GEA II—STUDY ON DOMESTIC WET APPLIANCES

Peter Karbo, Danish Energy Agency

This paper summarises the findings of a study on energy efficiency in European domestic washing machines, dishwashers and driers (wet appliances) carried out by the Group for Efficient Appliances (GEA).

The study identifies economically viable and technically feasible means to improve the energy efficiency of wet appliances without losses of performance and assesses the various policy options available to bring about these improvements.

Analyses were performed in four major areas:

- statistical analysis of the current wet appliance market in the European Union (EU)
- experimental analysis linking consumption of electricity and water with performance
- technical and economic analysis of design options for improving efficiencies
- impact analysis of possible policy options on electricity consumption and CO_2 emissions

Average energy efficiencies of wet appliances marketed in Europe may be improved substantially by use of proven technology which is also economically cost-effective. This is especially true for dishwashers and washing machines for which potential improvements of 33% and 25% in average efficiency are identified.

If policy measures are implemented to achieve the full economic and technical potential, the anual savings in year 2016 are projected to be

- 19 TWh of electricity
- worth $ 3 billion to consumers in terms of 1994 prices
- representing savings in CO_2 emissions of 10 million tonnes

Furthermore, by stimulating ‘‘good’’ consumer behaviour there seems to be a potential for improvements in energy savings which is of similar size as the potential impact of improved appliance technology.

INTRODUCTION

Wet appliances represent one of the major energy-consuming groups of appliances in households, accounting for about 10% of electricity consumption in the European household sector. 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 and their use can be accelerated to compensate for this growth.

Today, most households in the European Union (EU) own or rent a washing machine, the ownership of driers is increasing, especially in northern European countries, and dishwashing by machine is increasingly common in many households.

This increasing use of machines for traditionally manual tasks liberates time for the user, but while the cleaning of cloth and dishes by hand is fairly straightforward, the appliances that substitute for the manual operation are in no way simple. For both laundry and dishwashing, water, energy and detergent are the resources used by the appliances to wash and dry. The energy, usually electricity, is used for mechanical work, for heating water, and for drying purposes.

The use of appliances does not decrease the importance of human involvement in the process however. Modern cleaning of cloth and dishes is a man—machine operation in which both the operator (the consumer) and the machine are important in determining the outcome of the process. Operating the machine in a proper way is increasingly important as more sophisticated appliances become available.

Other factors also play an important part in the evolution of modern cleaning processes. Textiles, for example, have changed greatly. Synthetic and other materials have been developed in addition to traditional wool and cotton textiles. Optimal cleaning of the various textiles requires a wide range of conditions regarding such factors as temperature, detergent types, and degrees of mechanical action. Detergents have also changed a great deal. From the energy viewpoint, it is worth noting that new detergents do the job at lower temperatures than older ones.

BACKGROUND AND ORGANISATION OF THE STUDY

This study is supported by the European energy efficiency programme called SAVE (Specific Actions for Vigorus Energy Efficiency) which was adopted by the Council of the European Communities in October 1991. The objective of the programme is to strengthen the promotion of energy efficiency in the European Union (EU) in all energy consuming areas (homes, buildings, the transport sector, industry etc.). Possible government intervention under the SAVE programme includes information, voluntary agreements, legislation on standards, and promotional campaigns.

The reduction of energy consumption through improvements in energy efficiency has been a theme of growing interest among energy policy makers in the EU in recent years. Household appliances account for more than two-thirds of electricity consumption in the domestic sector and offer a significant potential for improving energy efficiency.

There are many good reasons for reducing energy consumption, but perhaps the most important lies in the corresponding reduction of pollutants associated with energy production and distribution, including emissions to the atmosphere of carbon dioxide (CO_2), the major cause of the greenhouse effect. In accordance with the United Nation (UN) Framework Convention on Climate Change, the EU is committed to stabilising the Union's emissions of carbon dioxide by the end of the century at the 1990 level. Initiatives to improve energy efficiencies have a central role to play in achieving this objective.

