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ENERGY EFFICIENCY STANDARDS FOR TRADED PRODUCTS

Annex I Expert Group on the United Nations Framework Convention on Climate Change
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FOREWORD

This Working Paper is one of a series of eighteen studies carried out under an Annex I Expert Group project on “Policies and Measures for Possible Common Action”. The studies were written by the OECD, together with the International Energy Agency, for the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The goal of the project was to assess a range of cost-effective greenhouse gas mitigation policies and measures for countries and Parties listed in Annex I to the UNFCCC. The working papers served as analytical input to negotiations under the UNFCCC. The working papers may also be useful to national policy makers. The measures analysed do not necessarily represent policy preferences of Annex I Parties.

The project benefited greatly from substantial input from delegates. Three successive chairmen of the Annex I Expert Group provided outstanding leadership for the project: Doug Russell (Canada); Ross Glasgow (Canada); and Ian Pickard (United Kingdom). The work was supervised by Jan Corfee Morlot (OECD). Fiona Mullins (OECD) drafted the initial framework which was used to structure the eighteen working papers.

The Annex I Parties or countries referred to in this document refer to those listed in Annex I to the UNFCCC: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Czechoslovakia (now Czech Republic and Slovakia), Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom and United States. Where this document refers to "countries" or "governments" it is also intended to include "regional economic organisations," if appropriate.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

EXECUTIVE SUMMARY

Full description of measure

This report examines energy efficiency performance standards for Annex I countries on refrigerators/freezers and office equipment, which were chosen as representative examples for analysis.

Context

Energy efficiency standards and labelling schemes for appliances and equipment are playing an increasingly important role in Annex I Parties' strategies to meet their energy and environmental policy goals.

Refrigeration is typically the largest domestic sector electricity end-use (about 20 per cent of domestic electricity consumption) and offers large potential for further improvements in energy efficiency. At present, there is a clear distinction between the type of refrigerators available in different regional markets. Most companies have shown little interest in selling the same models on different regional markets. However, there is a tendency toward greater inter-regional component sourcing and transfer of technology, and at least two refrigerator manufacturers have already developed into trans-global concerns.

Office equipment consumes nearly 80 TWh/year of electricity in OECD countries. The largest energy end-uses in the commercial sector are space conditioning and lighting, but office equipment is the fastest-growing electrical load in the commercial sector and may already represent 5 to 20 per cent of commercial electricity consumption. Unlike refrigerators, the product characteristics and energy efficiency of office equipment are quite similar in all countries.

In both the residential and commercial sectors, the potential for CO_2 reductions from saving a unit of electricity varies widely among different Annex I countries because of variations in the amount of carbon based fuel, such as coal, oil, or natural gas, that is used to produce electricity.

Policy objectives

Common action on product standards could contribute to a range of policy objectives, including increasing the energy efficiency of products, reducing the associated greenhouse gases (assuming fossil-fuels are used to produce electricity to operate the products), facilitating trade between countries with the same or similar levels of standards, and increasing consumers' disposable income by reducing energy costs.

Approach and methodology

Regional scenarios were developed using spreadsheet models to assess the greenhouse gas reduction effects of implementing the same energy efficiency standards for refrigerator/freezers and office equipment in different Annex I regions. The results are derived from analysts' best judgement on the value of key parameters, which in some cases greatly affects the results, notably, the autonomous energy efficiency assumption. These scenarios assume for the sake of analysis that mandatory minimum energy performance standards (MEPS) are implemented by all Annex I countries. Other sections of the report discuss a broader range of implementation options, based on information available from published and unpublished literature.

Rationale for common action

The main rationales for common action on product standards are: a potential reduction in trade distortions between countries adopting the standards; wider availability of cheaper and more efficient products through larger product runs; and possibly, bigger reductions in greenhouse gas emissions through some form of common action that would otherwise be possible if countries acted alone.

Possible participants and vehicles for action:

The implementation of product standards is most likely to occur at the national level regardless of the form of common action that might be agreed at the Annex I level. Participants for action on product standards at the national level could include governments, manufacturers, and consumer groups. Possible vehicles for action are: legislatures or parliaments, government departments, national standardisation bodies, industry associations, or individual industry representatives.

Possible participants at the regional level are: European Union (EU) countries, North America Free Trade Agreement (NAFTA) countries, Asia Pacific Economic Co-operation (APEC) countries, multinational industries; and industry associations. The main non-governmental international standardisation bodies, the International Standardisation Organisation (ISO) and the International Electrotechical Commission (IEC) would be important participants and vehicles for action. Other possible vehicles for action could be the International Energy Agency (for example, through implementing agreements), the Organisation for Economic Co-operation and Development (for co-ordination and analysis), and the European Commission.

Greenhouse gas emissions reduction potential

For refrigerators/freezers, the base case scenario results show that for most Annex I regions, there would be some base case improvements in energy efficiency, through new stock replacing the old and through efficiency improvements to the products. However, for North America and Australia/New Zealand, population growth begins to outweigh efficiency improvements towards the end of the scenario period, and for eastern Europe, more people are expected to buy more energy-intensive refrigerators as income rises[1]. Assumptions about future composition of the appliance stock are an uncertainty in the analysis. Most of the scenarios assume that consumers will not buy larger refrigerators or more energy-intensive,

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[1] The preliminary results presented in Figure 1 for Australia and New Zealand are indicative only and have not been fully reviewed owing to delays in receiving the case study for this region.

frost-free models with the money they save from more efficient appliances. The analyses for central and eastern Europe assume a gradual change in the type of appliance demanded is assumed as income rises.

The “introductory standard” scenario (equivalent to EU proposed standards), has a small effect on CO_2 emissions overall (4.5 per cent reduction from base case in 2020), but no effect in North America where standards are already more stringent than this level, and negligible effect in Japan. The “more rigorous” scenario (equivalent to the proposed US NAECA 1998 standards) has a large effect in all regions (25 per cent reduction from base case in 2020). The results show different effects from the same standards in different regions, because of differences in product attributes that influence energy use and product lifetimes, different population growth forecasts, differences in the mix of fuels used to produce electricity, and different starting levels of product energy efficiency. These results are indicative only, as the scenario analysis can in many cases only guess at future developments in key variables such as energy prices and assumes no fundamental technological changes take place. The scenario analysis cannot provide insights on the extent to which harmonised action by Annex I countries might achieve greater (or lesser) benefits than national action.

