STUDY ON EFFICIENT WASHING MACHINES, DISHWASHERS AND DRIERS

Ruud Trines
Netherlands Agency for Energy and Environment (NOVEM)
Member of the Group for Efficient Appliances (GEA).

SYNOPSIS

The study will define policy instruments in relation with efficiency targets for the short and medium term for domestic wet appliances.

ABSTRACT

The study aims at establishing a common European basis for defining efficiency in domestic washing mahines, clothes driers and dishwashers. This common basis will form the background for assessing the impact of policy development (e.g. labels, standards, rebate programmes) on energy consumption, environment, consumers and manufacturers.

1. INTRODUCTION

The study described in this paper was initiated as a SAVE project at the end of 1993. In July 1994 the interim report on wet appliances (washing machines, dishwashers and driers) was published which in detail describes the elements of the project and the methodologies used in the study. The interim report also summarises the preliminary findings of the study and highlights questions and issues of special interest identified during the analyses.
The aim of the interim report is to seek comments from manufacturers, consumer organisations and national energy agencies.

This paper outlines the scope and the phases of the study and describes some of the results, which are found in more detail in the interim report and draft versions of the final report. The final report of the study is scheduled for June 1995. This means that final results can be provided at the time of the ECEEE-conference.

2. BACKGROUND AND ORGANISATION

In recent years, energy efficiency has been a theme of growing interest of energy policy within the European Union. The advantages of a reduction of energy consumption are manyfold. The most important advantage is the corresponding reduction in the generation of pollutants associated with energy production and distribution, including emissions to the atmosphere of carbon dioxide and other greenhouse gases.

Household appliances account for more than two thirds - and wet appliances for for 10-20% - of electricity consumption in the domestic sector. Furthermore, market penetration of wet appliances is expected to continue to grow, resulting in increased energy consumption in the future, unless improvements in the efficiency of appliances can be accelerated to compensate for this growth.

The study presented in this paper aims at establishing a common EU basis for defining efficiency in domestic wet appliances. The common basis will form the background for assessing the impact of policy development (e.g. labelling, efficiency standards, rebate programmes) on energy consumption, environment, consumers and manufacturers.

The ultimate goal is to achieve lower energy and water consumption for wet appliances without loss of performance. This can be done by an increase in market penetration for efficient wet appliances, and implementation of new efficient technologies in the manufactured models.

The study is based on a series of national programmes of European countries regarding target values, standards, energy labels and procurement and rebate programmes.

The Group for Efficient Appliances, GEA, which performs the study is a working group established by E_R (the European Energy Network). The present GEA study includes DEA (Dk), Ademe (F), Novem (Nl), CCE (P), Forbairt (Ei), Oxford University on behalf of Department of Environment (UK), Swedish Board for Consumer Policies (Sw), and the Work Efficiency Institute (Fin). The study is closely coordinated with the DECADE project (performed by University of Oxford, UK) under the SAVE programme.

3. CONTENTS AND PROGRESS OF THE STUDY

The study is divided into parts, which constitute different coherent elements of the project. Together with the main-report, background reports describing details of analysis are available:

* Basic Assumptions, Test Methods and Consumer Behaviour
  Describes basic assumptions regarding appliance categories, energy efficiency, performance etc. and propose test methods to be used in the short term and in the long term. Furthermore, an overview of main characteristics of daily use of the appliances in question in European countries is presented.

* Statistical Analysis
  The aim of the statistical analysis is to give a picture of the efficiency of domestic wet appliances which are marketed in the EU. The analysis is based on data, which originates from manufacturers and is being collected through national energy agencies and consumer organisations. The results are presented in a subsequent section of this paper.

* Experimental Analysis linking Energy and Water Consumption with Performance
  The objective of the experimental analysis is to examine the influence of technological options of wet appliances on consumption of energy and water, and on performance.

* Technical/Economic Analysis of Design Options
  This part of the study deals with long-term efficiency targets. Topics studied are:
  1. Identification of technically and economically feasible design options and their saving potential.
  2. Assessment of Life Cycle Costs (LCC) and Simple Payback Period (SPP) related to these design options.
  The technical possibilities for achieving energy savings in the long term have been investigated by means of analysis of patents, literature, expert interviews and present top-of-the-range models.

