# An Experimental Investigation of Cooking, Refrigeration and Drying End-uses in 100 Households

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## ABSTRACT

This paper presents the findings of an experimental study performed in 100 French households on the end-use power demand and energy consumption of domestic appliances focusing on cooking appliances, but also covering domestic cold appliances[1] and clothes-dryers (Sidler and Waide 1999).

The study centred on the analysis of a database containing metered results for 517 cases of 32 types of domestic electrical appliance covering the main forms of electric cooking, as well as auxiliary uses, such as coffee-makers, kettles, etc… The households, all located in central France, were metered for a period of one month between January and July 1998. The power demand and energy consumption of each appliance was recorded every 10 minutes over the whole month using the DIACE monitoring system (Gilbert 1998). Annual energy consumption estimates were made from interpretation of this data in most cases by assuming that the usage in the second half of the year would be identical to that in the first. This enabled a hierarchy of cooking appliance energy consumption to be established wherein electric cookers (combined hob[2] and oven) used the most at 457 kWh/year, ahead of induction hobs[3] (337 kWh/year), ceramic hobs (281 kWh/year), and ovens (224 kWh/year).

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 568 kWh/year. A pronounced and regular monthly variation in cooking-related electricity consumption is found, with the energy consumption in January being 1.25 times the annual average monthly value and 0.72 times in June. Some 96% of all cooking related energy consumption was attributable to loads of less than 3 kW.

Interestingly, the standby power consumption of induction hobs was found to be very significant (30% of their total annual energy use) and to offset all their energy savings in the cooking mode compared to conventional hobs. However, this conclusion is not generic and would not apply to many newer induction hobs with low standby power levels.

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[1] Domestic refrigerators, freezers and their combinations
[2] hobs are also called ranges or cook-tops
[3] Induction hobs have induction coils embedded beneath a glass ceramic cooking surface. The induction coils use a frequency converter to raise the frequency of the mains AC, which causes electromagnetic eddy currents to be induced in the bottom of the cooking pans and thereby heats the food. This process is ordinarily more efficient than conventional electric resitance hobs.

# Introduction

The *ECUEL* project (Sidler and Waide 1999) was carried out in partnership with ADEME (The French National Energy and Environmental Agency), EDF (The French National Electricity Utility) and the CEC (Commission of the European Communities). The collection, analysis and processing of data were carried out by Cabinet SIDLER of France and PW Consulting of the UK. The aims of the study were, firstly, to provide an evaluation of the energy consumption levels involved in electric cooking, secondly, to gain a fuller understanding of the effect of external conditions on the operation and energy consumption of domestic cold appliances, and lastly, to ascertain whether using a tumble-dryer can reduce the energy consumption involved in ironing laundry.

The study centred around the establishment and analysis of a database containing 517 examples of 32 types of domestic electrical appliance covering the main forms of electric cooking, as well as auxiliary usages, such as coffee-makers, kettles, etc. Some 98 households in the Drôme and Ardèche regions, with an average of 3.2 people per household, were metered for a period of one month between January and July 1998. The measurement system used in the project, called *DIACE*, enabled specific information to be gathered about the daily and sub-daily operation of the appliances being monitored. The DIACE system is unobtrusive and reliable and uses power line carrier technology to transmit the readings from the individual meters to a collector. The stored data is remotely downloaded each day to a computer acting as a central data logger via a modem.

# Electric Cooking

## Overview

The saturation level of the main appliances monitored in the panel is indicated in Table 1.

Ranking the cooking appliances according to their average annual energy consumption enables those appliances that consume the most electricity to be highlighted. Electric cookers came top with 457 kWh/year, ahead of induction hobs (337 kWh/year), ceramic hobs (281 kWh/year), and ovens (224 kWh/year), see Figure 1.