This study was contracted in December 1993 between the European Commission and the Danish Energy Agency, with Ademe (France), Novem (The Netherlands) and Centre for Energy Conservation (Portugal) as associated contractors. It is based on a series of national programmes on target values, standards, energy labelling, and procurement and rebate programmes, and was carried out in cooperation with European energy agencies within the European Energy Network (E^nR).

The study was managed by GEA, and in addition to the above-mentioned organisations, the following also participated: Swedish Board for Consumer Policies, Irish Energy Centre, Ministry of Economic Affairs (Austria), Work Efficiency Institute (Finland), Department of the Environment (UK), Environmental Change Unit at the University of Oxford (UK), Stiftung Warentest, wfk and B.A.M. (Germany). The following institutions contributed to the study as consultants: CTTN-IREN (France), DEFU (Denmark), SWOKA (The Netherlands), van holsteijn en kemna (The Netherlands).

An interim report[1] was submitted in June 1994 and comments were received and taken into account throughout the course of the study. Industry was consulted about the commercial information used for statistical analysis and detailed discussions with industry also took place about technical/economic options for improving energy efficiency. The final report: ''Washing Machines, Driers and Dishwashers"[2] and background reports (three volumes)[3, 4, 5] was published in June 1995.

CONTENTS OF THE STUDY AND SOME BASIC RESULTS

The study was divided into the following components:

- **Basic Assumptions, Test Methods:** 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.

- **Consumer Behaviour:** An overview of main characteristics of daily use of the appliances in question is presented.
  - —More than 90% of the EU's 144 million households in 1994 own or rent a washing machine, while driers are possessed by approximately 20 million households and dishwashers by about 30 million.
  - —Ownership levels have been steadily increasing over recent decades. The number of domestic wet appliances installed is expected to grow in the years to come, mainly due to increases in the number of households in Europe.
  - —The average frequency of use of the appliances have been estimated to 4.6 cycles per week for washing machines, 2.9 cycles per week for driers, and 4.3 cycles per week for dishwashers.

- **The Wet Appliance Market in Western Europe:** An analysis of the market and major suppliers was part of the study.
  —The EU is currently the world's most important regional market for wet appliances with more than 40% of the global sales of laundry appliances and nearly 60% of dishwashers. The bulk of EU domestic appliance production originates from Germany, Italy, France, UK and Spain.

- **Statistical Analysis:** Information on more than 7000 wet appliances marketed in Western Europe has been collected and stored in a database. With a few exceptions, the data originate from manufacturers' information, and have been collected from the markets of all EU countries except Greece, Luxembourg and Spain. Table 1 shows simple average values to give an overview of essential appliance parameters.

- —Most of the specific energy consumptions are in the range of (25% of the average values.
  —The appliances are not equally distributed among European countries—driers and dishwashers particularly are more common in the northern areas.

  Energy efficiency of wet appliances has improved during the last two decades, particularly as a consequence of reductions in actual wash temperature and water consumption per wash. However, since 1970, ownership levels and the average number of times the wet appliances are used have increased and the total EU energy consumption has tripled.

- **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. The experimental analysis is closely linked to the part of the study concerned with technical/economic analysis of design options (see below).

Table 1. *Average Specific Energy Consumptions (SEC) Found and the Minimum/Maximum Ratios*

	average SEC	min/max
Washing machines (60°C)	0.43 kWh/kg	1:2.5
Air-vented tumble driers	0.65 kWh/kg	1:2.5
Condensor tumble driers	0.69 kWh/kg	1:4
Dishwashers	0.136 kWh/standard place-setting	1:3

Besides these basic elements of the study the report describes the results of technical and economic analysis of design options for wet appliances and policy options and the results of scenario analysis.