Figure 1. regional emissions from refrigerator freezers

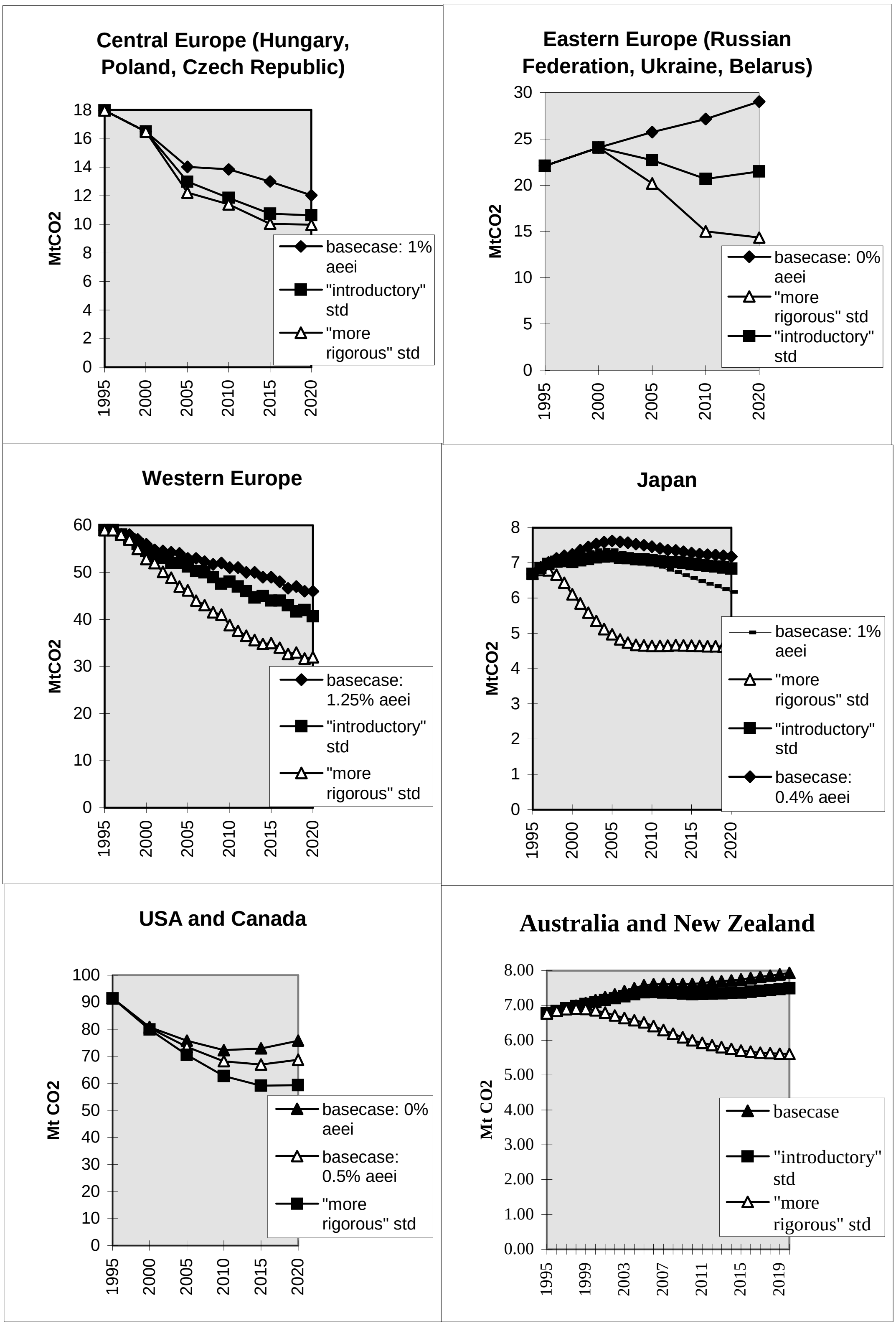
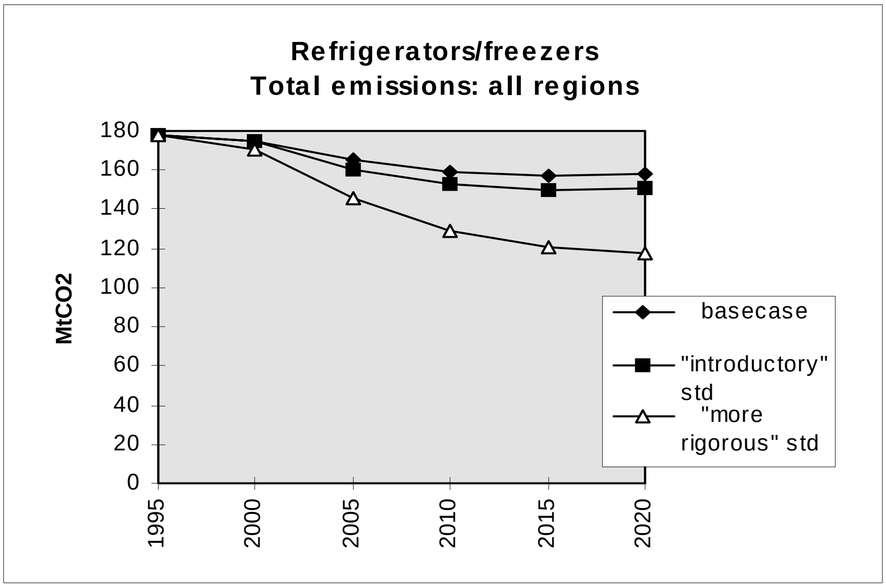
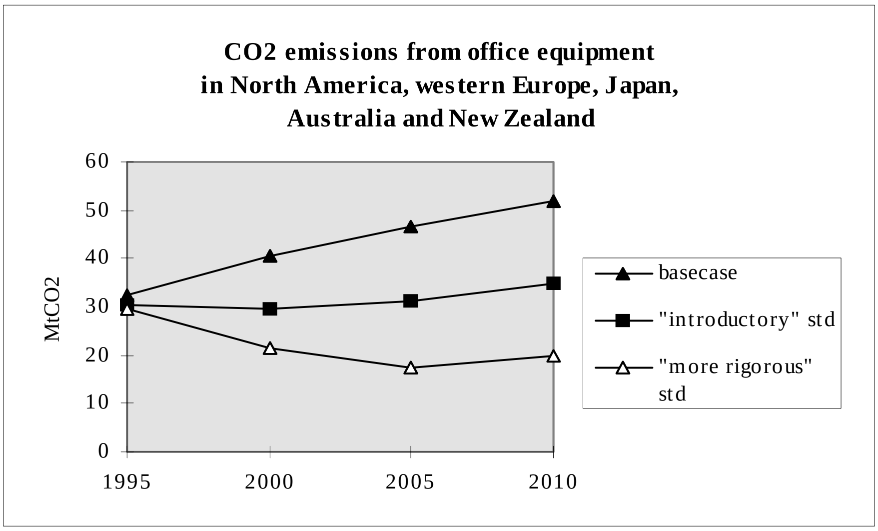