* Policy Options
  Suitable policy instruments to improve energy efficiency include Energy labels, Eco labels, Minimum fficiency standards, Rebate and Procurement programmes, increased energy and water prices etc. A survey f different types of instruments is presented in the interim report. An important point is that the policy instruments should be used in combination, since they achieve savings in different areas. E.g. some instruments promote improvements of technology and other instruments may affect consumer behaviour. The aim is to develop a more detailed cross-country comparison of:
  * The costs of different instruments
  * Effectiveness in terms of energy savings
  * The level of certainty that can be attached to any energy savings
  * The time-scale for achieving certain levels of savings

* Impact Analysis on Consumers
  The evaluation of the impact of new design options on consumer aspects is investigated. The two main isues are:
  * Prices, with special attention to price elasticity;
  * Consumer acceptance of design options.
  Due to time and cost restrictions, desk research and interviews by telephone with experts will be the main methods of research.

* Impact Analysis on Energy Consumption and Environment

Energy-saving scenarios will be used to evaluate the long-term impact of efficiency improvements for wet appliances by implementation of different policy instruments with special attention to impact on energy consumption of the wet appliances stock, at EU and national level. Environmental impact assessments with particular reference to CO_2, NOx and SO_2 emissions savings will be carried out. The impact on consumption of water and detergent will also be evaluated.

4. PRELIMINARY RESULTS

Further details about the study, the results obtained are found in the interim report, final report and background reports which can be requested from the Danish Energy Agency,

4.1 Appliance Categories

The descriptions of wet appliances used in the study are in accordance with relevant international standards for measuring the performance of wet appliances. Thus, the definitions and standards developed by CENELEC are used. The appliances are divided into five functional categories:
* Washing Machines
* Dishwashers
* Tumble Driers
* Cabinet Driers
* Washer-Driers

Furthermore, for dishwashers and driers subcategories are defined describing different size or technology.

4.2 Consumer Behaviour

Aspects of daily use of wet appliances in European countries are described by a set of variables which have most impact on energy and water consumption and for which data are available.
Important variables are:
* Penetration level, i.e. the percentage of households with the appliance in question installed
* Frequency of use, i.e. the number of cycles per week
* Operating conditions i.e. type of programme used, load of the appliance etc.

Complete data describing these variables is not available for all countries. However, some main characteristics can be derived from the information at hand.

Washing Machines:

Table 1. Aspects of Consumer Behaviour for Washing Machines (European mean).

variable	mean European value
Penetration level	82%
Wash cycles with pre-wash	17%
Temperature of wash cycle	
<30-40°C	47%
40-60°C	37%
70-90°C	15%
Frequency of use	4,6 cycles per week

Driers:

Table 2. Aspects of Consumer Behaviour for Driers (European mean)

variable	mean European value
Penetration level	22%
Frequency of use	3,4 cycles per week

Dishwashers:

Table 3. Aspects of Consumer Behaviour for Dishwashers (European mean)

variable	mean European value
Penetration level	31%
Temperature of dishwash cycle	
50-60°C	42%
>60°C	58%
Frequency of use	4,0 times per week

Use of European Mean Values:
With regard to driers and dishwashers it is necessary to use mean values. Because of lack of data no differences between countries can be determined. For washing machines more data are available.

For the purpose of calculation the following is recommended. For overall calculations, mean European values can be used. If, however, more detailed analyses at the country level are necessary, e.g. to calculate the impact on energy consumption per country for an appliance, specific values for that country should be used if they are available.

4.3 Efficiency of Appliances

Energy consumption of a wet appliance is measured together with other characteristics such as washing or drying performance using the test methods developed by International standardisation bodies. The methods describe in details the operating conditions to be used during the tests and the way performance is measured.

When determining energy efficiency of wet appliances the three characteristics of energy consumption, load of the appliance during test, and performance (washing or drying), are so important and interdependant that they should all be included.
In the study the expression

specific energy consumption given a minimum performance

is proposed as a measure of energy efficiency of the appliances, where the specific energy consumption is defined as energy consumption per unit of capacity.
A similar definition of water efficiency for washing machines and diswashers is used in the study.

4.4 Statistical Analysis

Data available:

The statistics described are based on information on appliances marketed in 11 European countries. These are Denmark, Finland, France, Ireland, The Netherlands, Portugal, Italy, Germany, UK, Belgium and Sweden. The data are collected in 1994 and 1995.
The amount of information in the database varies for different categories and models. The statistics presented are derived from data on energy and water consumption for around 3100 washing machines and around 2000 dishwashers. Information on energy consumption is available for 1250 driers. The amount of information on cabinet-driers is not yet sufficient for statistical analyses. Similarly, for washer-driers the amount of data is very limited.

