Assessing the market transformation for domestic appliances resulting from European Union policies

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1. SYNOPSIS

The paper presents the main results of EU policy actions to transform the domestic appliances market and the new policies that will be implemented in the framework of the Energy Efficiency Action Plan.

2. ABSTRACT

Since the launch of the PACE (1989) and SAVE (1992) programmes a great effort has been made to transform the appliances market. Since the adoption of a framework Directive for the labelling of domestic appliances in 1992, the majority of domestic appliances have been labelled. Moreover in 1996 the first minimum efficiency standard for refrigerator was adopted, this entered into force in 1999. In addition starting in 1996 a number of voluntary agreements have been concluded with manufacturers for TVs and VCRs, washing machines, dishwashers, electric storage, water heaters, and audio equipment. Since 1996 EU-wide sales data for appliances are bought and analysed to monitor the market transformation. The paper will present the first comprehensive analysis of the market transformation resulting from the implementation of EU policies in this area, in particular labelling and mandatory or voluntary standards.

3. INTRODUCTION

The paper gives an overview of: the energy saving policies for domestic appliances adopted by the European Union during the past ten years; the results achieved compared to the expected savings identified in the technical-economic analysis; the planned new policies, as described in the Commission Action Plan for Energy Efficiency and in the European Climate Change Programme (ECCP); and the expected results.
The residential sector consumed 612.6 TWh of final electricity in the EU in 1996. Of the electrical energy lighting accounted for 80 TWh, space and water heating for 220 TWh and appliances for 310 TWh. Residential final electricity consumption grew by an average of 2.8% per annum from 1990 to 1996. In total EU residential electricity consumption will have given rise to about 276 tonnes of CO_2 emissions in 1996.
The number of households and GDP per capita are strong drivers of appliance ownership and use. The number of households in the EU grew from 144 million in 1993 to 149 million in 1998. GDP per capita grew from 14600 ECU in 1990 to 15500 ECU in 1996.

There is still some degree of uncertainty about the energy consumption attributable to each residential end-use in the EU. The numbers given from each of the SAVE studies, when combined with those drawn from other sources such as end-use metering campaigns and utility estimates add up to more than the whole reported in the EU’s own statistics by at least 66 TWh. There is a need to clarify the uncertainties and improve confidence in the estimated consumption by each end-use, through more metering campaigns.

4. COLD APPLIANCES[1]

Cold appliances consumed about 118.4 TWh/year in 1995. The first technical economic analysis, *Study on energy efficiency standards for domestic refrigeration appliances*, (GEA I) (Group for Efficient Appliances, 1993), was carried out in 1992. Following this analysis, in 1994 the Commission published the energy labelling Directive (94/2/EC) of 21.1.94 which made the display of comparative energy information labels mandatory for cold appliances from 1.1.1995. Mandatory minimum energy efficiency requirements were announced in Directive (96/57/EC) of 3.9.1996 and came into force from 3.9.1999. Based on the recommendation of the study, a single straight line defines the maximum permissible energy consumption level as a function of the adjusted volume. The minimum energy efficiency requirements (actually a maximum energy consumption standard) is set at the boundary between class D and C of the energy labelling for most of the ten categories of cold appliance recognised in the two Directives.

The GEA I study identified that on average the most cost effective energy savings would occur for cold appliances that use about 55% of the energy of the average energy consumption of similar appliances in 1990 to 1992. This is coincident with the A class threshold.

A new SAVE study *Cold II* (ADEME, 2000) to provide technical guidance to the Commission to support the revision of the EU energy labelling and minimum energy efficiency standards regulations has been recently completed. The new analyses indicates the average LLCC EEI, i.e. the Energy Efficiency Index of the model at Least Life Cycle Cost ,is about 46.8% of the consumption of the average model of the 1992 GEA I analysis. This implies that cold appliance energy efficiency could still be improved by an average of 36% in relative terms before there is any net disadvantage for EU consumers. Maximum technical efficiency levels were not considered in the GEA I study although they are being considered in the Cold II study. Early indications suggest that the design of cold appliances with an EEI of 20% is technically possible but the exact values depend on the category and the other constraints imposed. The highest efficiency models on the market in 1999 had EEI of about 29%.

Table 1 summarises the sales weighted annual average cold appliance energy-efficiency index for the EU and individual Member States since pre-labelling and minimum efficiency standards times to 1999, the year in which the efficiency standards were implemented.