Figure 2. Combined refrigerator/freezer emissions scenarios



For office equipment, CO_2 emissions in the base case are expected to increase over the period to 2020 as equipment densities increase. The "introductory standard" scenario for office equipment (equivalent to the US Energy Star level) has a significant effect on CO_2 emissions when applied in the 3 regions included in the analysis (USA and Canada, western Europe, and Japan). Increasing efficiency levels to that of the "more rigorous" level (equivalent to the Swiss target level) gives a correspondingly larger reduction in CO_2 emissions. An uncertainty in the analysis is that there was little information on the extent to which office equipment in Japan and Europe already meets the Energy Star requirements, and the extent to which energy saving features are enabled while the equipment is in use.

Figure 3. total CO_2 emissions from office equipment



Saving energy in office equipment will also affect space conditioning. The issue is a complex one, because these effects vary regionally and by building type. This study has not included extra savings that may occur from cooling energy reductions.

Economic effects (costs and benefits)

For refrigerators and freezers, the cost of conserved energy (CCE) for refrigerators/freezers was calculated for the USA, Japan, western Europe and the Czech Republic. The method used was to estimate the increase in product price under a standard and divide this by the physical amount of energy saved, discounted over the lifetime of the products at two discount rates - 5 per cent and 10 per cent[2]. The CCE is well below the electricity price in the USA, Japan, and western Europe for both the “introductory” and “more rigorous” levels of energy efficiency, which suggests investment in more efficient refrigerators/freezers is very likely to be cost-effective for the consumer in these countries. However, in the Czech Republic, a country that is making the transition to a market economy, even the “introductory” level is not expected to be cost-effective for residential consumers at today’s electricity prices, although they may be cost-effective when compared with the cost of producing the electricity (no data were available on the cost of electricity supply).

It is difficult to predict the impact that common action to adopt product standards would have on prices faced by consumers. The figures used by the regional analysts to calculate the cost of conserved energy were generally derived from manufacturers’ estimates of the increased cost of producing more efficient products. Retrospective analysis of the US 1990 and 1993 refrigerator standards has shown that quality-adjusted prices continued to decline over time, consistent with historical trends after the implementation of the standards, which suggests they did not have a discernible effect on prices. Increases in first cost are not necessarily fully reflected in increased prices, as manufacturers may choose to reduce profit margins so that the price increase is lower than the cost increase. However, if the cost is fully passed on to retailers, the retail outlets may put a simple percentage mark-up on the products so that the price increase could be higher than the cost increase.

The data needed to assess the cost of conserved energy for office equipment standards were not available, but experts consulted for this study considered that for office equipment, the “introductory” standards are likely to be cost effective, as significant cost increases are not considered likely. While there were no data on increased cost to manufacturers for the “more rigorous” standards, the more advanced power-management required would have to cost no more than a few dollars per unit to be cost-effective, given the short lifetimes of office equipment. The equipment for which the economics are likely to be most favourable are copiers, which also have a longer life.

Political feasibility

There are wide differences in the national circumstances of Annex I countries, such as different energy prices (which affect the cost-effectiveness of standards), different fuel mix (which affects the impact of standards on CO_2 emissions), and different institutional and legal structures (which affect the policy tools that will be most feasible). Efficiency standards are often implemented in the context of other national (or regional) actions such as consumer information, labelling, demand side management programmes,

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2 The formula used is: $CCE = \delta C/\delta E[(1/i)[1-(1+i)-t]$ where δC is the increased first cost of the appliance to the consumer, δE is the physical energy saved (kWh) compared to base case, $[1-(1+i)-t]$ is the formula for discounting the physical energy saved, i is the discount rate, and t is the lifetime of the product.

financial incentives to consumers, and incentives to industry, which help promote innovation. Implementation options vary from legislation of mandatory regulations drawn up under broad enabling legislation, to government procurement policies, voluntary approaches with industry, or energy efficiency labels.

National standards, standards among a small group of countries, or even state or provincial level standards, can have an important catalytic effect on the likelihood and political acceptability of standards at a higher level of commonality. Unilateral action to implement standards, although it differentiates the market and can create a barrier to trade, can spur multi-lateral agreements. The Energy Star labelling scheme for computers in the United States has influenced the efficiency of computers sold world-wide because the United States is such a large market. Alternatively, regional international agreements can also stimulate national action; a multi-lateral commitment can facilitate politically difficult national reforms. Standards which are effectively non binding “technical specifications” can also be drawn up by an international body such as the ISO or the IEC, and then adopted at national level.

Other policy goals

Depending on the fuel mix, energy efficiency contributes to reduced, and therefore often cleaner, consumption of energy for producing electricity. Efficiency standards also contribute to improvement of trade flows, economic growth, and reduced dependence on imported electricity. Energy efficiency product standards could have small effects on employment, trade, and foreign investment.

Barriers to successful implementation and options for addressing them

Product standards are static instruments that can be viewed as preventing more dynamic and creative solutions from being found. This potential barrier to implementation can be reduced if performance-based standards are used, rather than requirements for specific technology.

Monitoring and enforcement costs can be significant, given the large number of products that are regulated, the rate of technological innovation, and the complex technical nature of the standards. For central and eastern Europe, lack of institutional and legal capacity is a barrier to implementation, monitoring, and enforcement of standards. Difficulties in integrating product standards into existing environmental and energy legislation may be a barrier in some countries.

Product standards could be viewed as forming a barrier to trade to those not adopting the standards.

The time allowed between announcement of the standards and their implementation can greatly affect the acceptability of standards to industry. If too short an interval is allowed, than opposition will be strong from manufacturers who are unable to sell their lower standard stocks and adapt their product lines before the standard is implemented.