Some 50 % of the total cooking-related energy consumption was attributable to electric hobs. All together the different types of ovens accounted for approximately 42 % of the total cooking-related energy consumption. This portion in turn, made up 14% of the household total non space-conditioning electricity consumption. The average annual energy consumption of all electric cooking appliances was 568 kWh/year. The monthly fluctuation of cooking-related electricity consumption was very marked with 1.25 times the average annual monthly energy consumption in January and 0.72 times in June, see Figure 2. Some 99 % of the power demand of electric cooking appliances was under 3 kW, Figure 3. This means that households who want to use electricity for cooking do not necessarily need to be charged using a higher electricity tariff associated with higher peak power demand as is commonly the case in France. The most significant financial gains are to be made, not so much in the area of energy savings, but in the improvement of household demand-side management.

**Table 1. List Of Appliances Monitored And Their Distribution Within The Household Sample**

| Appliance type | Saturation level in the panel | Appliance type | Saturation level in the panel |
|---|---|---|---|
| Iron | 90.8% | Induction hob | 9.2% |
| Coffee-maker | 81.6% | Catalytic mini-oven | 6.1% |
| Ceramic hob | 57.1% | Condenser clothes-dryer – automatic sensing of end of cycle | 6.1% |
| Microwave | 44.9% | Evacuation clothes-dryer – automatic sensing of end of cycle | 5.1% |
| Microwave + grill (and/or fan-assisted oven) | 32.7% | Steam-cooker (atmospheric pressure) | 4.1% |
| Deep-fryer | 24.5% | Condenser clothes-dryer – timer controlled | 4.1% |
| Pyrolytic fan-assisted main oven | 22.4% | Catalytic main oven using convection | 3.1% |
| Evacuation clothes dryers – timer controlled | 22.4% | Manually cleaned main oven using convection | 2.1% |
| Electric kettle | 19.4% | Washer-dryer | 2.0% |
| Electric cooker | 18.6% | Vorwerk (type of food mixer) | 2.0% |
| Pyrolytic main oven using convection | 17.3% | Portable induction hob | 2.0% |
| Catalytic fan-assisted main oven | 14.3% | Manually cleaned fan-assisted main oven | 2.0% |
| Sealed hob | 13.3% | Grill | 2.0% |
| Manually cleaned mini-oven | 12.2% | | |