Table 1. Cold appliance sales-weighted annual average energy efficiency indices for 1992 to 1999 (%)

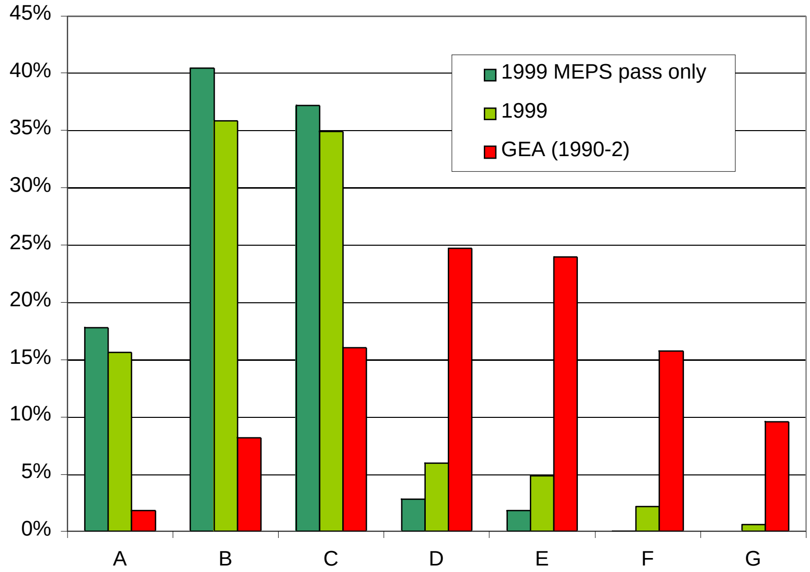
	EU	Aus	Bel	Den	Fra	GB	Ger	Ita	Nl	Por	Spa	Swe
1999 (2)	**74.8**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1999 (1)	**79.3**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1998	**82.3**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1997	**88.4**	81.3	88.2	NA	91.6	99.1	75.5	96.0	80.9	NA	91.7	87.0
1996	**91.8**	85.5	95.6	91.3	98.1	101.8	78.3	97.0	84.3	104.0	98.2	92.2
1995	**93.9**	87.9	97.0	93.1	101.6	103.4	80.6	99.3	88.2	106.3	100.5	95.0
1994	**96.1**	89.4	99.4	95.3	104.7	103.3	84.7	101.7	92.3	108.8	99.6	97.2
GEA (1990-92)	**102.2**	95.1	105.7	92.8	103.9	108.9	96.6	105.1	99.0	121.4	101.0	97.4

This data indicates that there has been a pronounced improvement in the energy efficiency of new cold appliances offered for sale in the EU since the time of the GEA study. The average cold appliance offered for sale at the beginning of 1999 used 22.5% less energy to perform the same task than one offered for sale in the period of 1990 to 1992. If it is assumed that the minimum efficiency standards Directive was fully respected after its implementation in September 1999 then the average efficiency index of cold appliances offered for sale immediately afterwards is likely to be in the region of 74 to 76%, suggesting that they would consume about 27% less energy than equivalent appliances sold in 1990-92. This represents an average annual energy efficiency improvement over the intervening period of about 4.3% per year.

Since the time of the GEA I study, used to define the current labelling system, there had been an average cold appliance efficiency improvement of two labelling classes by 1999, such that the greatest number of models were in the B and C classes as opposed to the D and E classes for the GEA I database. Furthermore the share of A class appliances had increased from 1.8% from 1990-92 to 15.6% in 1999. The strongest efficiency improvements appear to have occurred between 1992 and 1994, between 1997 and 1998 and again from 1998 to 1999. It can only be conjecture as to why these trends occurred as they have; however, it is possible that the improvement from 1992 to 1994 resulted from a general repositioning of the market in anticipation of the introduction of labelling and efficiency requirements while the increase in improvement from 1997 to 1999 was partly driven by the then pending minimum efficiency requirements and partly by the improving implementation and impact of the energy label.

Figure 1 shows the distribution by labelling class at the time of the GEA I analysis and in 1999, but also shows the distribution by labelling class in 1999 if models which would have failed to satisfy the September 1999 minimum efficiency requirements are left out. Some 12.2% of models offered for sale in 1999 did not satisfy the minimum efficiency requirements compared to 72% in 1990-92.

Figure 1. Share of EU cold appliance models by labelling class from 1990-92 to 1999



The new policies planned are the revision of the refrigeration appliance label and a new set of efficiency levels. The revision of the energy label is particularly urgent since there are only three classes left on the market and there are not incentives for manufacturers to improve refrigeration appliances beyond the A class level. The study recommend to place to new A class at the 30% energy efficiency index, the new label should be introduced sometime during 2003. The new minimum efficiency requirement shall be placed at an energy efficiency index of 55%, and should be introduced in 2005. As a temporary solution the SAVE sponsored project Energy Plus has launched a European wide procurement for combined refrigerators/freezers with an energy efficiency index of 0.42. This will stimulate in the short term the production of cold appliances with energy index of around 40%.

5. WASHING MACHINES

Washing machines consumed about 33.4 TWh/year in 1995. The first technical economic analysis *Washing Machines, Driers and Dishwashers*, (GEA Wet I) (Group for Efficient Appliances, 1995) was carried out in 1994. In 1995 the Commission published the energy labelling Directive (95/12/EC) of 23.5.95 which made the display of comparative energy information labels mandatory for washing machines from 30.9.1996. A negotiated agreement to impose minimum requirements on washing machine energy efficiency and a fleet target was reached between the European association of household appliance manufacturers, CECED, and the Commission on 24.7.1997 and is applicable from 22.10.1997 to 31.12.2001. Under the terms of the agreement CECED signatories agreed to discontinue production and importation of E, F and G energy class washing machines, excluding those with a load a capacity below 3 kg and vertical axis machines, after 31.12.1997; and of D energy class washing machines, excluding those with a load a capacity below 3 kg and with a maximum spin speed lower than 600 rpm, after 31.12.1999. The agreed fleet target was to reach a production weighted target for year 2000 of 0.24 kWh/Kg.