Time period

Product standards on fairly long-lived products would have some effect on emissions in the short term, but much greater effect in the longer term. Office equipment standards would make a significant impact sooner than standards on longer life products, such as refrigerators. The impact of refrigerator/freezer standards in Japan (where the refrigerator lifetimes average 8.5 years) would be faster than in the United States (where refrigerator lifetimes average 19 years).

European Union experience suggests that the time needed for researching, planning, and negotiating common standards at Annex I level could be about five years. Gradually increasing standards according to a schedule announced well in advance would minimise costs to manufacturers. Common action on product standards could occur in a sequence of steps that could be taken gradually by all Annex I countries. It is also possible that different options could be agreed to by different countries at different times. Some countries with economies in transition, for example, may not be in a position to commit to adopt common standards within the same time-frame as other Annex I countries.

Impact on other countries

Energy efficiency performance standards could have impacts on energy efficiency, greenhouse gas emissions, foreign investment, and trade in non-Annex I countries and non-participating Annex I countries.

Common action could lower costs for manufacturers who sell into Annex I markets by reducing the measurement and certification costs that they incur for each different test protocol or standard, but manufacturers who were not able to increase the efficiency of their products to meet higher standards would lose the ability to compete in the markets of countries who are party to the agreement.

The negative implications of Annex I refrigerator standards for non-Annex I countries are likely to be small in the near term because refrigerators/freezer characteristics differ from region to region, and there is consequently very little trade in refrigerator models between regions. The implications for non-Annex I countries of common office equipment standards are also likely to be small, since the majority of producers at present are in Annex I countries. The United States “Energy Star label programme has already become the *de facto* international energy efficiency standard for office equipment world-wide.

The adoption of minimum efficiency standards at multi-national level should stimulate the diffusion of more efficient technology to other countries, which would raise energy efficiency in these countries, lower their energy consumption costs, and reduce emissions associated with energy production.

Conclusion

Given the variety of national institutional and administrative structures, existing policies, and different preferences or requirements for legislation, approaches to implementation are likely to vary greatly among Annex I countries. It is also possible that different options could be agreed to by different countries at different times. Some levels make it unlikely that the same policy instruments could be used by all countries. Economies in transition, for example, may not be in a position to commit to adopt common standards within the same time frame as other Annex I countries. To achieve benefits from common action in terms of reduced greenhouse gas emissions, it is important to achieve better energy efficiency levels. To achieve trade benefits from common action, countries would need to adopt the same minimum energy efficiency levels. Possible options for common action are:

Option 1: Cost effective energy efficiency level

An option for common action is for Parties to agree to target cost-effective energy efficiency levels in specific products. Different levels of energy efficiency will be cost-effective for different countries. Although trade benefits would derive from common standards, from the point of view of cost-effectiveness, there is no reason that standards should be the same across countries. Analysis by national experts would be needed to assess the most cost-effective levels of energy efficiency, and agreement to implement these levels.

Option 2: Harmonisation of test protocols and measurement techniques

Harmonisation of measurement procedures and testing protocols would provide a foundation for standardisation of product requirements in the future. Manufacturers with a presence in more than one major market, and those wishing to expand to other markets, would benefit from harmonised test protocols or standards as the current multiplicity of tests and standards required by national programmes is very costly for manufacturers wishing to sell in more than one market.

Option 3: Minimum energy performance levels

Common minimum levels of energy efficiency would improve energy efficiency in some countries significantly, while, in principle, making no difference to energy efficiency in countries that have already exceeded the minimum level. However, some CO_2 emissions reductions would result and there would be additional trade benefits if countries adopted the same energy efficiency standards. Products that are traded widely are likely to be good candidates for agreement on common energy efficiency levels that could be achieved through a variety of policy instruments. Such agreements will facilitate trade in the products among countries that are party to the agreement.

- **Refrigerators and freezers** are traded predominantly within regions, because consumers in different regions like very different product characteristics in their refrigerator/freezer appliances. For this reason, it seems likely that while trade benefits would occur from regional common action, Annex I-wide common action would add little additional benefit and make the negotiations on test protocols and energy efficiency levels unnecessarily complex.

- **Office equipment** is traded more widely than refrigerators/freezers and is much more uniform in type across Annex I (and other) countries, so it would be technically more realistic to realise Annex I-wide common energy efficiency levels. Rapid improvements in technology for office equipment mean standards would need to be continually updated and strengthened to remain effective.

2. INTRODUCTION

Policy Objective

The aim of this study is to assess energy efficiency performance standards on products that are traded, as a possible measure for common action. Common action on product standards could contribute to a range of policy objectives, including increasing the energy efficiency of products, reducing the associated greenhouse gases (assuming fossil-fuels are used to produce electricity to operate the products), facilitating trade between countries with similar or same levels of standard, and increasing consumers' disposable income by reducing energy costs.

Approach And Methodology

Scope

Product standards were chosen by the Annex I Expert Group on the UNFCCC as one of a number of measures to be studied under the study of Policies and Measures for Common Action. The study examines energy efficiency standards on a few traded products which were chosen as representative examples:

- refrigerators, combination refrigerator/freezers, and freezers (referred to collectively as "refrigerators/freezers");
- office equipment (personal computers, monitors, photocopiers, printers, fax machines);
- electric motors; air conditioners and home heating appliances (information provided in Appendix A).

The analytical work in this study has been limited to refrigerators/freezers and office equipment. Refrigerators/freezers were chosen because this product is the subject of considerable activity by Annex I countries already, it is a large consumer of energy, and refrigeration technology is similar in all countries, although the size and characteristics of refrigerator products vary markedly among different regions. Office equipment is a rapidly growing category of energy end-use and is one of the most internationally traded products. The study develops comparable emissions scenarios to assess the effects of specific energy efficiency standards on refrigerators/freezers and office equipment in each Annex I region.

To the extent possible, electric motors, air conditioners and home heating appliances have been considered (in Appendix 1) from the information that was available. Many other products could be included in this type of analysis, but would have required more time and resources than were available for this study. Products that could be assessed as possible candidates for energy efficiency standards and for common action in future work are: lighting; televisions and other home entertainment appliances; conventional or micro-wave ovens; and washing machines, dryers, and dishwashers (although energy use in these appliances is greatly influenced by how consumers choose to operate them).

The study aims to cover all Annex I countries. However, four Annex I countries have not been included in the analytical sections of the report: Slovakia, Bulgaria, Romania, and Iceland. These countries would not change the overall results of the study significantly.