LONG-TERM EFFICIENCY TARGETS: A TECHNICAL AND ECONOMIC ANALYSIS

In this section, a discussion of the projects long-term efficiency targets is presented. Topics included:

(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.
(3) Assessment of the correlation between performance characteristics and these design options.

The design option costs are assessed in two ways—a commercial analysis and a engineering analysis—based on consumer prices of marketed appliances and on an estimation of assemble component costs, respectively.

The concept of an average European machine (the ''basecase'') is defined. Design options that will be technically feasible and economically attractive to the consumer within the next 5 to 10 years are identified. The ultimate goal is to contribute to the discussion on reasonable and generally acceptable long-term target values.

A ranking of the options according to Payback Period (PP) and the total real costs over the life of the machine (Life Cycle Costs) are used to determine the point at which price increase is no longer compensated by the product's improved energy efficiency.

For *washing machines* a **standard basecase** and a **real-life basecase** were defined, both on the basis of the 60°C cotton cycle without pre-wash.:

- **The Standard Basecase**, 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.

- **The Real-life Basecase,** 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 detergent are free variables in the Real-life Basecase

The definitions of the basecases and the options studied are shown in figures 1 and 2.

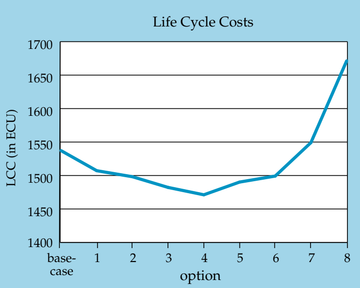
The Standard Basecase is appropriate when implementing certain policy measures such as labelling and minimum efficiency standards. The Real-life Basecase supplies decision support when assessing an appropriate mix of instruments, which may also include other policy measures such as promotion of better consumer behaviour, retailer training programmes, subsidies, and technology procurement. The Real-life Basecase offers a wider range of design options than the Standard Basecase, and its saving potential is also estimated to be higher (see below).

Figure 3 gives a breaf summary of the Standard Basecase. The breakdown of Life Cycle Costs shows that energy costs represent a relatively small part of the operating costs. The breakdown of energy consumption per cycle illustrates that the heating energy (for water, heat loss and load) constitutes 86% of the total in the 60°C cotton cycle. The overview of component costs shows that the motor group and other electrical components (controls, sensors, etc.) make up half of the machine price. Product price was estimated to be a factor of 3.3 higher than the component costs.

Figure 1. *Standard Basecase and Design Options*

Washing Machine

Standard Basecase according to EN 60456 with 4.5 kg load, 126 g IEC-A detergent. (1.39 kWh & 83.5 l/ cycle)



Technical design options

1: Improved water level control [proven technology]
2: Longer time, lower temperature, including biostep (or, alternatively, improved mechanical action) [proven]
3: Basic improvement thermal efficiency [proven]
4: Reduction of tub-drum clearances, larger drum
5: Improved rinsing efficiency, 3 rinses [proven]
6: Basic improvement motor efficiency [proven]
7: Extended motor efficiency improvement [experimental]
8: Extended water economy improvement [experimental]

base	1	2	3	4	5	6	7	8	← Design option no.
0.30	0.29	0.28	0.25	0.23	0.23	0.20	0.18	0.17	← Energy kWh/kg
D	D	D	C	B/C	B/C	B	A	A	← Efficiency class EU label
18.50	16.60	16.60	16.60	14.60	11.80	11.40	11.40	11.00	← Water l/kg

Table 2 gives a summary of the target values that were found. The row ‘‘basecase’’ shows the average European machine and the row ‘‘economic’’ describes a machine with available technical options which are economically attractive for the consumer (lowest point in Life Cycle Cost curves). The row ‘‘technically feasible’’ describes a machine with all technical options which are technically feasible (minimum values of consumption).