The energy consumption of washing machines is measured under standard test conditions using the EN 60456 test procedure which measures their consumption for a complete 60 °C cotton-load wash-cycle at maximum load capacity. The energy efficiency of a washing machine is defined by the ratio of the tested energy consumption (in kWh) to the load capacity (in kg). The A class boundary is set at 0.19 KWh/kg. There are some difficulties in the interpretation of the GEA's technical-economic analysis caused by the fact that the EN 60456 test procedure was modified in 1994 such that the wash temperature was changed from 90°C to 60°C and the clothing load was modified so that cotton towels with a greater water absorbency were included in the wash. Changing the wash temperature from 90°C to 60°C has been estimated to reduce the energy consumption by about 34%. using the new test procedure as the reference; however, no results are yet available. The best washing machines on the market in 1997 had a specific energy consumption of 0.188 kWh/cycle i.e. were just better than the minimum A requirement.

Bearing in mind the difficulties of interpreting market average efficiency trends for washing machines as a result of the change in test procedure, the average energy efficiency of new washing machines available for sale in the EU had improved by an estimated 20% from pre-labelling in 1993-1994 to 1999.

Table 2. Washing machine sales-weighted annual average specific energy (kWh/cycle/kg)

GEA 1994	1996	1997	1998	1999
0.286	0.260	0.242	0.234	0.228

The technical economic analysis by GEA in 1993 estimated that an electricity consumption of 0.165 kWh/kg was possible. This value was confirmed by the *Washing Machines II Study* (Novem, 2000), and this is roughly the best we can expect for the coming years for the 60°C cotton cycle. The GEA study identified that the Least Life Cycle Cost was associated with a 28% energy saving compared to the reference 'real-life' base-case washing machine.

The new policies planned are the revision of the washing machines labelling Directive and a new voluntary agreement. The new Washing Machine technical-economic analysis indicates that the best appliance on the market can reach a specific energy consumption of 0.17 kWh/kg. This would suggest a new A-class border at 0.17 kWh/kg (at present: 0.19 kWh/kg). The highest energy consumption on the market is limited to 0.27 kWh/kg (standard) or 0.31 kWh/kg (exceptions) by the CECED negotiated agreement. This means a spread of 0.10 to 0.14 and divided in 7 classes, a class width of 0.02 kWh/kg. This would shift the current A/B border to B/C and create a good differentiation, however the measurement tolerances make it practically impossible to implement a correct labelling at these class widths. The second planned policy action is to update the production weighted specific energy consumption target to 0.21 kWh/kg in 2003.

System considerations, such as the hot fill, are rather difficult to take into account in European level analyses and policies; they are perhaps more appropriately dealt at local level. This because this option make sense from an energy/climate change point of view only in specific cases, such as it is feed by a solar hot water supply system, or if the washing-machine is located near an efficient gas boiler (this of course depend also from the nature of the electricity generation).

6. DISHWASHERS

Dishwashers consumed about 14.1 TWh/year in 1995. The first technical economic analysis *Washing Machines, Driers and Dishwashers*, (GEA Wet I), (Group for Efficient Appliances, 1995), was carried out in 1994. In 1997 the Commission published the energy labelling Directive (97/17/EC) of 16.4.97 which made the display of comparative energy information labels mandatory for dishwashers from 31.12.1998. In fact most Member States didn't implement this legislation until 1999. A negotiated agreement to impose minimum requirements on dishwashers was reached between the European major household appliances association, CECED, and the Commission on 19.9.2000. Under the terms of the agreement CECED signatories agreed to discontinue production and importation of E, F and G energy class dishwashers, for those models with a place settings bigger or equal 10, and of E and F energy class for those models with a place settings below 10 after 31.12.2000; after 31.12.2004 an additional energy class will be phased out. The agreed fleet target is to reach a production weighted target reduction by 20% of energy consumption by year 2002 compared to the base case.

For dishwashers the efficiency class grades A to G in terms of the energy consumption per standard wash cycle (kWh/cycle) based on Norm EN 60436. Both the dish cleaning and dish drying performance are ranked from A to G. The number of standard place settings and water consumption are also indicated on the label. Dishwasher penetration in the EU ranged from 20 to 50% depending on the country in 1997, with an average of about 35%. A recent stock model analysis carried out in the context of the European Climate Change Programme, has estimated an increase penetration of dishwasher from 37% in year 2000 to 46 % in year 2010. Even with the introduction of ambitious policy measurers the consumption in year 2010 would be higher then in 1990 by 3 TWh, however if there where no policy measures the consumption would be 5 TWh higher.

7. CLOTHES-DRYERS

Dryers consumed about 10.6 TWh/year in 1995. The first technical economic analysis *Washing Machines, Driers and Dishwashers* (GEA Wet I), (Group for Efficient Appliances, 1995, was carried out in 1994. In 1995 the Commission published the energy labelling Directive (95/13/EC) of 23.5.95 which made the display of comparative energy information labels mandatory for clothes-dryers from 30.9.1996. There are no European voluntary agreements or mandatory minimum efficiency standards applying to this product.

