Preparing Minimum Energy Efficiency Standards for European Appliances

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The European Community (EC) is investigating the possibility of implementing energy efficiency standards on European households appliances. The EC recently commissioned a study of the impact of potential appliance standards on electricity consumption in the twelve EC nations. This study looks at refrigerators, freezers, dishwashers, clothes washers, and clothes dryers. The impact of minimum efficiency standards on electricity use over the time period from 1995-2010 is estimated.

Because efficiency standards appear as a promising measure to rationalize residential electricity use, many other European countries outside EC (Scandinavia, Switzerland) already agree on adopting future EC regulations. The general context of the European appliances industry as well as the results of the study described above will be presented. The political considerations and the approach in the definition of energy efficiency standards in Europe will also be discussed.

Introduction

In 1986, the Council of Ministers of the European Communities adopted the goal of improving end-use energy-efficiency by 20% before 1995. However, in 1988 and 1990, surveys of initiatives taken by member states revealed that the objectives could not be fulfilled unless more effective programs were established. In 1989, the Council adopted the PACE program, an action plan for the efficient use of energy, which includes energy labeling and the introduction of efficiency standards for household appliances. During the same year, the EC established an objective to stabilize the emission of CO_2 at its 1990 level by the year 2000.

In 1991, the French Agency for the Environment and Energy Management (ADEME, formely-AFME) performed an analysis of the European appliance market for the Directorate General for Energy (DGXVII) of the Commission of the European Community[1]. This study estimated the electricity savings that would be derived from energy efficiency standards for five residential appliances: refrigerators, freezers, clothes washers, clothes dryers and dishwashers. Since the ADEME study concluded that greatest energy savings would come from standards for refrigerators and freezers, ADEME and EC have focused their attention on these products.

This paper will discuss the general context of domestic appliances in the European Community, the main results of the completed ADEME study, and the work in progress for establishing standards in the EC.

Overview of the European Situation

The World's Largest Appliance Market

The population of the twelve EC nations (325 million) is greater than the U.S. population (250 million). There are approximately 125 million households in the EC nations and less than 100 million in the U.S.A. Therefore, the appliance market is potentially larger in the EC than in the U.S.A. As more countries join the EC, its market will continue to grow. In 1988, total EC electricity consumption was equal to 1,615 TWh (10^{12} Wh): The average residential use was equal to 26% of the total, ranging from 22 to 35% for individual countries.

The levels of appliance ownership (level of saturations or market penetration) vary greatly from one appliance to another and from one country to another. Table 1 presents the level of saturation for the major household appliances. Except for Greece and Portugal, ownership of a first refrigerator is essentially at a maximum. Freezer market penetration ranges from 18 to 70%. Clothes washer penetrations are much higher than clothes dryer saturations and dishwasher penetrations are low, ranging from 4 to 35%.

Table 1. Appliance Saturations in EC Member Nations and in the USA (in % of equipped households) (Source 1)

	BE Belgium	DE West Germany	DK Denmark	ES Spain	FR France	GR Greece	IR Ireland	IT Italy	LU Luxem-bourg	NL Nether-lands	PO Portugal	UK Great-Britain	EC Eur. Comm.	USA USA
Refrig.	98	96	100	94	97	74	92	99	99	98	83	93	95	100
Freezer	60	58	64	18	42	25	21	22	70	47	28	38	40	42
Clo.-.Dry.	35	21	21	4	10	2	12	4	24	15	2	34	16	45
Clo.-Was.	95	91	67	92	86	69	77	94	91	90	43	89	87	72
DishWas.	24	35	27	9,5	30	4	10	22	24	10	7	9	21	50
El. Cook.	34	78	76	3	87	74		4	34	16			55	
El.Wa.He.	28	35	7	19	36		54	50	38	18	7	67	40	

Europe (EC plus Scandinavian countries) is a major producer of household appliances. The figures in Table 2 compare the level of production between Europe, USA and Japan[2]. The European appliance industry was traditionaly based on small, family-owned companies. During the last decade, due to a slower growth rate and the opening of national markets, this industry was forced to concentrate. Many companies merged and today four appliance manufacturers account for more than 50% of the major electric appliances produced in Europe.