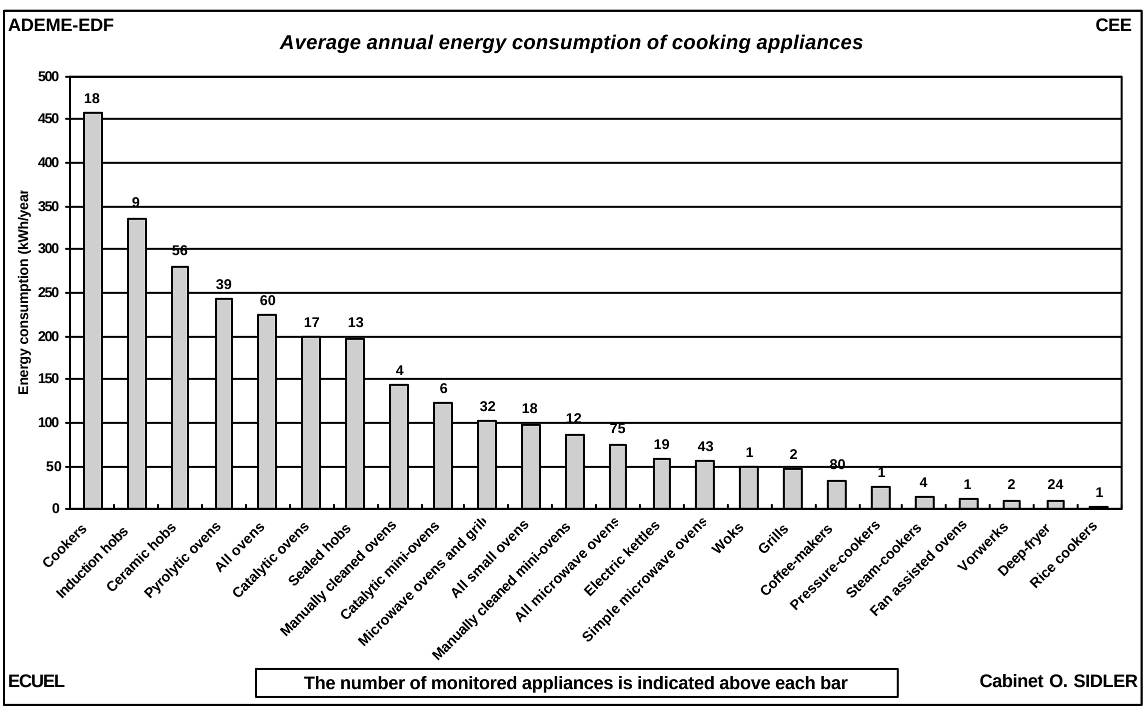


**Figure 1. Annual Average Monthly Energy Consumption Of Electric Cooking Appliances**

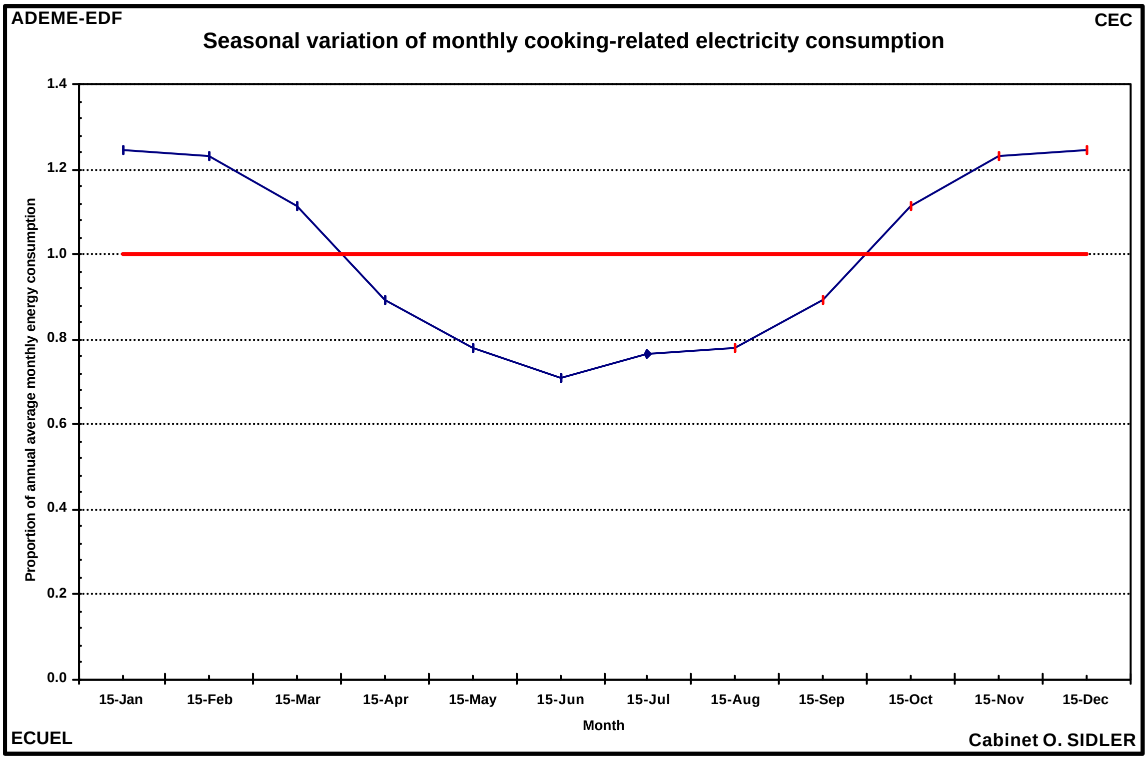


**Figure 2. Seasonal Variation Of Monthly Cooking-Related Electricity Consumption**

Note: values for August to December are estimations and are assumed to be symmetrical with the values for May to January