The energy consumption of electric clothes-dryers is measured under standard test conditions using the EN 61121 test procedure which measures their consumption to complete a dry cotton drying cycle at maximum load capacity. The energy efficiency of a clothes-dryer is defined by the ratio of the tested energy consumption (in kWh) to the load capacity (in kg). The labelling classes are defined in terms of this ratio, C. A distinction is made between air-vented dryers and condensing dryers because the air-vented dryers provide a slightly lower service as the moisture extracted from the clothes remains in the vented air for these dryers while it is condensed by a dehumidifier for the condenser dryers. On average the air-vented dryers have slightly lower energy consumption and are typically 36% less expensive than the condenser dryers.

The average energy efficiency of new clothes-dryers available for sale in the EU has improved by a very small degree since the introduction of energy labelling. At the outset of energy labelling almost all clothes-dryers on the market were either class C or D and there were no A or B class appliances on the market. Since that time most D rated clothes-dryers have been upgraded to C class appliances, but it is not possible to make significant further improvements in efficiency without adopting fundamentally different technologies such as using a heat pump. The label has been successful in stimulating the market for class A clothes-dryers and there are now at least 3 heat pump dryers on the market. The fact that there is no energy label for gas-fired clothes-dryers means that it is not possible for European consumers to compare the performance of gas fired dryers to other gas dryers or more importantly to electric clothes-dryers and this is probably inhibiting the rate of up-take gas-fired clothes-dryers. The only new policy option envisaged is to establish a voluntary market share target for class A dryers.
Ownership of clothes-dryers has risen from 22% of households in the EU in 1995 to 27% in 2000. Ownership levels are much higher in northern European countries, such as the UK, than in southern Europe. The vast majority of clothes-dryers sold in the EU are electric but some gas models exist. Nonetheless, there is a considerable primary energy, and hence CO_2, saving achievable in Europe by fuel switching from electric to gas clothes-dryers.

As indicated for dishwashers the recent stock model analysis carried out in the context of the ECCP, has included an increase penetration of dishwasher from 27% in year 2000 to 35% in year 2010. Even with the introduction of ambitious policy measurers the consumption in year 2010 would be higher then in 1990 by 3 TWh, however if there where no policy measures the consumption would be 6 TWh higher.

8. ROOM AIR CONDITIONERS

Domestic and offices room air-conditioners consumed about 11 TWh/year in 1996. The technical economic analysis has been conducted in 1997-1998, *Energy Efficiency of Room Air Conditioners (EERAC)*, (Ecoles des Mines de Paris, 1999). There are currently no energy efficiency regulations nor voluntary agreements in place for room air conditioners in the EU. The EERAC study recommended the introduction of mandatory comparative energy labelling for room air conditioners (RACs). A draft proposal is currently under discussion at the labelling committee. The study also recommended that either a set of minimum energy efficiency standards be imposed or that a voluntary agreement should be reached with industry (Eurovent and CECED) having at least the same energy saving impact.
The EERAC study recommended that minimum energy efficiency standards be introduced for RACs as described in Table 3.

Table 3. Recommended minimum energy efficiency standards (MEES) for room air-conditioners to be sold in the EU (source: *EERAC study*)

RAC type	First MEES level[a] EER (W/W)	Present best EER value (W/W)	Second MEES level[b] EER (W/W)
Multi-split, air-cooled	2.63	3.74	2.89
Packaged, air-cooled	2.38	2.97	2.62
Packaged, water-cooled	3.32	5.42	3.55
Single-duct, air-cooled	1.80	3.09	2.28
Single-duct, water-cooled	2.36	3.62	2.60
Split, air-cooled	2.48	3.56	2.73
Split, water-cooled	2.75	2.88	3.03

Abbreviation: EER = energy-efficiency ratio.

The European Standard EN814 specifies the terms, definitions and methods for the rating and performance of air- and water-cooled air-conditioners and largely mirrors the international RAC test standard ISO5151, although there are some significant differences in the applicability of the standards.

Inspection of the distribution of RAC EERs about the average EER by type (i.e. split-packaged, multi-split-packaged, single-packaged and single-duct) on the European market shows that there are clear energy-efficiency performance differences between comparable products. The most efficient products use only 35% as much electricity as the least-efficient products when providing the same cooling service. This range is typical of the performance differences that can exist in an unregulated market and shows that there is a very considerable potential to save energy through policy intervention.

In 1997/98, the average EERs for single-phase, cooling-only, air-cooled RACs on the EU market were 2.63 W/W for multi-split-packaged units, 2.48 W/W for split-packaged units, 2.38 W/W for single-packaged units and 1.80 W/W for single-duct units.