Table 2. Production Figures in Europe, USA and Japan (in thousand of units, 1989) (Source 2)

	Europe	USA	Japan
Refrigerators	10486	6207	5079
Freezers	4086	1283	101
Clothes-Washers	10682	6166	4857
Clothes-Dryers	2322	4545	449
Dishwashers	3078	4026	78

To illustrate the level of exchange within EC countries, the production, exportation, importation and national markets of refrigerators and clothes washers are presented for the four biggest EC countries in Table 3. The difference between production and purchases is accounted for by imports and exports. For example, Italy exported far more refrigerators than it imported and the reverse is true for Great-Britain. In the future, as trade barriers are relaxed, appliances should move even more freely across borders.

The Programs of the European Community

The Commission (or government) of the European Community has implemented several goals to stabilize CO_2 emissions in general and reduce the electrical consumption of European households. Two actions have been developed for appliances: energy consumption labelling and minimum efficiency standards. For refrigerators and freezers, labelling is planned for early 1993. Minimum efficiency standards will follow depending on the results of analyses currently in progress. The U.S. DOE minimum efficiency standards can not be transferred to Europe for three main reasons: first there is a great deal of inconsistency between the U.S. DOE and the ISO (International Standard Organization) test procedure used in Europe. For example, for measuring the energy consumption of fridges and freezers, the ambiant temperature of the test chamber is 32°C (90°F) in the US DOE test procedure and 25°C (77°F) in the ISO test. Secondly the appliances themselves are not designed to perform the same service. For example, an American freezer is designed to keep frozen food at -15°C (5°F). A European freezer keeps frozen food at -18°C (-0,4°F). Finally, there are technological differences between the appliances across the Atlantic ocean. The best

Table 3. National Production, Exportation, Importation and National Market of Refrigerators and Clothes Washers in France, Germany, Great-Britain and Italy (in thousands of units, 1990) (Source 1)

Refrigerators	Production (P)	Exportation (E)	Importation (I)	National Market (M)	Indep. Ratio (E-I)/M
France	451			1988	
Germany	2822	1375	1041	2488	13%
Great-Britain	1223	113	910	2020	-39%
Italy	4695	3230	255	1720	173%
Clothes-Washers					
France	1460	397	850	1913	-24%
Germany	2494	1242	630	1882	33%
Great-Britain	1234	71	790	1953	-37%
Italy	4630	3145	237	1722	169%

illustration of this is the clothes washer: a vertical axis tub with an agitator in the US and a rotating drum on an horizontal axis in Europe.

However, European experts benefit greatly from the US experiences in this area and found it possible to adopt the methodology developed by the U.S. DOE[3].

Results of the ADEME Study

Overview

In 1991, The European Community commissioned ADEME to investigate the potential impact of appliance standards on European appliances. In the latter part of 1991, the ADEME published the results of their study for the Commission of the European Community[1]. It was found that a cumulative 390 TWh could be saved over the time period from 1995-2010. These energy savings would be accomplished through minimum energy efficiency standards for refrigerators, freezers, clothes-washers, clothes-dryers and dishwashers. The ADEME study estimated that 306 TWh (78% of total) of electricity savings would come from refrigerator and freezer standards commencing in 1995. Since the vast majority of predicted savings from energy efficiency standards would come from refrigerators and freezers, the rest of the ADEME report focuses on those two product types. The ADEME study has to be taken as an explorative work. The minimum efficiency standards are proposed despite the lack of a uniform test procedure for some appliances and are based on scattered available data. Nonetheless, the general results are encouraging enough to motivate the Commission of EC to further investigate minimum efficiency standards.

Absence Uniform Testing Procedures

Only refrigerators and freezers have a uniform performance test procedure throughout the European Community, the EN 153 norm that follows the recommendations of the ISO[4]. Yet there is still no test procedure for no-frost, forced convection refrigerators and freezers in the EC. This technology comes from the USA and is barely known in Europe. For all other appliances (clothes washers, clothes dryers, dishwashers...) each EC country follows its own test procedure, loosely based on the same international test recommendations such as ISO. Despite the progressive integration of the European market, there is still a lack of agreement in the European norms, particularly the procedures for testing the energy consumption of household appliances. This absence of uniform standards slows down efforts to promote the efficient use of electricity in European appliances. This is particulary true for clothes washers, clothes dryers and dishwashers, for which manufacturer and consumer organizations do not want energy performance and quality performance (such as washing performance) to be treated separately.