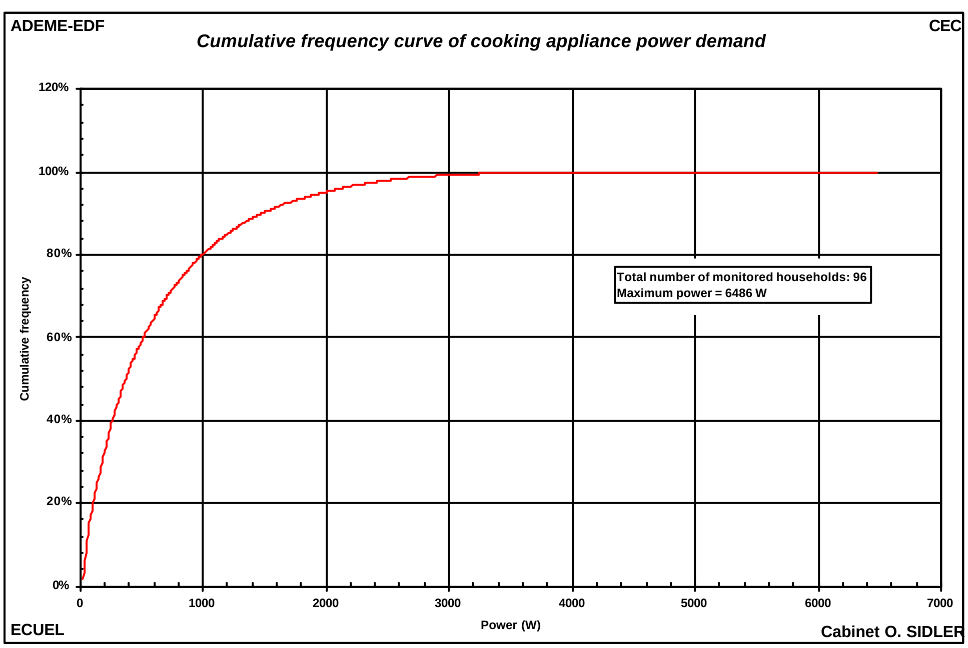


**Figure 3. Cumulative Frequency Curve Of Cooking Appliance Power Demand**

## Electric hobs

The typical daily power demand of an electric hob is shown in Figure 4.