It should be noted that the permitted measurement tolerances for the EER are approximately _6%, that variable-speed units are not accommodated by the test procedure and that some uncertainties about practical test conditions remain for single-duct RACs. Following one of the new EU study's recommendations, the European Commission has asked CEN, the European standards body, to improve the standard's accuracy and applicability.
There are currently about 7.5 million RACs installed in the EU, but with annual sales reaching 1.6 million by 1996 and growing at an average of 12% each year, the total is expected to rise dramatically in the coming decades. Sales in 1996 were dominated by Italy and Spain, which accounted for 47% of the EU total, while Germany, France, Greece and the UK accounted for another 41%. About 40% of RACs sold in the EU are

imported and the rest are produced internally. Since 1990 the RAC stock in the EU has grown by a startling 35% per annum on average, while annual RAC sales have doubled over the same period. The EU stock is forecast to grow to 21 million by 2010, although there is a very large uncertainty in these projections given the immaturity of the market. There is also great uncertainty surrounding the average number of hours of equivalent full power usage per year in the EU, and this is compounded by a lack of metered data. Average usage was estimated in the EU study from two extensive consumer telephone surveys and from computer simulations of building cooling demand based on knowledge of the building stock, climate, occupancy patterns and comfort thresholds. Perhaps surprisingly, the two independent methods produced similar results, with estimated average annual usage values of 519 hours in the residential sector, 768 hours in hotels, 803 hours in offices and 1019 hours in other commercial uses. This gives an EU average of 773 hours across all sectors. Forecast RAC energy consumption under a business-as-usual scenario is projected to increase from 11.0 TWh in 1996 to 30 TWh/year by 2010. Increasing the average EER in line with the study's policy recommendations would save up to 3 TWh per year by 2010, about 10% of the business-as-usual scenario.

9. DOMESTIC ELECTRIC STORAGE WATER HEATERS (DESWHS)

Domestic electric storage water heaters consumed 68 TWh in 1995 and are thus the second most important group of domestic appliances in energy terms behind cold appliances. Standing losses accounted for 22% or 19 TWh of this total, which is roughly the total electricity consumption of Ireland. The technical economic analysis *Analysis of Energy Efficiency of Domestic Electric Storage Water Heaters*, (EVA, 1998) was carried out in 1997. The market average thresholds in table 4 were recommended by the EVA study as appropriate levels for mandatory minimum efficiency standards, but have since been adopted as the production weighted targets for 2002 under the terms of the negotiated agreement.

Table 4. Average DESWH standing losses ('base case') as a function of rated storage capacity

Type of DESWH	Capacity, V, in litres	Base case for standing losses
Vertical	> 50–1000	0.2 + 0.051 _ $V^{2/3}$
Horizontal	> 50–300	0.75 + 0.008 _ V
Small	5–50	0.13 + 0.0553 _ $V^{2/3}$

The negotiated agreement to impose minimum energy performance requirements on DESWHs was reached between the European household appliances association, CECED, and the European Commission on 19.3.2000. Under the terms of the agreement the CECED members who manufacture DESWHs have agreed to stop producing or importing into the EU market DESWH products with standing losses above some thresholds after 31.12.2000 and to have attained production weighted average DESWH standing losses of no more than the thresholds defined in table 4 by the beginning of 2002 (except for UK manufacturers who have until the end of 2002 to reach the targets). In addition to agreeing to meet these targets CECED manufacturers have committed themselves to displaying the standing loss performance of their appliances as soon as a labelling or information Directive is agreed (i.e. in advance of its implementation at Member State level). The draft labelling Directive proposal has already been submitted to the labelling committee.

Thus far DESWH efficiency in the EU has been defined purely in terms of the standing losses. Standing losses typically only account for 22% of DESWH energy consumption, but as the efficiency of the electric water heating process is close to 100% there is little to be gained in raising the efficiency of the water heating process unless a heat pump or alternative energy source were to be considered. The IEC 379/HD 500 S1 standard defines the reference method for the measurement of standing losses over a 24-hour period. The voluntary agreement refers to standing loss measurements made under the CENELEC Harmonised Document HD500.S1, which is equivalent to IEC 379.

A sensitivity analysis used to identify the relevant technical parameters influencing standing losses. This showed that the main influence on standing losses is the ratio of insulation thickness at the walls to the thermal conductivity of the insulation. Using the thermal conductivity of PU foam (0.035 W/m K) and using average values for all physical parameters of DESWHs, an average insulation thickness of 4–5 cm was found for the 'base case' DESWH models in 1995.

The EU average least life cycle cost for DESWH equipment has been estimated to coincide with insulation levels of from 6.4 to 9.3 cm depending on the equipment type. Moving from a business as usual (BAU) to a least life cycle cost scenario is forecast to lead to a reduction in annual standing losses equivalent to 34% of the BAU standing losses by 2020. This would amount to an annual saving of 5.3 TWh by 2020. The thresholds in the current voluntary agreement fall someway short of the estimated LLCC standing loss levels.
About 30% (43.5 million) of the EU's 142 million households use electric water heating systems. The percentage of households in each country using electricity to heat water is more than 40% in Luxemburg, Austria, France and Germany, between 30 and 40% in Italy, Belgium and Finland, just over 20% in the UK, between 10 and 20% in Portugal, Sweden, the Netherlands, Ireland, Denmark and Spain, and less than 10% in Greece. The energy consumption of the stock of DESWH equipment in the EU was forecast in the EVA study to fall gradually to about 77 TWh/year by 2020. This was reduction was forecast to occur without policy intervention due to a trend of falling sales and slightly raised efficiency levels.