Methodology for Defining Efficiency Standards

Appliances have to be analyzed by categories in order to assure that direct comparisons of energy performances are possible. A category includes all appliances that present the same service to the user. There are two methods of defining minimum energy efficiency standards for households appliances. One is a statistical approach and the second is an engineering approach.

A statistical approach involves collecting efficiency data for the product of interest and setting a standard level so as to eliminate some chosen percentage of the models being offered at the time of the analysis. This approach was used to develop the minimum efficiency standards for clothes-washers, clothes-dryers and dishwashers.

The engineering approach consists for the analysis of the manufacturing costs for improving the efficiency of a baseline model. A certain number of technological options are identified to increase the energy efficiency of the appliance. Each design option is analyzed separately to obtain energy consumption and incremental cost to manufacture the more efficient product. Next, design options are combined to achieve higher energy savings. The interesting combinations of design options are the ones that are both technically feasible and economically justified (i.e. short payback time and low life cycle cost). An engineering approach was performed for refrigerators and freezers.

The ADEME study defined several categories of refrigerators and freezers based on the minimum attainable temperature of the freezer compartment. A star system, described in Table 4, is used to designate this freezer temperature and, by extension, the categories. Only one-star and four-star fridge/freezer categories were examined in the engineering analysis because of their large market shares. The energy consumption of a refrigerator or freezer varies with the adjusted volume of the unit. The adjusted volume accounts for the fact that there is a greater temperature difference between ambient (25°C) and freezer temperatures than between ambient and fresh food compartment temperatures. It is equal to the sum of fresh food volume plus the product of the freezer volume and the AV coefficient (see Table 4).

Table 4. Four Categories of Refrigerator-Freezers and Definition of the Adjusted Volume (Source 1)

Adjusted Volume = Volume of fresh food comp. + Ω * Volume of freezer comp.

$$\Omega = \frac{(T^\circ \text{ ambiant} - T^\circ \text{ freezer comp.})}{(T^\circ \text{ ambiant} - T^\circ \text{ fresh food comp.})}$$

Categories	T° Freezer Compartment	Ω
0 et 1 star (*)	-6°C (21,2°F)	1,55
2 stars (**)	-12°C (10,4°F)	1,85
3 stars (***)	-18°C (-0,4°F)	2,15
4 stars (****)	-18°C (-0,4°F)	2,15

Results of the Analysis

Figure 1 shows 4-star refrigerator-freezer data for models sold in 1990, collected from France, the Netherlands, and Germany. The horizontal axis represents the adjusted volume, the vertical axis the annual energy consumption measured according to the EN153 test procedure. Each point represents an individual unit. Minimum efficiency standards for refrigerators and freezers are defined as a line, that is an equation linking adjusted volume and maximum allowable energy consumption. Units above the line have to be upgraded or be eliminated from the market. The baseline is the average of the 1990 market.

On this baseline, a four star refrigerator-freezer, using 516 kWh/yr, with 325 liters of adjusted volume was analyzed using five design options. This analysis was performed using data from French manufacturers. The results of this analysis are shown in Table 5. One option, aerogel insulation, was eliminated from the table because its payback period (19.2 yrs) was considered to be too long. The design options are as follows: the first is a semi-direct intake compressor, the second is an increase in door insulation thickness by 15mm, the third is an increase in wall insulation thickness by 15mm and 30mm in the refrigerator and freezer compartments, respectively, and the fourth is a reduction in door leakage. It was assumed that CFC replacement will not affect the efficiency of the refrigeration system; it will, however, increase the insulation thermal conductivity by 5%.