Furthermore, the table shows a significant saving potential for technical improvement through technologies that are experimental, irrespective of restrictive policy measures and promotional activities in the fields of consumer behaviour and infrastructure. Adequate stimulation of these technologies by policy makers, for instance through procurement and/or R&D subsidies, seems worthwhile and might also make some presently experimental options economical.

From the analysis it is concluded that the potential for energy savings by proven technological improvements identified as being economically cost-effective shows that the efficiency of the average new European washing machine can be improved by 25%. Similar results were developed for dishwashers (33%). and driers (10%). Tables 3 and 4 gives a summary of the target values that were found for dishwashers and driers.

POLICY OPTIONS AND SCENARIO ANALYSIS—MAJOR RESULTS

The following policy options are investigated: information for consumers (labelling schemes, product lists, and usage information), minimum efficiency standards, and economic instruments (taxes, rebates and subsidies, procurement programmes, R&D subsidies).

The policy options may influence either purchasing or usage patterns and will vary in the certainty of their impact.

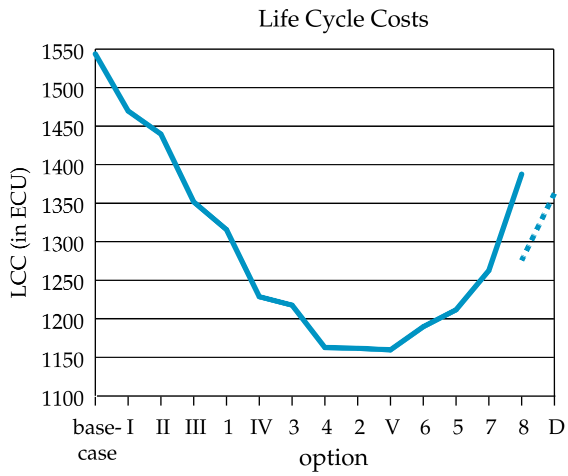
Policy instruments work best in combination, since they have different effects. Energy labels (or product lists) are a necessary precursor to other policy instruments that depend upon consumer awareness of relative energy consumption, such as cash rebates. The effectiveness of labels on the wet appliances will depend heavily on retailer and government support. Standards put pressure on poor performers and are most appropriate for optimising existing technologies. Procurement programmes encourage new product development.

Economic instruments, whether applied nationally or regionally, provide a useful adjunct to minimum efficiency standards. The most inefficient appliances should be removed from the market by an effective minimum standards

Figure 2. *Real-life Basecase and Options*

Washing Machine

Real-life Basecase with 3 kg load, 135 g IEC-A detergent. (1.32 kWh & 75.5 l/cycle)



Consumer options (not in EN 60456 test procedure):

- I: 15-20% downscaling (improved loading efficiency smaller households)
- II: Lower programme temperature setting (through detergent improvements)
- III: Reduced detergent loss (e.g.tub valve)
- IV: Automatic/improved detergent dosage (dual component)
- V: ECO-button

Technical design options (EN 60456)

as in fig. 1

Infrastructural options (e.g. other heat sources and hot-fill)

D*: Washing machine heated directly (heat exchanger in the machine) by district heating

base	I	II	III	1	IV	3	4	2	V	6	5	7	8	D	Design option no.
0.45	0.38	0.34	0.34	0.31	0.31	0.28	0.23	0.22	0.21	0.21	0.19	0.17	0.15	0,04*	Energy kWh/kg
25	21.3	21.3	21.3	17.4	17.4	17.4	11.8	11.8	11.8	9.9	9.9	9.9	8.6	8.6	Water l/kg
135	135	135	110	110	78	78	78	78	78	78	78	78	78	78	Detergent g/cycle