10. OVENS

Electric ovens consumed 16.2 TWh in 1995 The technical economic analysis *Efficient Domestic Ovens*, (TTS Institute, 2000) was carried out in 1999. As yet there are no EU regulations or voluntary agreements applying to gas or electric oven energy efficiency.

The TTS study recommends the introduction of minimum energy efficiency requirements (MEES) or voluntary agreements with industry that result in removing from the market those electric ovens with worse performances than the current market average (1.2 kWh/cycle), to be followed some years later by a second-round threshold of either 0.8 or 0.9 kWh/cycle. For gas ovens the study recommends a first-round target of 1.5 kWh (or 5.4 MJ) per cycle and a second-round target of 1.25 kWh (4.5 MJ) per cycle.

Until recently, electric oven energy consumption in Europe was defined through a standard test, HD 376 S2 (CENELEC HD-376S2-1998), which determined energy use on the basis of: the pre-heat energy consumption needed to attain 200 _ C for natural-convection ovens, or 175 _ C for forced-convection ovens; the steady-state energy consumption needed to maintain an oven temperature of 200 _ C for natural-convection units (or 175 _ C for forced-convection ovens). However, recently these two tests have been replaced with a single test, European standard prEN 50304, May 98, more commonly known as the 'brick test', wherein a wet brick is heated from 5 _ C to 60 _ C. For gas ovens, the European standard EN 30 2.1 (CEN, A979) is used, and a brick test is also under development.

Overall, the maximum technical energy-saving potential from combined options is thought to be approximately 54% for electric ovens and 55% for gas ovens compared to the average oven of each type. The existence of electric ovens with brick test energy consumption of 0.6–0.7 kWh per cycle confirms that the combined maximum technical savings potentials are achievable at least in the case of electric ovens. A draft proposal for an energy efficiency label set the class A at this level.

The large majority of households in Europe possess either an electric or gas oven. Few estimates on oven energy consumption exist, but a recent end-use metering study in France found that electric ovens account for 39% (224 kWh/year) of electric cooking consumption in French households, and hobs for 42%. This puts ovens far ahead of the myriad of other cooking appliances, such as microwaves, kettles, grills, coffee-makers, food mixers, etc., which together account for the remaining 19%. However, it is not appropriate to extrapolate from these results to the whole of Europe or elsewhere, as the TTS study has found that oven usage varies very substantially by country and depends strongly on the local cooking and eating culture. For example, Dutch households used their ovens, on average, only 45 times per year in 1998, while oven usage in French households was 5 times greater.

In total, there are thought to be almost 89 million electric ovens and 55 million gas ovens in the EU. Overall, the ownership of ovens is fairly saturated, so most sales are for replacements; however, the type and features of the ovens being bought are changing and both these factors have an influence on oven energy consumption.

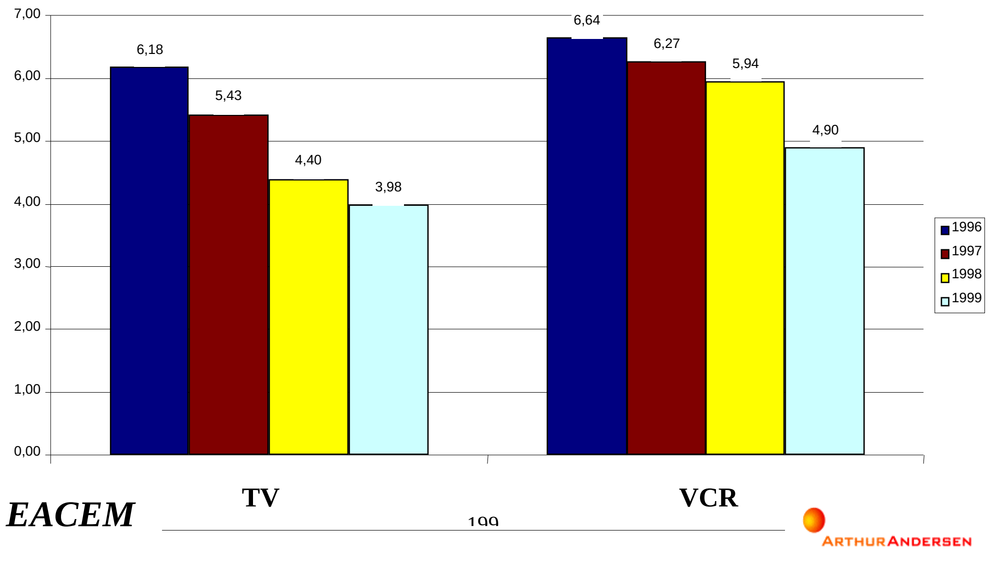
There are currently about 144 million ovens installed in the EU, with annual sales reaching 14.3 million (for cookers) by 1998, up 12% from 1993. Most households in the EU have at least one oven, although there is a wide distribution by fuel type such that on average 61% of households own an electric oven and 38% a gas oven. Estimated electricity consumption by EU ovens since 1970 has remained relatively constant, and this is related to different pressures on consumption cancelling each other out. The improved efficiency of electric ovens together with a reduction in the average number of times households use their ovens over the course of a year are both driving consumption down. There has been a decrease in oven gas consumption over the last few decades, despite no marked improvement in gas oven efficiency (excluding the phase-out of standing pilot lights). The reduction in gas consumption wholly results from declining usage and consumers switching to electric ovens. This trend is thought likely to continue into the future, this is justified by an increasing market share of electric ovens, which are perceived as more practical and to include new features such as microwaves and other cooking functions. Forecast electric oven energy consumption under a business-as-usual scenario is projected to increase from 12 TWh in 1998 to 12.5 TWh/year by 2020; however, this profile assumes that the number of oven-baked dishes continues to decline, which may not be the case. For gas ovens the annual energy consumption is projected to decline from 31.5 PJ (8.8 TWh) in 1998 to 27.12 PJ in 2020 (7.5 TWh).