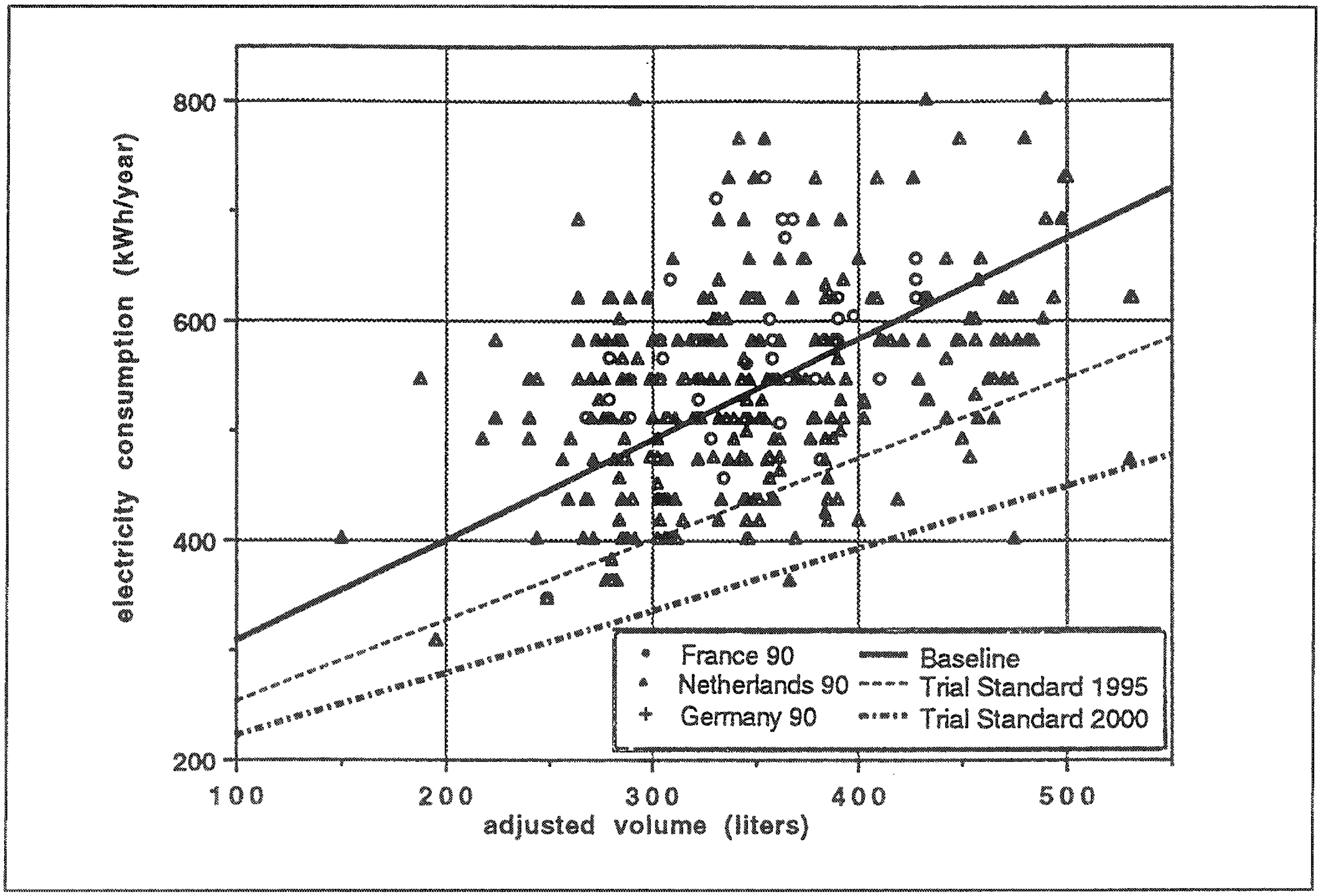

Figure 1. Energy Use Versus AV for 4 Refrigerator-Freezers on the European Market[1] Baseline Equation: Emax = 216 + 0.915*AV (AV in liters, Emax in kWh/year) Trial Standard Level 1995: Emax = 180 + 0.733*AV; Trial Standard Level 2000: Emax = 164 + 0.569*AV*

Details of these design options can be found in the ADEME report. The cost and payback periods are both cumulative, relative to the baseline model. For payback period calculations, the electricity cost is 0.0928 ECU/kWh, where ECU are European Community Units (1 ECU = 1,07 $US). The life-cycle cost minimum occurs at level 3. Level 3 was choosen as the trial standard line for year 2000. An intermediate trial standard line was designed for 1995, corresponding to the level of options 2 in table 5. The trial efficiency line for 1995 was estimated to save an average of 19% in energy consumption compared to the baseline. The second level (trial standard line 2000) would save an additional 14% with respect to the baseline.

