action on the part of the user (eg it is a rapid and «hands free» means for transferring useful information).

Overall the three tested information-transfer methods can influence significant proportions of consumers to save energy when cooking without requiring them to engage in some arduous energy-saving procedure or purchase a new higher-efficiency appliance. The magnitude of the savings achieved by households equipped with ECIs indicates considerable promise for this information-transfer approach.

CO_2 emission savings are estimated in Table 8 which shows the savings achievable per million households assuming an average consumption of 500 kWh per annum and average emission factor of 910 tonnes of CO_2

per GWh of consumed electricity (Bennett, 1998). Although these parameters vary considerably within the EU, they are taken here as approximate overall mean values.

Table 8 : - Potential CO_2 Savings Resulting from the Three Tested Information-Transfer Methods

Information-Transfer Method	Proportion of households with savings >10%	Average percentage saving achieved	Potential annual energy savings GWh	Potential annual CO_2 emissions savings 10^3 tonnes
Information-Pack	25%	13%	16.3	14.8
ECI	70%	20%	70.0	63.7
ECI + Information-Pack	44%	19%	41.8	38.0

Assuming one million households in the UK were equipped with the ECIs (ie about 10% of the electric cooker users), the annual CO_2 emission savings would amount to about 0.64 mega-tonnes. If a similar replication rate was achieved across the estimated 80 million EU households which use electric cookers, (assuming a similar average emission factor), the total annual saving would amount to about 560 GWh of electricity or 5.1 mega-tonnes of CO_2 emissions.

7 - REFERENCES

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