Introducing mandatory minimum energy efficiency standards or negotiated agreements in line with the SAVE study's policy recommendations would save up to 4.3 TWh of electricity and 2.3 PJ (6.4 TWh) of gas per year by 2020, about 23% of the business-as-usual totals. In terms of CO_2, this is forecast to avoid up to 1.85 million tonnes of annual emissions by 2020.

11. CONSUMER ELECTRONICS

Consumer electronics (TV, VCR, audio equipment, IRDs) consumed 44 TWh in 1995. The technical economic analysis for the on-mode has been conducted in 1997-1998 *Analysis of Energy Consumption and Efficiency Potential for TVs in on-mode*, (Novem, 1998). The technical economic analysis for the stand-by-mode has been conducted in 1995-1996 *Study of Standby Losses and Energy Savings Potential for Television and Video Recorder Sets in Europe*, (Novem, 1996). The European Commission has reached a negotiated agreement with European industry regarding TVs and VCRs standby power consumption. The agreed target are: televisions and video recorders with stand-by consumption greater than 10 W will not be commercialised after 1 January 2000; each manufacturers has individually to reach a sales-weighted average (per company) of 6 W by year 2000. Manufacturers agreed that the company sales-weighted average would be progressively reduced towards 3 Watts by year 2009. The 1999 average stand-by consumption reached by the companies participating in the voluntary agreement was 3.98 W for TVs and 4.90 W for VCRs. The best company for TVs in having an average of 1.26 W and the worse having an average of 9.0 W. The results (sales based) of the negotiated agreement are shown if figure 2.

Figure 2. Average Standby Power Consumption (Watts)
(based upon 1999-figures)



An additional agreement for audio equipment has been reached during year 2000. The targets for this agreement are as follows: maximum allowed stand-by consumption of 5 W for all equipment marketed after 1/1/2001; maximum allowed stand-by consumption of 3 W for all equipment marketed after 1/1/2004; maximum allowed stand-by consumption of 1 W for all equipment marketed after 1/1/2007. There are no regulations or agreements regarding on-mode power consumption. The TV on mode study recommended the introduction of mandatory comparative energy labelling for TVs. To this end the European Commission has already made a proposal to the labelling Committee for introducing a Directive for labelling TV. The study proposal was based on a technical and statistical analysis of TVs on the market which suggested that the efficiency classifications would be appropriate. The proposed labelling scheme uses the principle that the lower boundary of the 'D' category corresponds to the market average, the boundary for the 'A' category to the best technology, and the boundary for the 'G' category to the least-efficient technology.

The TV on-mode study estimates that cost effective design options from the consumers perspective would result in a 38% TV on-mode power reduction compared

In a typical European household the main TV is on for an average of 5.6 hours per day, while second TV sets are typically watched for 50% of this time. The market for TVs is divided almost equally between small, medium and large sets, although there is a slight trend towards the smaller and larger units at the expense of the medium-size sets. This blend of TV types gives an average all-TV on-mode consumption of 64 W under realistic operating luminance levels. The average penetration of TVs into EU households in 1995 was 135%, but the total stock grew at 4.3% per annum from 1991 to 1997, resulting in a forecast penetration rate of about 177% by 2010 and a stock of 288 million units. This means that if existing technology is maintained, TV on-mode consumption in the EU would be expected to increase from 22 TWh/year in 1995 to 41 TWh/year in 2010; however, were best available technology used, this could be limited to only 30 TWh/year.

The above projections take no account of potentially radical shifts in preferred technology. The popularisation of digital pay-TV is poised to have a large impact on overall TV energy consumption as additional, integrated receiver decoder (IRD) equipment is required to receive and decode the signal. There are signs that IRD use is about to increase dramatically as a result of huge market stimuli such as the decision by major TV service companies in the UK to give away IRD set-top boxes in order to build the long-term market for subscription TV. Owing to the absence of a standby passive mode, IRDs currently use an average of 21.5 W continuously and hence would add an extra consumption of 188 kWh/year per participating household. If IRD ownership were to rise to 50% of EU households by 2010, a not unrealistic prospect, and were IRDs to continue not to have a standby passive mode or even a normal on/off switch, total TV-related energy demand could increase by an additional 15.3 TWh/year.

To limit this large energy consumption the Commission has proposed to all concerned parties to sign a Code of Conduct which would introduce power management for this equipment together with targets for the consumption in standby.