Energy Savings

Table 6 summarizes the trial efficiency standards for each appliance studied. An end-use energy consumption model was used to project energy savings from efficiency standards. If the standards defined in Table 6 above were applied to the EC as a whole, total energy use of the stocks of the five appliances analyzed would stabilize at the 1990 level by the year 2000 and then drop (see Figure 2). In 1990, all the refrigerators, freezers, clothes-washers, clothes-dryers and dishwashers in the EC consumed about 152 TWh. This accounts for 36% of residential electricity consumption and 9% of total EC

*Table 5. Results of Cost-Effectiveness Analysis for Refrigerator-Freezers (**** - 1 compressor, adjusted volume = 325 liters) (Source 1)*

Combination of Design Options	Elec. Cons. kWh/yr	Energy Savings ΔkWh/yr	Savings *(a) %	Cumul Paybck Years	Life-Cycle Cost *(c) ECU 91
0 Baseline	516	*(a)	*(a)	*(b)	936
1 = 0 + compressor direct aspiration	449	67	13,0%	1,61	893
2 = 1 + increase door thickness (+15mm)	420	96	18,6%	1,76	875
3 = 2 + increase wall thickness (+15mm)	351	165	32,0%	3,45	858
4 = 3 + improve door leakage	333	183	35,5%	4,62	869

*(a) Savings compared to baseline.
*(b) For pay back calculations, electricity cost of 0,0928 ECU/kWh.
*(c) Discount rate 9%, average life-time = 13 years.

Table 6. Trial Efficiency Standards for European Appliances (Source 1)

	Average Performance in 1990	Trial Efficiency Standard 1995 % appliance savings compared to 1990 level	Trial Efficiency Standard 2000 % appliance savings compared to 1990 level
Refrigerator (****)	0,915*AV+216	19%	17%
Freezer (Chest)	0,48*AV+217	33%	37%
Clothes-Washers	0,47 kWh/kg (90°C wash)	15%	-
Clothes-Dryers	0,90 kWh/kg (cotton)	5%	-
Dishwashers	1,90 kWh/wash	16%	-

electricity consumption. Over a 15 year period, these efficiency standards would save 390 TWh; an amount equivalent to the 1991 electricity consumption of France. Figure 3 presents projections of the evolution and distribution of energy consumption of the stock of appliances with and without the proposed efficiency standards.

A Favorable Climate for Progress

Despite the lack of uniform testing procedures and adequate data on the stock of European appliances, the ADEME study affirms the availability of substantial electricity savings and provides support for the European Community in its efforts to limit CO_2 emissions and reduce the electricity consumption of its residential sector. Furthermore, the methodology proposed by ADEME, specifically the engineering approach based on US