Appliance energy efficiencies are expressed as specific energy consumption, defined as

$$\frac{\text{Energy Consumption}}{\text{Capacity}}$$

This means that an energy-efficient appliance is associated with a low value of the specific energy consumption.

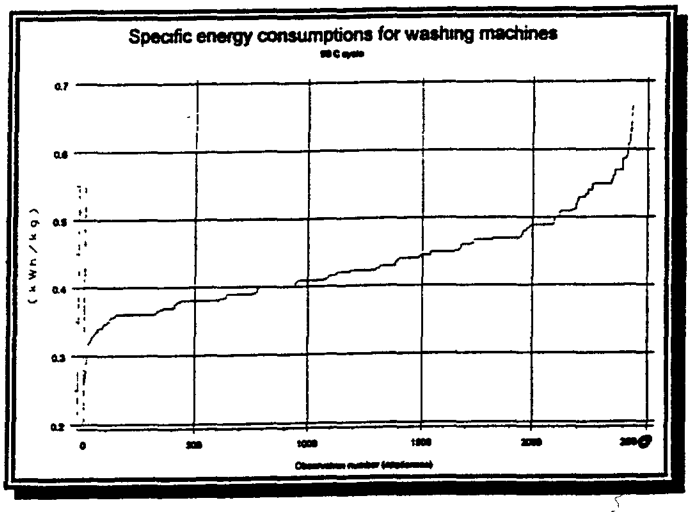
For washing machines the capacity is defined as the washload (kg), stated by the manufacturer. The capacity for dishwashers is defined as the number of settings, and for driers as the amount of dry cloth (kg) the appliance can handle, as per manufacturer's claims. Similarly, the specific water consumption for washing machines and dishwashers is defined using the capacity stated by the manufacturer.

Washing Machines:

Energy consumption will vary depending on the programme performed by the appliance. In the statistical analysis washing machines have been assessed on the 90°C cotton cycle without pre-wash, the reason for this being that the amount of data on 60°C and especially 40°C programmes are limited.
We remark that energy consumption data for the 90°C cycle do not necessary indicate relative efficiencies for the 60°C and 40°C cycles. Given the large share of the two lower-temperature cycles the validity of the 90°C cycle-standard as a measure for efficiency is limited. Therefore it is proposed that the CENELEC standard cycle should be changed to a mix of at least 2 cycles with different temperatures.

The distribution of specific energy consumptions for washing machines for the 90°C cycle without pre-wash - sorted by size - is shown in figure 1. The minimum/maximum ratio is 1:3. About 80% of the specific energy consumptions is in the range +/- 25% of the average value, which is 0.43 kWh/kg. The average specific energy consumptions differ when comparing the markets country by country. According to the information available, the average for the French and Portugese market is 0.46 kWh/kg while the averages in Denmark, Netherlands and Sweden are 0.41 kWh/kg.

Figure 1. Specific Energy Consumption for Washing Machines, 90°C Cycle



The overall average of specific water consumption for the 90°C cycle amounts to 17.4 litres per kg. When average water consumptions in different countries are compared, the same pattern as for energy consumption is observed. There seems to be a close correlation between average specific energy consumption and average water consumption.

Dishwashers:

The majority of dishwashers are 12 settings machines. Small dishwashers (less than 10 settings) account for 15% of the market and 12 settings machines account for 80%.

For dishwashers the 65°C cycle has been used to depict the efficiencies of appliances. The energy consumption for a 65°C cycle depends on the number of settings. This may cause problems when energy consumptions and especially specific energy consumptions of different sized machines are compared. Also the use of the 65°C alone as a measure for energy efficiency may cause problems, because two models with identical energy consumption for the standard 65°C cycle may differ in their 50/55°C cycle consumption values.

For small machines the specific energy consumption may be rèlatively high, indicating low efficiency. There are several ways to avoid the disadvantage and the report describes various methods which could be used.

The table below shows the average specific energy consumption for dishwashers. Energy efficiency for small dishwashers is calculated using an adjusted energy consumption, which takes the number of settings into account, while no adjustment is made for standard size dishwashers.

The specific energy consumptions are divided into the countries in which the dishwashers are sold. All the values are for the 65°C cycle. The average specific energy consumption is 0.138 kWh/setting.