12. CONCLUSIONS

For most of the policy actions implemented for domestic appliances the full effects will be felt only when the appliance stock will be completely replaced by appliances more efficient meeting to the targets of the policy actions. For cold appliances and washing machines savings in excess of about 20% have already been achieved, together will a great decline of stand-by consumption for TVs and VCRs. For dishwasher, electric storage water, and audio equipment the effect will only be visible by 2010.

Energy savings potentials realisable by new policy actions from substituting more efficient equipment for each end-use are indicated in Table 5, this include assumption for ownership levels. Many appliances such as cold appliances, washing machines, ovens and water heaters have had relatively slow evolutions in ownership and sales volumes. Others such as clothes-dryers, dishwashers, air conditioners and satellite decoders are anticipated to have quite steady or rapid rises in penetration rates. Periodically entire new classes of appliances enter the market which have the potential to become significant energy consumers such as satellite decoder set top boxes, home PCs and other office equipment, and flat screen TVs. The energy savings potentials have been calculated assuming that the existing stock of appliances is gradually replaced by those whose efficiency would correspond or be close to the least life cycle product cost for the consumer. This would be the result of ambitious EU policies including minimum efficiency requirements and challenging energy labelling. To achieve these targets it would also require some changes in consumer behaviour and other components (e.g. detergents) especially for wet appliances under real usage conditions. Appliance usage is also evolving and sometimes quite rapidly. Clothes-washer energy consumption is strongly linked to the availability of high quality low temperature detergents and to prevalent fabrics, but also to trends in the frequency of washes. Cooking energy use is very dependent on trends in cooking culture. Hot water energy consumption has been rising year on year in many EU countries in response to changing user habits. Lastly, energy consumption trends in one end-use can effect another, for example higher average spin speeds and hence spin drying performance in washing machines can result in energy savings among clothes-dryers. Or changes in the use of cold appliance storage for frozen food and pre-cooked ready meals is likely to effect cooking energy consumption. Potentially, more important than these considerations are systematic changes in the fuel of choice for given appliance types. Switching electric water and space heating to natural gas would save a very significant amount of primary energy although not necessarily CO_2 emissions, depending on the generation fuel mix in the country where it occurs. The potential impact of fuel switching is beyond the scope of this paper but is an important consideration in the development of a CO_2 abatement strategy for this sector.

The data in Table 5 drawn mostly from SAVE sponsored studies and the ECCP work gives a rough indication that annual electricity savings of more than 154.3 TWh/year are potentially achievable across the EU by substituting appliances with efficiencies at the least life cycle cost for those in the current stock. As this coincides with the least life cycle product cost it would also save European consumers billions of Euro in life cycle costs for the appliances concerned. Annual running cost savings of about 18 billion Euro would be achieved through the increase in efficiency but this would be partially offset by the rise in purchase price of new products. In reality this substitution would occur over time as new appliances join the stock and old ones are retired. The major part of the potential savings are attributable to efficiency gains for two end-uses: cold appliances and consumer electronics. Were all appliances currently in use to be substituted by those having maximum technically achievable efficiency levels the annual savings are estimated to be greater than 171 TWh but this is not necessarily in the best economic interests of average consumers. The least life cycle costs savings scenarios do not consider the monetary societal value of avoided CO_2 emissions. Were these to be added into the economic calculations to produce a societal optimum efficiency level scenario greater savings potentials than the LLCC efficiency scenario would ensue. As results of the ECCP the Commission will present the planned Framework Directive for efficiency standards for electric equipment, which should facilitate the adoption of dynamic efficiency requirements set at minimum LCC. This will be followed by a revision of the Framework Directive for labelling, to make the label more dynamic and challenging.

Table 5

	Consumption 1990	Consumption 1995	Consumption 2010BaU/2010 policy scenario	Savings 1990/2010 policy scenario	Savings 2010BaU vs 2010 policy scenario
Refrigerators and freezers	123.6	118.4	96.2/80.7	42.92	15.5
Washing machines	40.0	33.4	23.7/17.1	22.9	6.6
Dishwashers	12.8	14.1	17.6/15.6	-2.8	2.0
Driers	8.2	10.6	14/11.4	-5.8	2.6
Room air-conditioners	1.6	2.5	7.5/6.7	-23	2.8
Electric storage water heater	72	68	68/65.2	6.8	2.8
Electric ovens	15.1	16.2	16.5/16.1	-1.0	0.4
Consumer electronics stand-by	15	20	26/4	11	22
Lighting	85	89	112/84	1.0	27.4
Consumer electronics on mode	25	25	50/40	-25	10
Office equipment	3	10	65/32	62	33

	Consumption 1990	Consumption 1995	Consumption 2010BaU/2010 policy scenario	Savings 1990/2010 policy scenario	Savings 2010BaU vs 2010 policy scenario
Heat pump/domestic electric heating	150	150	150/125	25	25
Miscellaneous	26.5	29	39	-12.5	
Central heating circulation pumps	30	32	37/30	0	7
Total	607.8	618	722.5/566.8	38.5	154.3

13. REFERENCES

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14. END NOTES

[1] A generic term to denote domestic refrigerators, freezers and their combinations