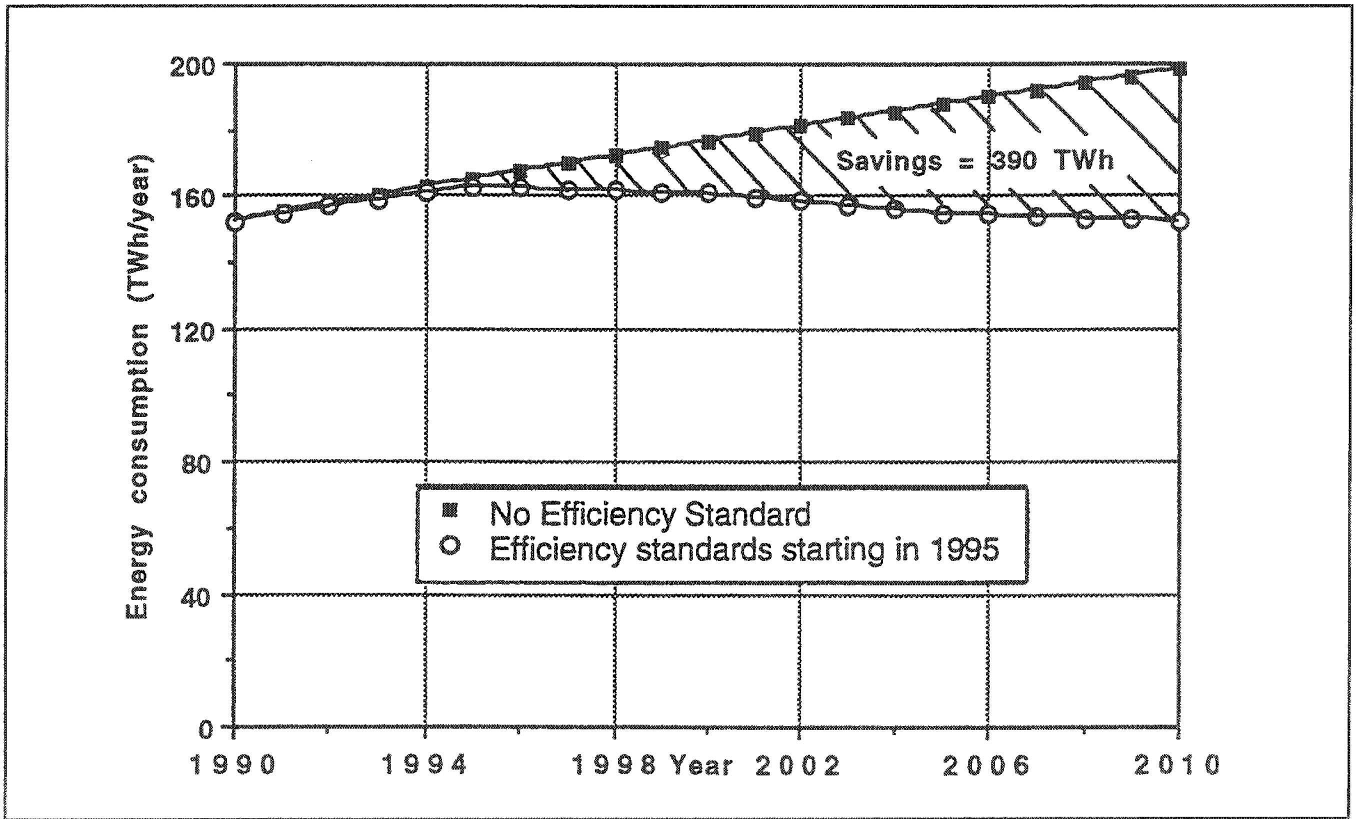

Figure 2. Evolution of Total Consumption of Appliance Stocks in EC[1]

experience with minimum efficiency standards, satisfies most parties, from the national and EC administrations to the appliance manufacturers.

There is today a favorable climate for setting both an energy labelling scheme and minimum effiency standards for appliances in Europe, both inside and outside EC countries. During 1991, the Nordic Countries (Sweden, Norway, Finland and Denmark) established a Commission of experts to prepare the ground for appliance energy labelling and minimum efficiency standards[5,6,7]. Elsewhere, Switzerland has planned an ambitious energy program called Energy 2000, featuring minimum efficiency targets for household appliances.

In December 1991, the Netherlands notified the Commission of the EC their desire to make mandatory minimum efficiency standards for refrigerators and freezers on Dutch territory. The proposed standards are based on a statistical analysis of the Dutch refrigerator and freezer market[8]. Because the Netherlands are members in EC, the Dutch notification applies pressure on the Commission of the EC to accelerate the process of setting uniform appliances efficiency standards throughout EC.

Towards the end of 1991, the Danish Energy Agency (DEA), the Netherlands Agency for Energy and Environment (NOVEM), and the French Agency ADEME decided to consolidate their national efforts on appliance energy efficiency. The three national agencies created a consortium, the Group for Efficient Appliances (GEA). The goal of GEA is to carry out technical and economic analyses on efficiency standards for European appliances throughout EC. Early in 1992, GEA presented a proposal to the Commission of the EC to perform all the necessary analysis for establishing minimum efficiency standards for refrigerators and freezers[9]. The main steps of this program are:

1. data collection;

2. final definition of product categories;

3. definition of a short term minimum efficiency standards based on a statistical analysis of today's market;

4. a complete cost-effectiveness (engineering) analysis;

5. definition of longer term efficiency standards;