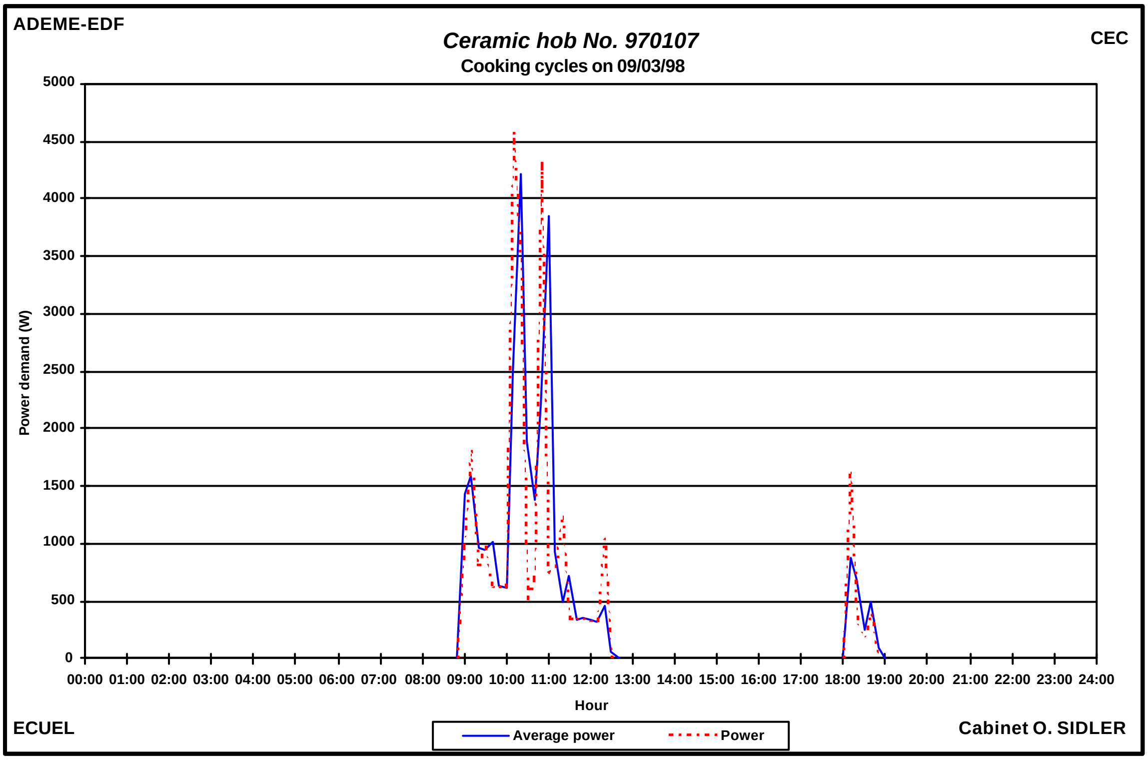


**Figure 4. Daily Power Demand Of An Electric Hob**

Due to their standby power demand (between 8 and 18 W, 30 % of the total energy consumption) and their heavy daily use (58 min./day.), induction hobs were those that used the most energy. If, however, we view the results in terms of energy consumption per hour of use, we find that the different forms of cooking technology ranked in the order we would have expected, given their relative energy efficiency. Sealed hobs (efficiency: 50 %, energy consumption: 1161 Wh/h) were less efficient than ceramic hobs (efficiency: up to 70 %, energy consumption: 999 Wh/h) or induction hobs (efficiency: 82 %, energy consumption: 588 Wh/h). From a purely financial perspective, there is no advantage in choosing an induction hob over a sealed hob (it would take 282 years to achieve payback). The criteria involved in the purchase of a hob of this type are related more to such considerations as ease of use, aesthetics, and the safety of the appliance.

## Ovens

The typical daily power demand of an electric oven is given in Figure 5.