Methodology

Consultants in six regional sub-groups of Annex I countries were asked to develop comparable scenarios of the effects of energy efficiency standards on refrigerators/freezers and office equipment. A synthesis of this work provides the analytical information on costs and effects of standards presented in Sections 5 of the report. The full consultants' reports are listed in the Technical Annex at the back of the report and are available from the OECD upon request.

For refrigerators and freezers, six regional sub-groups have been analysed: western Europe; central Europe (Czech Republic, Hungary, Poland); countries from the Commonwealth of Independent States (CIS); Japan; United States and Canada; and Australia/New Zealand. Spreadsheet models were developed by analysts for each region to assess the greenhouse gas reduction potential and costs of minimum energy efficiency standards. The analysis assumes that the standards are announced in 1996 to commence in the year 2000. Energy efficiency standards were assumed to be set at the same level in each region, but from different starting points as appropriate in each regional context.

The refrigerator/freezer scenarios were taken to 2020 to provide a picture of the energy savings possible for this period under a given set of assumptions. The analysts were given a common methodology to assess the energy consumption of typical refrigerators/freezers in their region under EU and US standards. The regional scenarios for refrigerators/freezers were provided by:

- Western Europe Paul Waide, PW Consulting.
- Central Europe Vladimir Prochazka, Zora Voraekova, Milos Tichy, SEVEn, Czech Republic.
- CIS countries Igor Bashmakov and Svetlana Sorokina, CENEf, Russian Federation
- Japan Hidetoshi Nakagami, Yoshiyuki Arakida, Barbara Litt Jyukankyo Research Institute, Japan.
- USA and Canada Isaac Turiel, USA.
- Australia and New Zealand Lloyd Harrington.

For office equipment, which has much higher homogeneity of product type between regions, one model was used to assess the greenhouse gas reduction and cost of energy efficiency standards in four regional sub-groups: western Europe, North America, Japan, and Australia/New Zealand. Jim McMahon (USA) used the Lawrence Berkeley National Laboratory (LBNL) spreadsheet model for these scenarios. Region specific data for the analysis were provided by the Jyukankyo Research Institute (for Japan), Jacques Roturier, University of Bordeaux (for western Europe), and George Wilkenfeld (Australia/New Zealand). Central and eastern European experts advise that the data required to assess the effects of standards on office equipment are not readily available in their countries, so these regions have not been included in the office equipment analysis. The office equipment scenarios have only been taken to the year 2010, because expected technology changes such as fax/computer combinations are likely to make analysis based on today's products inappropriate within the next 15 years.

Due to information and resource constraints, it was not possible to fully assess the costs and effects of standards on electric motors, home heating appliances (electric space heaters and water heaters), and air conditioners. A literature review and advice from experts were used to provide information on existing energy efficiency standards for these products, current energy use, potential energy savings and associated greenhouse gases emission reductions, and the possible cost of energy efficiency standards. A review of information on the energy efficiency of European home heating appliances, air conditioners and electric motors was provided by Dominique Gusbin (COHERENCE, Belgium). For North America, information on these products was provided by Jim McMahon and Isaac Turiel (United States). A synthesis of this information is presented in Appendix A, with the aim of clarifying whether further study should be done to assess energy efficiency standards for these products as possible measures for common action.

Organisation of the study

The study addresses the issues outlined in the "Framework for Analysis and Assessment of Common Actions" that was developed by the Annex I Expert Group. Section 1 describes the methods used and the measures that have been assessed. Section 2 provides background information on implementation options, energy efficiency, and market trends as the context for the study. Sections 3 and 4 describe rationales for common action, possible participants and vehicles for action. The analytical results on the greenhouse gas reduction potential and cost of energy efficiency standards for refrigerator/freezers and office equipment are presented in Sections 5 to 7. These sections contain the analytical work that was carried out for this study. Sections 8 to 12 provide information on related measures - testing protocols and monitoring processes, political feasibility, timing, and impacts on other countries, including possible GATT implications of standards. Conclusions are presented in Section 13. Information on other products is provided in Appendix A

Description of Measures

The study assesses mandatory minimum energy efficiency performance standards on two types of product:

- refrigerators/freezers; and
- office equipment.

These products were selected as examples for full analysis from a wide range of products that might be the subject of energy efficiency standards, because there is a great deal of information available on them, they are major (in the case of refrigerators/freezers) or growing (in the case of office equipment) energy end-uses, and are traded internationally.

A base case and two levels of energy efficiency were assessed for each product: an "introductory" level, and a "more rigorous" level. These standards are described briefly below:

Table 1: Standards assumed to be implemented in the regional emissions scenarios

Product	Scenario: "Base case"	Scenario: "More rigorous" standard	Scenario: "Introductory" standard
Refrigerators & Freezers	No new standards	US NAECA 1998[3]	EU proposal[4]
Office Equipment:			
Personal Computers	No new standards	Swiss 1999 target	US Energy Star levels
Monitors	No new standards	Swiss 1999 target	US Energy Star levels
Printers	No new standards	Swiss 1999 target	US Energy Star levels
Copiers	No new standards	Swiss 1999 Target:	US Energy Star levels
Fax machines	No new standards	Swiss 1999 Target	US Energy Star levels

The **"base case" scenario** assumes that no new standards are adopted, that countries use only the standards and other measures in place, as of 1996, and that all improvements in product efficiency come only from market-driven technological improvements.

The **"introductory" standard scenario** assumes that all Annex I countries adopt and implement standards at least as stringent as those expected to be widely used in the near future. For refrigerator/freezers, the "introductory" level is assumed to be that of the proposed EU standards. This standard aims to reduce energy consumption from new refrigerators/freezers by 15 per cent in western Europe. The introductory standard has no impact on energy consumption in the United States and Canada because energy efficiency standards in North America are already higher than the EU proposed levels. These countries are assumed to continue to use their more stringent standards. For office equipment, levels of energy efficiency equivalent to those specified in the United States' Energy Star labelling scheme are assumed to be implemented in each region. About 60 per cent of personal computers (PCs) and nearly all monitors already meet Energy Star levels.

The **"more rigorous" standard scenario**, assumes that all Annex I countries adopt and implement standards equivalent to the highest level expected to be adopted by any country in the near future. For refrigerators/freezers, this standard is assumed to be the proposed US NAECA standards that were originally expected to take effect in 1998, but have been delayed. This standard would reduce the energy consumption of a typical 500 litre (18 cubic foot) refrigerator in the United States by 25 per cent to 30 per

3 This standard was proposed by the US Department of Energy based on a negotiated agreement among representatives of manufacturers, utilities, states and efficiency and environment advocates. No decision has been made yet on whether to issue the standard in final form in the near future or to reopen negotiations (US DOE).