Table 4. Specific Energy Consumptions Standard Size Dishwashing Machines. Divided by Countries

Country	Number of Machines	Average (kWh/setting)
Denmark	107	0.127
Belgium	12	0.155
France	760	0.142
Germany	330	0.132
The Netherlands	238	0.127
Ireland	16	0.144
Italy	77	0.137
Misc.	45	0.150
Sweden	47	0.143
UK	72	0.154
ALL	1704	0.138

Distributions of specific energy consumptions for dishwashers have been calculated from the energy consumptions for 65°C cycles, according to the specified methods. The minimum/maximum ratio is 1:3, but most of the specific energy consumptions are in the range +/- 20% of the average value.

The average specific water consumptions have been calculated for 12 settings machines using data from the 65°C cycles. The values for the individual countries are very close, ranging from 1.9 litres per setting tot 2.1 litres per setting. Denmark and the Netherlands have relative low water consumptions (1.7) and UK relatively high (2.63).

Driers:

Driers are divided into three different categories, tumble driers, washer-driers and cabinet driers and furthermore for tumble and washer-driers two sub-categories representing different drying technologies are defined:

1. Air-vented driers.
2. Condenser driers.

Air-vented washer-driers and cabinet driers are not included in this preliminary statistical analysis due to lack of data. Information on condenser washer-driers is limited, but in spite of this it has been decided to include this appliance in the analysis. Consequently, there may be substantial uncertainty about the results concerning condenser washer-driers.
The table below shows the average specific energy consumptions for air-vented and condensor tumble driers and condensor washer-driers divided into the countries in which they are sold. The specific energy consumptions are based on dry cotton programmes. The average values are 0.65 kWh/kg for air-vented driers, 0.69 kWh/kg for condensor driers and 0.76 kWh/kg for washer-driers.

The distribution of specific energy consumptions for air-vented and condenser tumble driers calculated from the energy consumptions for the dry cotton programmes range from around 0.4 kWh/kg to around 0.8 kWh/kg. For washer-driers the specific energy consumption range from 0.65 to 1.1 kWh/kg. Most of the specific energy consumptions are in the range +/- 15% of the average value. The specific energy consumptions of driers are clearly not as dispersed as the specific energy consumptions of washing machines and dishwashers.

Table 6. Average Specific Energy Consumptions for Air-vented and Condenser Tumble Driers and Condenser Washer-Driers

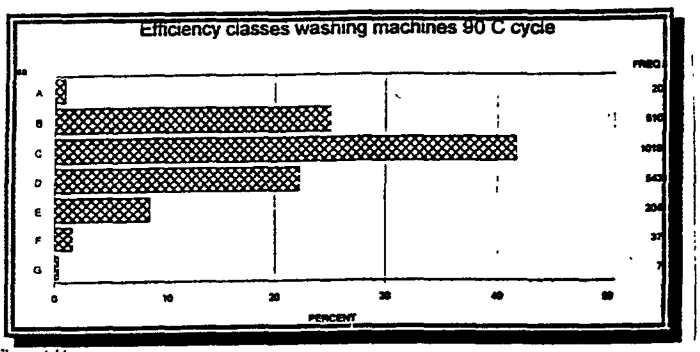
Country	Air-vented Tumble Drier Average (kWh/kg)	Condenser Tumble Drier Average (kWh/kg)	Condenser Washer-Drier Average (kWh/kg)
Denmark	0.63	0.69	.
Finland	.	0.69	.
France	0.58	0.63	.
Germany	0.64	0.71	0.74
Netherlands	0.68	0.73	0.88
Ireland	0.68	0.73	0.66
Misc.	0.79	0.82	.
Sweden	0.71	0.76	0.78
UK	0.80	0.79	.
ALL	0.65	0.69	0.76

4.4 Use of statistical results

1. ENERGY LABELLING:

One of the purposes of the statistical analysis is to use the information available to describe the distribution of appliances within an energy labelling scheme for wet appliances.
As an example of this application of the database the figure below shows the distribution of washing machines in energy classes using the same definition of the classes as in the EU energy labelling for refrigeration appliances. It is difficult te evaluate the impact of energy labelling on efficiency. One could argue that all appliances (except class A) move one (or even two?) efficiency classes upward but only to the very limit between two classes.