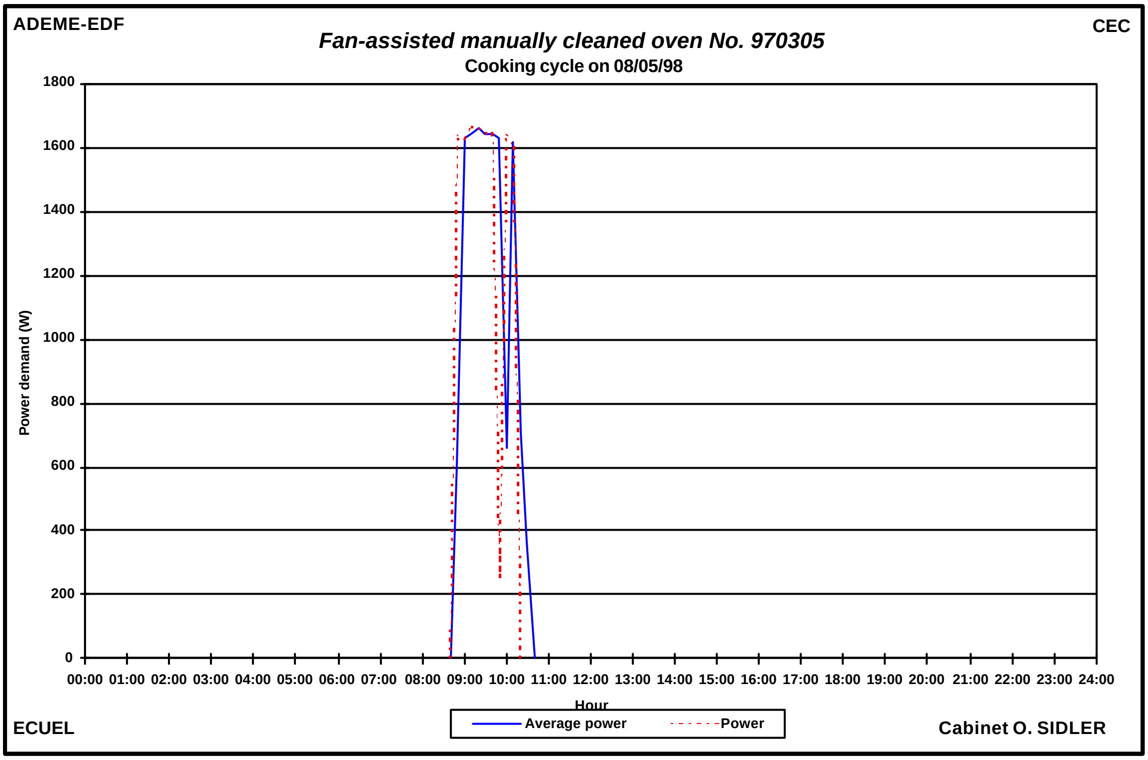


**Figure 5. Daily Power Demand Of An Electric Oven**

The average energy consumption per household of ovens was 224 kWh/year. The value recorded for convection ovens was 233 kWh/year and for fan-assisted ovens was 219 kWh/year. The average energy consumption of a cooking period of an oven was 889 Wh. Catalytic-ovens used 199 kWh/year, pyrolytic-ovens[4] used 243 kWh/year and manually cleaned ovens used 224 kWh/year. The average cleaning cycle of a pyrolytic-oven used 3490 Wh, although this facility was rarely used, and only accounted for 11 % of the total energy consumption of ovens with this kind of cleaning system. This level of energy consumption could be reduced by improving oven insulation quality.

For electric ovens, just as for electric hobs, the most efficient form of technology, from an energy saving perspective, is also that which exhibited the highest overall energy consumption levels. This was due to the relatively heavier use of these appliances.

[4] Ovens which are automatically cleaned by activation of a high temperature 'pyrolytic' heating cycle.

### Mini-ovens

In most cases in which the large capacity of a traditional oven is unnecessary mini-ovens are a good substitute for large ovens in terms of power demand and energy consumption savings. The maximum recorded power demand of mini-ovens was 34 % lower (2410 W) than that of large ovens and their annual energy consumption was less than half (99 kWh/year). Given an equal amount of use, replacing a large oven with a mini-oven could lead to a 27 % energy saving on average. As cooking periods for mini-ovens are usually shorter than for large ovens, the resulting savings could be greater still.

### Microwave ovens

The average annual energy consumption of microwaves that were monitored during the *ECUEL* study was 75 kWh/year. The power demand of basic microwaves was around 1500 W. In the case of combination microwaves, this figure was as much as double. Basic microwave ovens used 55 kWh/year, whereas microwave ovens with grill or combination modes used 102 kWh/year. Most of the microwave ovens that were monitored, were used mainly for defrosting or re-heating food, rather than for actual cooking as such. The average energy consumption of a cooking period was 69 Wh. Microwave ovens do not give any energy savings compared to electric ovens when they are used for traditional cooking techniques.