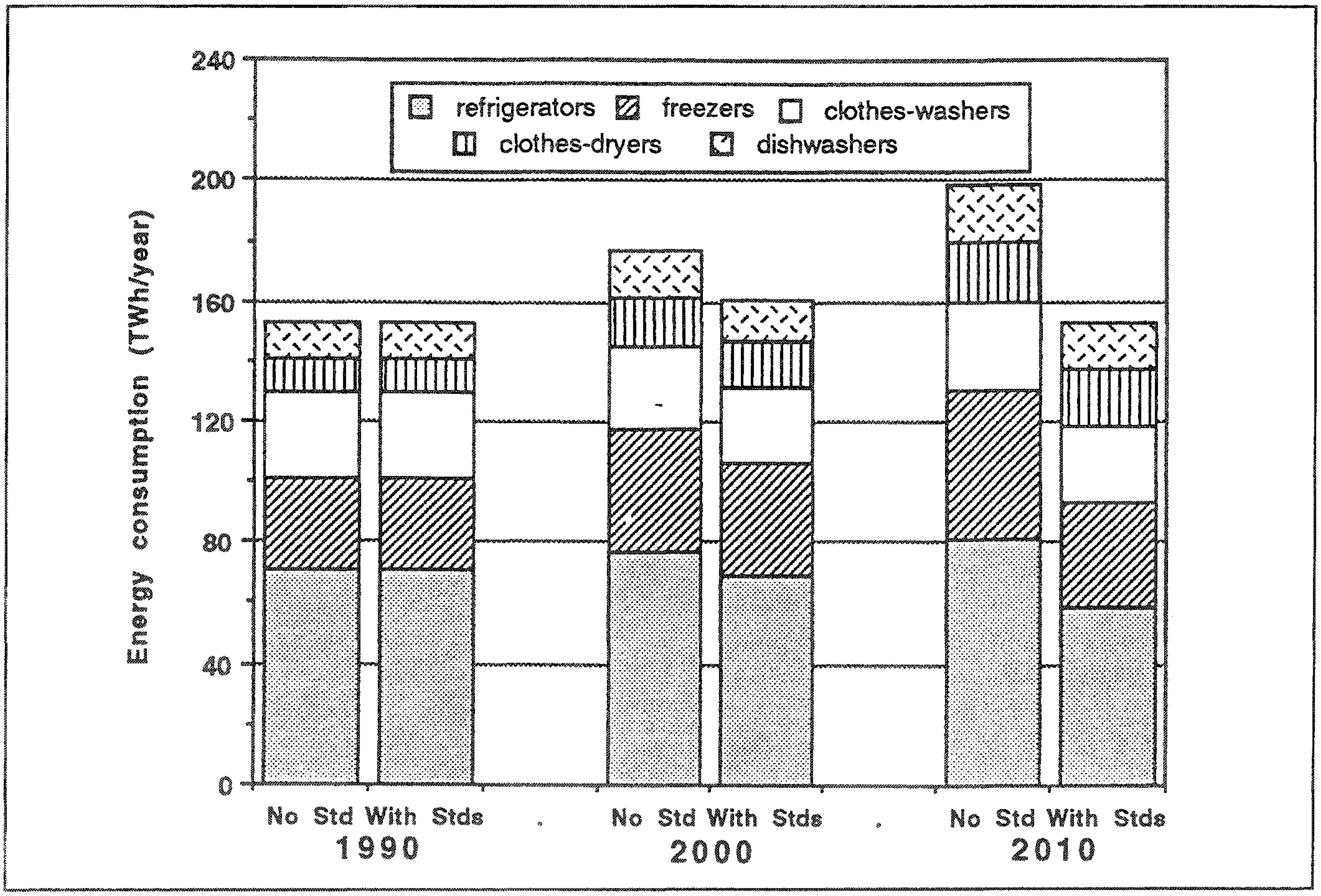

Figure 3. Projected Distribution of Electricity Consumption of the Appliance Stocks in EC[1]

6. evaluatation of impact of the proposed standards on the appliance industry, the EC total electricity consumption and the EC environment.

GEA has already established contacts with European refrigerator and freezer manufacturers through a questionnaire[10,11] and several meetings and workshops[12,13]. GEA is eager to expand its contacts with the European industry, as the cooperation of manufacturers in performing the analysis is essential to the success of the project. GEA plans to present the Commission of the European Community a final report detailing the analysis as well as proposed efficiency standards for European household refrigerators and freezers at the end of 1992.

Conclusion

Although much more work remains to be done, the establishement of uniform efficiency standards for household appliances in the European Community now seems to be likely. Only two or three years ago, few who were knowledgeable about the process would have expected such rapid developments. The ADEME study shows clearly the benefits of efficiency standards. Because efficiency standards appear as the most promising measure to diminish residential electricity use, many other European countries outside EC (Scandinavia, Switzerland) are seriously considering the adoption of the future EC regulations. Former Eastern bloc nations that today face critical energy problems could certainly adopt the coming efficiency standards, as these countries use similar types of refrigerators and freezers and the same test procedure (EN 153). Thus, the results of GEA's refrigerator and freezer analysis are likely to have a much wider geographical impact than initially thought, and a much larger benefit for the global environment as well.

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