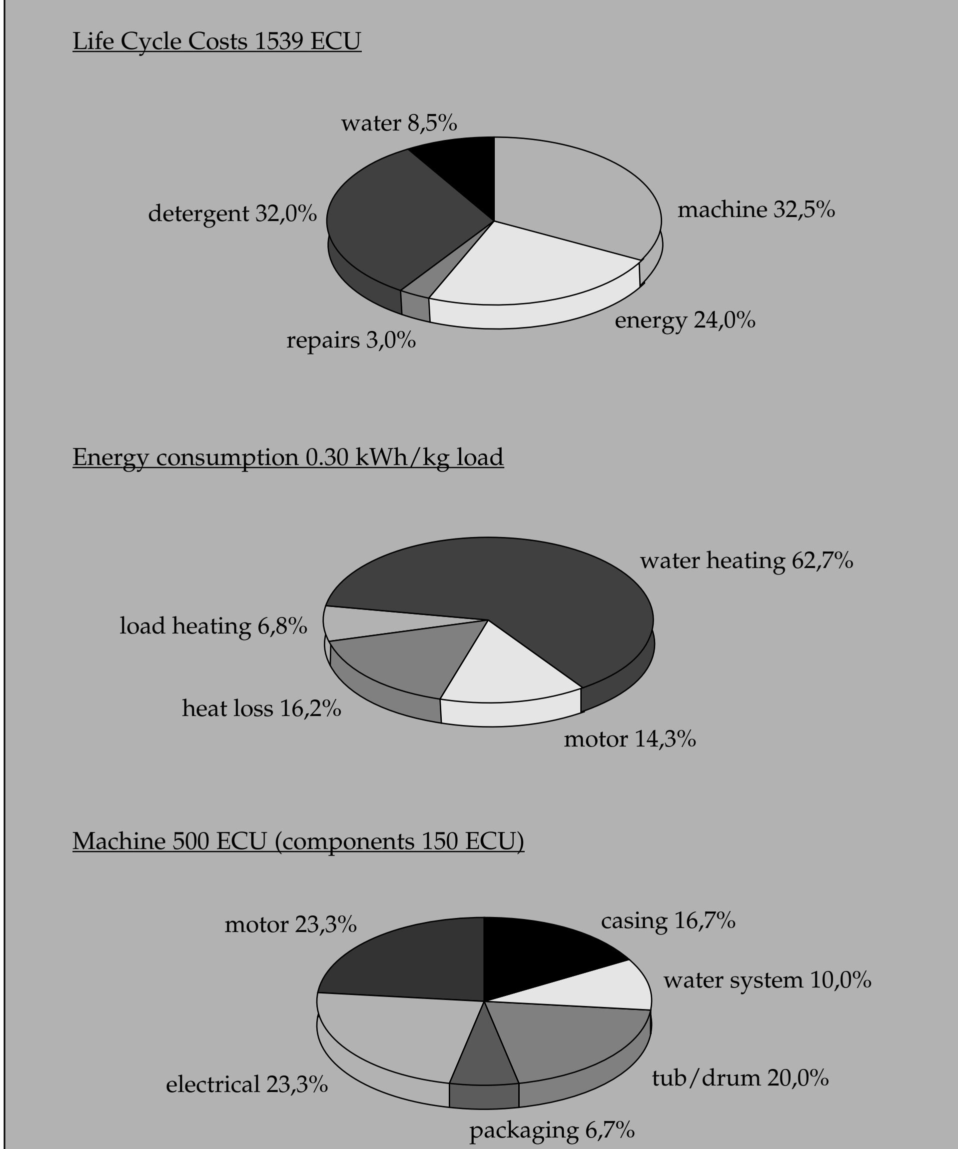
* shown as an example. Feasibility of infrastructural options depends on the local situation. Payback Periods of infrastructural options are usually good.

approach. Rebates can be focussed on increasing incentives to consumers to buy the most efficient machines.

The effect of most policy options has been difficult to gauge because of the lack of information on both consumer habits and preferences. The uncertainty about consumer preferences when purchasing a new machine has been highlighted, but more data are also needed to assess the impact of policies on consumer usage patterns. This is particularly important for appliances where both the level of service and energy consumption are dependent upon a range of user choices: the programme, duration, temperature, load and so forth. There is considerable potential for consumer education programmes that would save energy, water and detergents. None of these behavioural savings would be accessed by labels, minimum standards or economic instruments.