4 A draft Directive on common standards of electricity consumption in new domestic refrigerators, freezers and their combinations was proposed by the European Commission on 7 December 1994. A common position was adopted by European Ministers of Energy in December 1995 on standards that would improve overall refrigerator/freezer efficiency by 15 per cent. The European Parliament has yet to finally consider and approve the proposed standards. The proposed efficiency standards are performance based, and would be set as a function of volume for eight different categories of refrigerator/freezers which reflect the main types of appliance (e.g. star rating, automatic defrosting, etc.).

cent, compared to the current NAECA 1993 standards. For office equipment, the "more rigorous" standard is equivalent to the levels of a Swiss target for 1999. The effect on energy use of the Swiss target levels on office equipment energy use ranges from roughly 25 per cent for photo-copiers to over 90 per cent for printers. Very few personal computers meet this standard at present, but some monitors meet this standard already.

No specific measures were assessed for electric motors, home heating appliances or air conditioners, as noted above.

Extent of commonality

Office equipment product types are similar world-wide, and exactly the same spreadsheet model and approach was used for all regions. The analysis on office equipment could therefore be described as assessing common action at Annex I level. The refrigerator/freezer analysis comes closer to assessing regional common action by sub-groups of Annex I countries because refrigerators/freezer product types differ widely in different regions, and each regional analyst has used slightly different methodologies and assumptions.

Implementation assumptions

For the purposes of the modelling work on regional scenarios, mandatory minimum energy performance standards were assumed to be implemented at national level in all Annex I countries. However, the standards from which the "introductory" and "more rigorous" levels of energy efficiency were derived for our analysis are not necessarily mandatory. For example, the Energy Star labelling scheme is not mandatory, but we assume the "introductory" standard for office equipment (equivalent to the Energy Star level of energy efficiency) is implemented as a mandatory minimum performance level.

3. CONTEXT

Product standards can be effective in encouraging the development, marketing and purchase of more efficient products. They can be particularly useful for products where the energy costs are not usually taken into account in consumers' purchase decisions. In both the residential and commercial sectors, lack of information on the savings that are possible from efficient technologies prevents market penetration of economically efficient appliances. In this context, manufacturers have little incentive to produce appliances which are more efficient but more expensive to produce (although greater efficiency does not always mean higher costs). Appliance manufacturers strive to increase productivity and maximise profits. Product characteristics other than energy efficiency, such as low noise, size or speed often play a predominant role in the investment decisions of consumers and hence in the marketing strategies of suppliers (IEA 1989 p.148).

The efficiency gap between opportunities for "cost-effective" investments in energy efficiency and actual investments reflects high transaction costs for consumers and firms related to uncertainties, conflicting incentives of building owners and tenants, and information costs. Well-designed performance based standards can lower or eliminate these transactions costs. Standards can shift investments to economically optimal choices and improve competition between energy efficiency and energy supply.

Range of Implementation Options in Annex I Countries

Energy efficiency standards and labelling schemes for appliances and equipment are playing an increasingly important role in Annex I countries' strategies to meet their energy and environmental policy goals. There are many product energy efficiency standards in place or proposed in Annex I countries and some developing countries, particularly for refrigerators/freezers. The types and stringency of standards vary widely, from alternative methods of implementing standards, such as legislation and/or technical specifications, or voluntary approaches and industry norms, to procurement programmes, economic instruments, provision of information through product labels (which can enhance product energy efficiency by calling attention to more efficient products), or education programmes to raise consumer awareness. Product labels are among the second "tranche" of measures which will be assessed after the analysis on product standards is completed. Economic instruments such as energy taxes, fees on less efficient appliances and rebates on efficient appliances raise the cost of wasting energy and can indirectly improve product efficiency, but the effect depends on consumers' response to the price signals. Information and education to raise consumer awareness is often considered to be less effective than other measures. However, it is likely that information to raise consumer awareness could be an important part of a package of measures to improve energy efficiency, despite the fact that its effect is difficult to measure.

Implementation options that have been used in different Annex I countries' in the past to implement product standards are described here, but the advantages and disadvantages of using these policy instruments to improve product energy efficiency are country specific and have not been fully explored in this study.

Western Europe

In western Europe, the use of product standards ranges from countries that “make.. almost sole use of legislation in laying down ... environmental product policy,” (Bennett 1994) such as Switzerland and Spain, to countries that prefer to keep product legislation to a minimum, such as the United Kingdom in recent years. In the Netherlands and the United Kingdom, the majority of environmental product standards in the past were set through legislation, but the use of technical specifications which do not require legislation is also well developed. Germany tends to rely on technical specifications rather than legislation, and is interested in incorporating environmental aspects into technical specifications. Sweden sets product standards under legislation and to a small extent uses voluntary agreements. In Austria, legislation has been used for most environmental product standards, but technical specifications and voluntary approaches are also used. In Finland, Norway, and Sweden environmental legislation has developed along the same lines because of their intensive co-operation on a wide range of matters. Legislation is the tool most used for product standards, with some incorporation of environmental aspects in technical standards and increasing interest in the use of voluntary agreements. In Germany, the Netherlands, and to some extent the United Kingdom, the recent environmental policy trend has been towards the use of voluntary approaches (Bennett 1994).

In the process of negotiating the proposed EU standard, strict and rapidly implemented mandatory energy efficiency standards were not considered to be acceptable by some national governments concerned by their domestic industry and by the appliance manufacturers (Europe Information Service). For instance, the United Kingdom was opposed to higher standards, especially if compulsory, on the grounds that it did not want to put its domestic industry out of business (British refrigerators are significantly less efficient than those produced in other parts of the EU). Germany was also opposed to more stringent mandatory standards on the grounds that this would close off markets for German manufacturers' less efficient models and force them to up-grade their production lines sooner than would otherwise be necessary.

European Union

The European Community has a well-developed internal market. The Treaty of the European Union requires industry and commerce to operate under similar conditions across the EU as far as practicable, to prevent barriers to trade, thus providing the framework for harmonised EU-wide standards relating to tradable goods like refrigeration appliances.