### Other cooking appliances

Electric kettles should not be overlooked when considering overall energy consumption levels. Their average annual energy consumption of 58 kWh/year was greater than that of basic microwave ovens. Depending on the appliance, the power demand ranged from between 750 W and 1750 W. Most electric coffee-makers had a lower power demand than that of kettles (686 W on average). Their average annual energy consumption was also lower at 34 kWh/year. The average power demand of deep-fryers was 1542 W. They used 11 kWh/year and were used mainly during the summer probably due to the French preference for using these appliances outside in order to minimise the accumulation of fatty odours in the kitchen. The average power demand of steam-cookers was 683 W. They used an average of 15 kWh/year.

## Clothes-dryers and Irons

Clothes-dryers are amongst the most power hungry household appliances. They are becoming increasingly widespread, especially in communal housing. Their average annual energy consumption, as measured during the *ECUEL* study, was 427 kWh/year. On average, a drying cycle used 2205 Wh/cycle. In order to reduce dryer energy consumption, a washing machine with a minimum spin speed of 800 r.p.m. should be used as it is far more efficient to extract water through spinning than via heating in a dryer.

Steam-generating ironing systems had a power demand of up to 2500 W, whereas that of a normal iron rarely exceeded 1500 W. On average, irons used 37 kWh/year.

One can not sensibly justify the use of electric clothes-dryers on the basis of reducing the energy consumption of irons (they use 11 times more electricity than irons). Moreover, the energy consumption levels of irons were found to be some 39 % higher in households that owned an electric clothes-dryer than in those that do not. This is not to suggest, of course, that the presence of a clothes-dryer actually increases the energy consumption of irons, but the same phenomenon was recorded in French Guyana (Sidler 1998), where the energy consumption of irons was 22 % lower in households in which there was no clothes-dryer.

## Domestic Cold Appliances

By studying the location of cold appliances within the household it was possible to show that simply by keeping a cold appliance in a non-heated store room rather than a kitchen, average annual energy savings of 36 % were achieved.

The measurement of the compartment temperatures of appliances showed that most freezers were not operating at the recommended temperature (-18 °C). On average, the compartment temperatures of freezers were 3.1 °C lower than this temperature. This produced energy consumption levels within the appliances that computer simulations indicate are 17.6 % higher than they would have been had the appliances been operating at the recommended temperature.

Taken individually, the estimated annual energy consumption values recorded in the *ECUEL* study did not show a strong correlation with those measured according to the European standard EN153. However, the average of these estimates was 97% of the average of the manufacturer declared energy consumption values recorded under standard test conditions. This suggests that the EN153 test standard is a reliable means of establishing the average annual energy consumption of cold appliances being used in south central France.

## Consolidated Results

The comparison of the results of the *ECUEL* measurement campaign with those from other countries, indicates that they were far more accurate than the estimates used up until now (see Table 2 and (TTS Institute 2000), (Kasanen 2000)). Detailed end-use metering campaigns, such as *ECUEL*, are needed to improve understanding of the different areas of electricity use, and to provide more accurate data for forecasting with predictive models.

**Table 2. Comparison Of Electric Cooking And Drying Annual Energy Consumption Values Between Studies In Different Countries (kWh/year)**

| Appliance | *Ecuel* [1] | CIEL [2] | French Guyana [3] | Swed [4] | Aust [5] | France [6] | France [7] | GE [8] | UK [8] | IT [8] | NL [8] | AU [8] | DK [8] | FI [8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measured values | | | | | Estimated values | | | | | | | | |
| Cooking total | 568 | | | 570 | | 1000 | | | 631 | | 143 | | | 435 |
| Ovens (all types) | 224 | | 169 | 194 | 233 | 300 | 111 | 90 | 277 | 138 | 46 | 456 | 153 | 200 |
| Cookers | 457 | | | 496 | | | | 600 | 547 | 885 | | | | |
| Hobs (all types) | 273 | | 186 | 317 | 187 | | 418 | | | | | | | |
| Sealed Hotplate Hobs | 198 | | | | | 600 | 432 | | | | | | | |
| Ceramic Hobs | 281 | | | | | 550 | 389 | | | | | | | |
| Induction Hobs | 337 | | | | | 400 | 285 | | | | | | | |
| Micro-waves | 75 | 49 | 36 | 50 | 67 | 100 | 60 | | | | | | | |
| Mini-ovens | 99 | 64 | | | | | | | | | | | | |
| Coffee-makers | 34 | 24 | 34 | 36 | | | | | | | | | | |
| Clothes-dryers | 427 | 437 | 296 | | | | | | | | | | | |