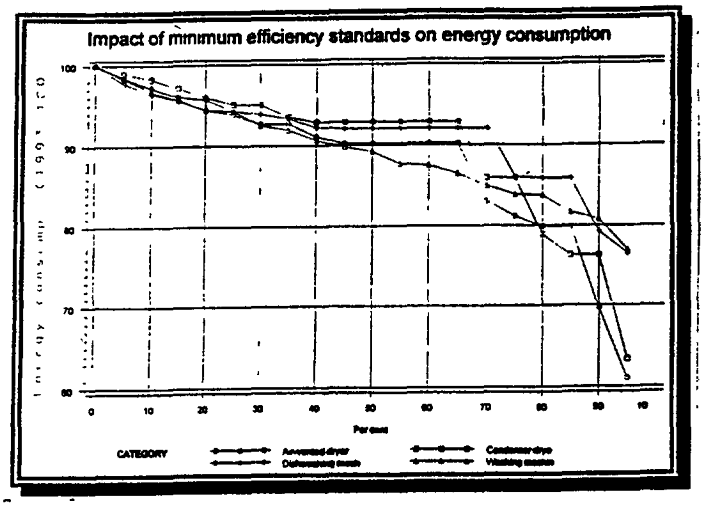
Figure 2. Washing Machines - Distribution in Energy Classes



2. IMPACT OF ENERGY EFFICIENCY STANDARDS:

One important purpose of this study is to estimate the impact on energy consumption of minimum efficiency standards.
If an efficiency standard was to be introduced, a certain percentage of the models - those with efficiencies less than that set by the standard - would be affected.
The figure below illustrates the possible impact on average energy consumption for new appliances as a function of the percentage of models affected by minimum efficiency standards.

Figure 3. Impact of Minimum Efficiency Standards on Energy Consumption



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It appears from the figure that in order to achieve an energy saving of 10% it will be necessary to affect between 45% (washing machines) and 75% (dishwashers) of the models available on the present market. Affecting 50% of the models implies an improvement between 7% (condenser driers) and 11% (washing machines), while affecting 90% of the models implies an improvement in energy efficiency between 19% (washing machines) and 30% (driers).

The statistical analysis shows that as expected a spin-off effect of minimum energy efficiency standards would be a reduction in water consumption. Furthermore, average maximum spin speed for washing machines would probably increase for the appliances left on the market after the introduction of such standards. This would result in reduced demand for energy using driers in the subsequent drying of washed cloth.

4.5 Long term efficiency targets Washing machines

Two separate basecases were defined, both on the basis of the 60°C cotton cycle without prewash.

- Standard Basecase (SB) which defines performance, energy and water consumption according to EN 60456 at a fixed 4.5 kg load and 126 g/cycle IEC-A detergent
- Real-life Basecase (RB) which defines performance, energy and water consumption according to real-life conditions, starting from a 3 kg load and 135 g/cycle IEC-A detergent. Loading efficiency, programme temperature setting, type and quantity of the detergent are free variables.

The SB is functional for implementing policy instruments like labelling or efficiency standards. The RB is more functional to assess instruments like consumer behaviour, retailer training, subsidies and technology procurement. The RB offers a wider range of design options and the savings potential is thus higher.

The following technical options are considered:

1 Improved water level control
2 Longer time and lower temperature including biostep
3 Improvement thermal efficiency
4 Reduction of tub-drum clearance, improved rinsing cycle
5 Improvement motor efficiency
6 Extended thermal efficiency improvement
7 Extended motor efficiency improvement
8 Extended water economy improvement

Also consumer options are investigated:

1 15/20% downscaling (improved loading efficiency)
2 Lower programme temperature setting (other detergent)

Finally an infrastructural option like hot-fill/direct heating was considered.

It appears that on a life-cycle costs base it is economical to reduce the electricity consumption by 30% (SB) to 50% RB). When considering technically feasability it is possible to reduce electricity consumption by 50% (SB) to 65% (RB). The reductions in water consumption are a litlle less. These reductions can be achieved without loss of performance and may therefor be considered as efficiency targets for the next future.

4.6 Impact on consumers

Two major impacts of energy efficient appliances on consumers are identified: Price and Options.
Experts think consumers are willing to pay about 10% more for wet appliances that consume considerately (15%) less energy. The price elasticity of energy is small. The importance of taking care of running costs at the point of purchase differs from one country to another.
There is a lot of discussion on the consumers' acceptance of design options like hot-fill, natural gas energy-supply and longer programme duration. A single European wide approach is not likely. The situation may differ between countries.

5. REFERENCES

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