The European Committee of Manufacturers of Electrical Domestic Equipment (CECED) initially argued for voluntary approaches, but none of the concrete proposals proved to be satisfactory to all parties involved. Moreover, voluntary agreements were considered by some member states to be politically less acceptable than standards, as they would not prevent the import of less efficient refrigeration appliances from non-EU countries.

The first proposal for EU refrigerator energy efficiency standards, in 1993, called for two successively more demanding levels of energy efficiency performance coming into force on 1 January, 1998 and 1 January, 2001 or 2002. The first stage was designed to achieve an average improvement of 10 per cent and the second of 30 per cent (across both old and new appliances). A stronger European Parliament proposal for standards giving an average improvement of 40 per cent was reduced in the final agreement in December 1995 among EU Energy Ministers for an average improvement of 15 per cent. Industry was a strong lobby group in this process, arguing that the cost of standards would be higher than that estimated in analysis used by the EC (which was also used in the cost-effectiveness analysis for this study). This points to the importance of understanding the effect of standards on the costs and competitiveness of industry, and the attitude of industry towards efficiency standards to enable a comprehensive assessment of the level of standard that might meet the needs of all interested parties.

In the European Union (EU), the tools that can be used to introduce policies are legislation at EU level that is binding on member countries, and EU Directives which define general performance goals, such as “not harmful to the environment” or “heat insulated”, which are implemented through a variety of instruments at the national level. Directives are the most commonly used instrument for EU environmental measures, perhaps because they leave to each Member State’s discretion the exact form and methods which are used to implement the measures, and so encompass the many differences in administrative procedures between EU Member States.

Japan, United States, Canada, Australia, New Zealand

In Japan, there are relatively few formal environmental product standards. Public authorities rely heavily on self-regulation by industry. Industry generally first establishes standards or targets amongst themselves, and the Government (MITI) sets standards when 60 per cent to 80 per cent of firms can meet the industry standard (Bennett 1994).

In the United States, there is a strong trend towards using voluntary approaches for environmental policy, but a wide array of environmental standards have been legislated (Bennett 1994). The proposed US 1998 refrigerator standards were reached by a consensus process, and in October, 1994, a joint letter signed by the trade association (AHAM) representing manufacturers, members of the energy sector, and environmental groups supported the proposed levels. The proposed standards have not yet been finalised, and now some manufacturers have reversed their position and oppose the standards (McMahon *et al* - Technical Annex). United States legislation requires that energy efficiency standards be set at the maximum level that is technically feasible and cost-effective (under the 7 per cent discount rate used by utilities), taking into account the likely impact of the standard on consumers, manufacturers and the nation.

Another United States policy instrument is the executive order. An executive order was used to direct the United States government (the world's largest purchaser of office equipment) to purchase Energy Star equipment. This market-pull strategy has had a strong effect on the market penetration of Energy Star office equipment, and is one of the primary drivers leading to the program's success. A similar activity is the energy-efficient office equipment procurement collaborative, comprised of state and federal government procurement agencies and utilities (IEA draft 1996). Both Federal and State governments have the power to set standards. In addition, in the United States, many private standards are developed by private standards development bodies which sell this service to industry (Bennett 1994).

The NAFTA provides a strong incentive to support the implementation of harmonised standards in North America. For example, Canada has acted to harmonise its minimum efficiency standards with those of the United States, adopting the US 1993 standards in February 1995. This principle could apply to other groups of countries that are trade partners.

In New Zealand, the trend is away from legislation, regulations are kept to a minimum, and there is strong interest in voluntary approaches. Australia has had a mandatory labelling scheme and, following prolonged consultation with interest groups, will implement mandatory minimum energy performance standards on refrigerators/freezers in 1999. Australia and New Zealand are working towards harmonising their standards.

Central and Eastern Europe and Commonwealth of Independent States (CIS)

Central European countries are already moving to harmonise their standards with the European Union and other OECD countries. If energy efficiency standards were not implemented in the central Europe, it is likely that cheap and inefficient appliances from countries with EU standards would be imported into these countries (SEVEN - Technical annex).

Russia and other CIS countries have a long history of development of energy efficiency standards for refrigerators. The first standards were introduced in 1976. New standards were introduced in 1987, with the aim of bringing energy efficiency up to the west European level. After the split of the USSR in 1987, these were recognised as national standards. Russia, Ukraine, Belarus, and other CIS countries consequently have standards for energy efficiency of refrigerators. However, since 1990, refrigerator efficiency standards have become voluntary in Russia because of the economic recession. Consequently, very few refrigerator models produced between 1990-1993 in Russia were in accordance with 1991 energy efficiency standards (and this is possibly true of other eastern European countries also). There has also been no barrier to inefficient products being imported to Russia since they became voluntary. National legislation would be needed to implement mandatory energy efficiency standards (CENEf - Technical Annex).

Refrigerators/Freezers

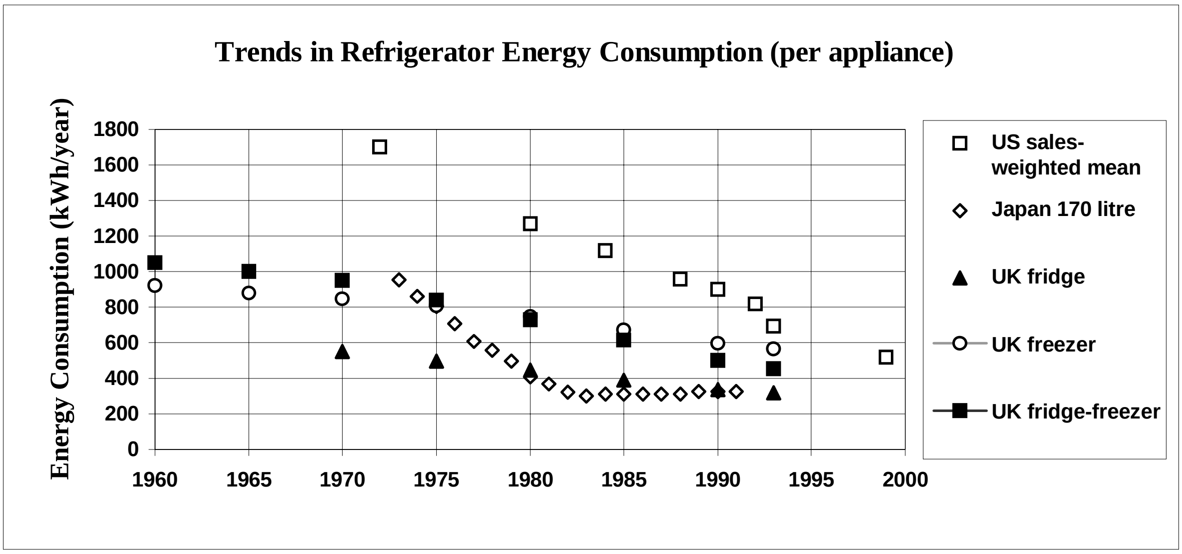
For refrigerators/freezers, energy efficiency standards have been set in the United States, Canada, Mexico, the European Union (proposed), Australia, Japan (voluntary), China and Korea (a mix of voluntary and mandatory), and Russia (originally mandatory, now effectively voluntary). All of these countries have test protocols, and all except China have labelling schemes in place (IEA 1996). The German government reached an agreement in January 1980 with German manufacturers to voluntarily improve the average efficiency of refrigeration appliances by 15 per cent to 20 per cent by 1985 (Gusbin, 1995), but this was subsequently discontinued. New Zealand has a voluntary labelling scheme for refrigerators. Australia has a mandatory labelling scheme, and plans to introduce mandatory minimum energy performance standards for refrigerators/freezers in 1999. Both New Zealand and Australia are working to implement common standards for refrigerators. Switzerland and Denmark are implementing energy efficiency targets for refrigerators/freezers.