Other influential policies could include links between the detergent industry and appliance manufacturers, for instance on lower wash temperatures and multi-component detergent dosage. The influence of the washing instructions on clothes' labels is poorly understood and may be hindering the use of cool-temperature programmes. There will be wider environmental benefits from policies to encourage fuel switching away from electricity, by the use of hot-fill and gas-fired machines.

Figure 3. *Washing Machine: Definition of Standard Basecase, for the 60°C cotton cycle, machine with 4.5 kg load (EN60456). Breakdown of Life Cycle Costs, energy consumption and machine price*



Life Cycle Costs are based on a 12 year product life, 230 cycles/year, discount rate 5%, energy price 0.13 ECU/kWh, water price 0.77 ECU/m^3, detergent price 1.92 ECU/kg and 5 ECU annual repair costs. Spin speed was set at 900 rpm. Water consumption is 18.5 litres/kg load. In terms of wash performance according to prA11 EN 60456, the basecase was estimated to be a class D machine (WP=0.96).

There are opportunities to make substantial reductions in the consumption of energy, water and detergents in the wet appliances, without any loss in the standard of performance. Perhaps half of the energy used in these machines could be saved by implementing a comprehensive selection of the policies outlined above. These would include proven technology that is cost-effective at today's prices and consumer education programmes that could be launched and produce

Table 2. *Long-term Efficiency Target Values for Washing Machines*

	Energy (kWh/kg load)		Water (l/kg load)		Detergent (g/cycle)	
	Standard Basecase	Real-life Basecase	Standard Basecase	Real-life Basecase	Standard Basecase	Real-life Basecase
Basecase	0.3	0.45	18.5	25	126	135
Economic	0.23	0.21	14.6	12	126	78
Techn. feasible (proven)	0.2	0.17	11.4	11	126	78
Experimental	.17	.15	10.6	8.6	126	50?

Table 3 *Long-term Efficiency Target Values for Dishwashers*

	Energy (Wh/setting)		Water (l/standard place-setting)	
	Standard Basecase	Real-life Basecase	Standard Basecase	Real-life Basecase
Basecase	138.00	126.00	2.00	2.00
Economic	92.00	90.00	1.75	1.75
Techn.feasible (proven)	87.00	76.00	1.67	1.67
Experimental	83.00	71.00	1.25	1.25

Table 4. *Long-term Efficiency Target Values for Driers*

	Venting drier Energy (kWh/kg load)		Condensing drier Energy (kWh/kg load)	
	Standard Basecase	Real-life Basecase	Standard Basecase	Real-life Basecase
Basecase	.71	.74	.75	.79
Economic + Techn.feasible (proven)	.64	.66	.74	.77
Experimental	—	—	.38	.40

results very quickly. Many of the consumer education initiatives should be undertaken by national governments to respect cultural and regional variations.

The most secure savings, however, will come from policies on minimum standards of efficiency and they would come most rapidly if they are promoted by a supportive manufacturing industry.

For the whole EU in 1994 the electricity consumption for laundry and dishwashing is estimated to be around 60 TWh, corresponding to consumer expenditure of approximately $ 10 billion and approximately 30 million tonnes CO_2 emissions.

Scenario analyses for the coming two decades show that without policy intervention the electricity consumption for laundry and dishwashing in Europe is estimated to increase by 9 TWh to more than 68 TWh in the year 2016, due to the continuation of current trends (‘‘business-as-usual’’).

Policy intervention is needed to achieve the savings potential identified by technical and economic analysis.