Sources: [1] (Sidler and Waide 1999); [2] (Sidler 1996); [3] (Sidler 1998); [4] (NUTEK 1995); [5] (Pacific Power 1995); [6] (CFE 1997); [7] (INESTENE 1998); [8] (TTS Institute 2000)

## Conclusion

The principal interest of the ECUEL measurement campaign is to be able to precisely identify the energy consumption levels of various common cooking appliances and thereby significantly improve upon the hitherto crude estimates of their energy use. It might be questioned whether a measurement campaign in a 100 households is really representative of the average behaviour in a large European country? If a precision of 0.1% is required then the answer is certainly no, as a sample of at least 1000 households would be required. Nonetheless a measurement campaign on a sample of 100 households would be expected to give results within ~±5% of the national average, which is far more reliable than those made without end-use metering. Furthermore, end-use measurement campaigns using very fine measurement intervals also enable typical appliance load profiles to be measured. The ECUEL campaign has shown that contrary to what was previously believed the household cooking energy consumption for all cooking appliances combined is mostly satisfied by loads of less than 3kW in France. The study has also illustrated the continued importance of reducing standby demand and lends weight to the call to reduce such loads to less than 1W in all but the most exceptional cases.

For cold appliances the study has shown that the energy consumption recorded by the European test procedure EN 153 is quite representative of the average in situ consumption for such appliances in south-central France. However, the study has also revealed a significant waste of energy that occurs because users regularly fail to set their thermostats to produce the recommended storage temperature conditions. It seems probable that significant savings could be achieved if the temperature display and optimum storage conditions were made more transparent.

## References


CFE. 1997. '*La cuisson domestique : un pas vers le tout-électrique*', in *Bâtiment Relations Elec* - N°22.

Gilbert, Jérôme. 1998. '*Demonstration of the DIACE end-use metering system*' in *Non-intrusive and other end-use metering systems,* Amsterdam, The Netherlands, 21-23 September, Novem, Sittard, The Netherlands.

INESTENE. 1998. values used in the MURELEC software - personal correspondence, INESTENE, Paris.

Kasanen, Pirkko. 2000. '*Ovens provide food for thought' Appliance Efficiency,* Vol 4(1).

NUTEK. 1995. *Domestic electricity in detached houses* - R1995:30, Stockolm Sweden.

Pacific Power. 1995. *The residential end-use study* - Pacific Power and Electricity Distributors of New South Wales and the Australian Capital Territory, Australia.

Sidler, Olivier. 1996. *Demand Side Management: End-Use Metering Campaign in the Residential Sector* - Cabinet SIDLER for the Commission of the European Communities, contract N° 4.1031/Z/93-58, ADEME and EDF. Translated by Paul Waide of PW Consulting.

Sidler, Olivier. 1998. *Campagne de mesures sur les usages électriques dans le secteur résidentiel en Guyane* - Cabinet Sidler for ADEME, Contract N° 96.45.045, Paris, France, June.

Sidler, Olivier and Paul Waide. 1999. *Electricity demand-side management: an experimental investigation of cooking appliances, domestic cold appliances and clothes-dryers in 100 households: project ECUEL,* Cabinet Sidler & PW Consulting for the Commission of the European Communities, contract N° 4.1031/Z/96-164, ADEME, and EDF, June. Translated by Paul Waide of PW Consulting.

TTS Institute (Work Efficiency Institute). 2000. *Efficient Domestic Ovens* for the Commission of the European Communities, contract N° 4.1031/D/97-047, Helsinki, Finland, January.