If a first step of minimum efficiency standards (10% improvement in the average energy efficiency) is introduced in the year 2000 the electricity consumption in 2016 for laundry and dishwashing in Europe is estimated to decrease to around 61 TWh. This represents a 7 TWh electricity saving in the year 2016 compared to the ‘‘business-as-usual’’ scenario. The corresponding reduction in consumer expenditure is$ 1.1 billion and a reduction of 3.5 million tonnes CO_2 emissions may be expected from the implementation of efficiency standards.

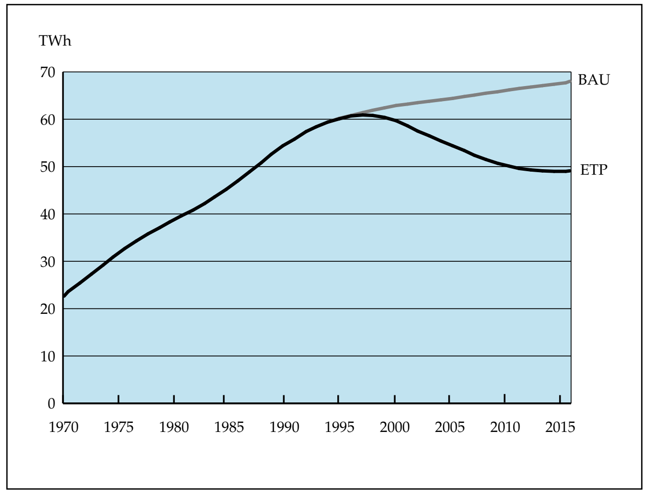
The cumulative savings over the period from a first step of minimum efficiency standards are projected to be 83 TWh of electricity, worth almost $14 billion to consumers at 1994 prices and representing savings in CO_2 emissions of almost 43 million tonnes.

Figure 4 shows that, if policy measures are implemented to achieve the full economic and technical potential the electricity consumption in 2016 for laundry and dishwashing in Europe is estimated to decrease to less than 50 TWh (back to 1988 levels).

This represents a 19 TWh electricity saving in the year 2016 compared to the ‘‘business-as-usual’’ scenario with a corresponding reduction in consumer expenditure of approximately $ 3 billion and a reduction of almost 10 million tonnes CO_2 emissions.

The cumulative savings over the period are projected to be 222 TWh of electricity worth $ 37 billion to consumers at 1994 prices and representing savings in CO_2 emissions of 114 million tonnes.

Figure 4. *EU Electricity Consumption by Wet Appliances*



The long-term effect would be greater as the impact of the improved technology diffuses through the stock of appliances.

Further reductions are available from non-technical sources, such as policy-driven consumer education and infrastructure changes, but these are not indicated in Figure 4.

The economic and technical potential for energy saving that exists in 2016 is greatest in absolute terms for washing machines (11 TWh), but is a higher proportion of dishwasher consumption (35%). Even when the full economic and technical potential is achieved for driers, this would not result in a lower level of total electricity consumption, due to upward pressure from increased household numbers.

OTHER FINDINGS

There seem to be sufficient grounds for the formulation of ‘‘soft targets’’ and promotional activities aimed at the stimulation of both good consumer behaviour and infrastructural options, mainly fuel switching to hot-fill or gas-fired machines. For washing machines, for example, saving potential in addition to that from technical options may reach another 25% through improved consumer behaviour, and up to another 25% through infrastructural options.

Other suitable topics for ‘‘soft targets’’ include spin speed, educating the owners of driers of the substantial energy benefits they derive from high spin speeds in washing machines.

Accurate information to enable consumers to compare the performance of different machines is an essential prerequisite for most other policies. One of the purposes of the statistical analysis was to use the information available to describe the distribution of appliances within an energy labelling system for wet appliances. The EU Labelling Committee has adopted the labelling directive for washing machines with the efficiency classes shown in Table 5. An example of the labels to be used is shown in Figure 5. The energy labels are expected to be on all three appliances by mid-1997 and will thus provide the necessary launch-pad for other initiatives.

Test methods should be updated more speedily, in order to keep pace with policy instruments and changes in technology. New methods should be developed to generate results that better reflect actual consumer use.

Investigation of the effects of tolerances in test methods on labelling schemes is also required to facilitate effective legal control of labelling schemes and to ensure consumers receive accurate information.

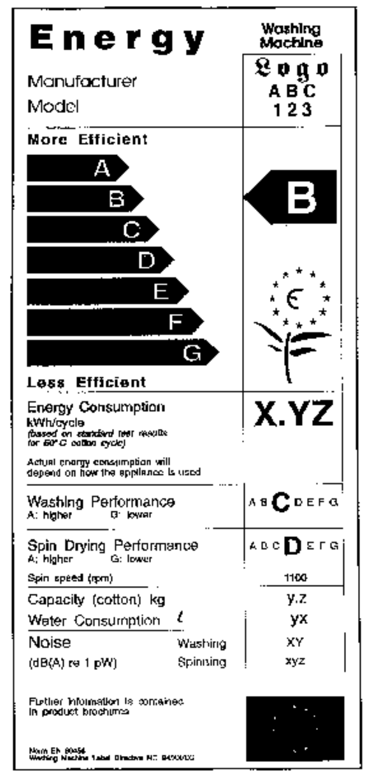
Although a general picture of the way the average European consumer uses wet appliances is presented, numerous data gaps are identified. These gaps are important because they influence our understanding of the ways in which possible policy measures will affect specific countries. There is, therefore, a definite need for more data on consumer behaviour, both at the European level and especially at the country level, including pilot projects to gain practical experience and to tune options to the specific requirements of national markets.

The average efficiency of appliances marketed in northern European countries appears to be higher than in southern European countries. This distribution may reflect national differences in awareness and consumer information on environmental issues. Other factors such as climate, social and economic conditions may also help to explain these variations in average efficiency. However, there is a need for further investigation into the reasons for such differences between countries to assess the likely impacts of policy intervention on individual countries.

Table 5. *Efficiency Classes for Washing Machines*

Efficiency class	Specific energy consumption, SEC 60°C cycle (kWh/kg)
A	SEC≤0.19
B	0.19<SEC≤0.23
C	0.23<SEC≤0.27
D	0.27<SEC≤0.31
E	0.31<SEC≤0.35
F	0.35<SEC≤0.39
G	0.39<SEC

Figure 5. *The New EU Label for Washing Machines*



In order to improve statistical information, it is neccesary to continue the collection of data on the energy consumption of European wet appliances. The forthcoming energy labels will provide a unique basis for systematic comparison of efficiency-related data in the EU and will allow trends to be monitored.

REFERENCES

GROUP FOR EFFICIENT APPLIANCES. July 1994. *Study of Efficient Washing Machines, Dishwashers and Driers, Interim Report*. Danish Energy Agency. Copenhagen. Denmark.

GROUP FOR EFFICIENT APPLIANCES. June 1995. *Washing Machines, Driers and Dishwashers, Final Report*. Danish Energy Agency. Copenhagen. Denmark.

GROUP FOR EFFICIENT APPLIANCES. June 1995. Washing Machines, Driers and Dishwashers, Background Reports. *Volume l, Basic Assumptions and Impact Analyses.* Danish Energy Agency. Copenhagen. Denmark.

GROUP FOR EFFICIENT APPLIANCES. June 1995. Washing Machines, Driers and Dishwashers, Background Reports. *Volume ll, Experimental Analyses linking Energy and Water Consumption with Performace.* Danish Energy Agency. Copenhagen. Denmark.

GROUP FOR EFFICIENT APPLIANCES. June 1995. Washing Machines, Driers and Dishwashers, Background Reports. *Volume lll, Long-term Efficiency Targets, Technical and Economic Analyses.* Danish Energy Agency. Copenhagen. Denmark.