Refrigerator/freezer energy efficiency

Refrigeration consumed more than 350 TWh of electricity in Annex I countries in 1995 (IEA 1996), and is typically the largest domestic sector electricity end-use, representing about 20 per cent of total domestic electricity consumption. Refrigerators/freezers offer very large potential for further improvements in energy efficiency. There is a wide gap between the efficiency of the best available technology and market average levels of efficiency.

New refrigerator efficiency has improved dramatically in major markets over the last 20 years, as shown below for the United States, Japan and the United Kingdom.

Figure 4: trends in refrigerator energy consumption



Source: IEA 1996
N.B.: figures for different countries are not directly comparable as different test procedures are used by the USA, Japan, and Europe to measure energy consumption.

The technical options driving these improvements refrigerator/freezer efficiency were increasing the motor/compressor efficiency, improved thermal insulation, and better energy controls (IEA 1991, p. 67), which have more than outweighed unit energy consumption increases, from increasing size of refrigerator/freezers and additional features such as automatic defrost, ice-making, and low temperature compartments.

Figure 4 suggests that average energy use per appliance is converging for the three major refrigerator/freezer markets, but when the size of refrigerators/freezers is taken into account, there are still significant differences in energy efficiency between regions, as shown in Table 2 below.

Table 2. Average energy use for new refrigerator/freezers in the Annex I regions:

Region	**Refrigerators** average kWh/l/yr	**Refrigerator/ freezers** avg kWh/l/yr	**Freezers** avg kWh/l/yr
West Europe	2.5	2	1
Czech Republic (1995)	2.2kWh	2.1kWh	1.8kWh
Russia	1.99kWh (255l)		
Japan (1993)	4kWh	1.7kWh	2.5kWh
North America - US (1995)	3kWh (108l)	1.1kWh	0.76kWh

Source: regional analysts for Japan and North America (see Technical Annex); western Europe range is from "Home Energy" Jan/Feb 1996; for eastern Europe, the figure is from a personal communication from CENEf.

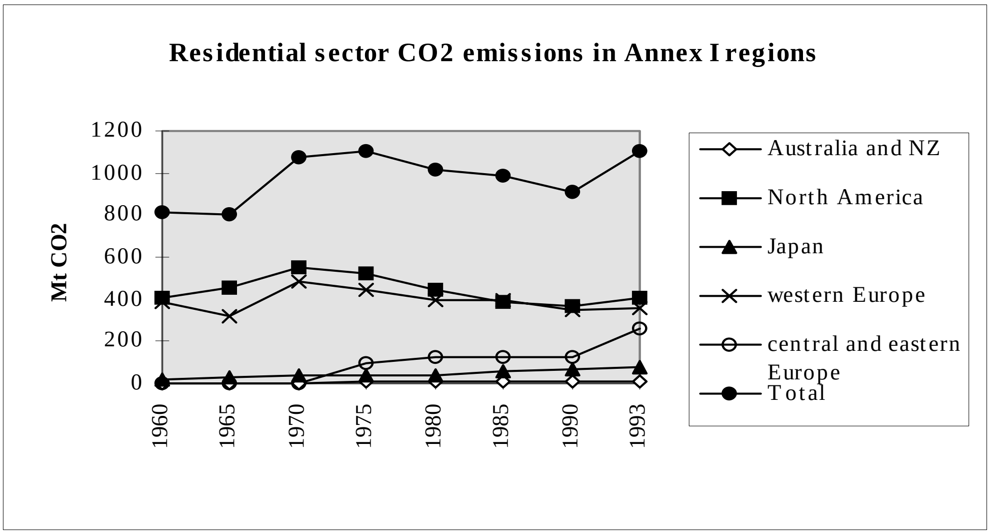
N.B.: Figures for different countries are not directly comparable, as different test procedures are used by the USA, Japan, and Europe to measure energy consumption.

The most common volume of North American refrigerators is approximately 500 litres (17.5 cu.ft); the largest are more than 860 litres (30 cu.ft) (IEA 1996). For the whole range of sizes typically sold in the United States, however, the American products consume significantly less energy per litre per year than those in other countries. The average sales-weighted size of Australian refrigerators was 336 litres in 1992 (GWA 1993), which is midway between the average-sized Canadian refrigerator (463 litres) and the average-sized Western European refrigerator (275 litres). The most popular size range for new Japanese refrigerators was reported to be 280–340 litres in 1986 (Meier 1987), with almost all the units sold in Japan being refrigerator-freezers. The average size of Russian refrigerators owned in 1992 was approximately 230 litres, of which some 80 per cent were single-door models and the remainder were double-door models (CENEf 1995).

Residential sector CO_2 emissions

The emission trends shown in figure 5 below reflect both different levels of electricity use in different regions, different sizes of regions in terms of population and income, and different levels of fossil fuel used for producing electricity. Countries using mostly hydro-electricity or other non-carbon fuels will not achieve significant CO_2 savings from improving the energy efficiency of products, although improving energy efficiency may be a goal for other reasons.

Figure 5. CO_2 emissions from electricity: residential sector

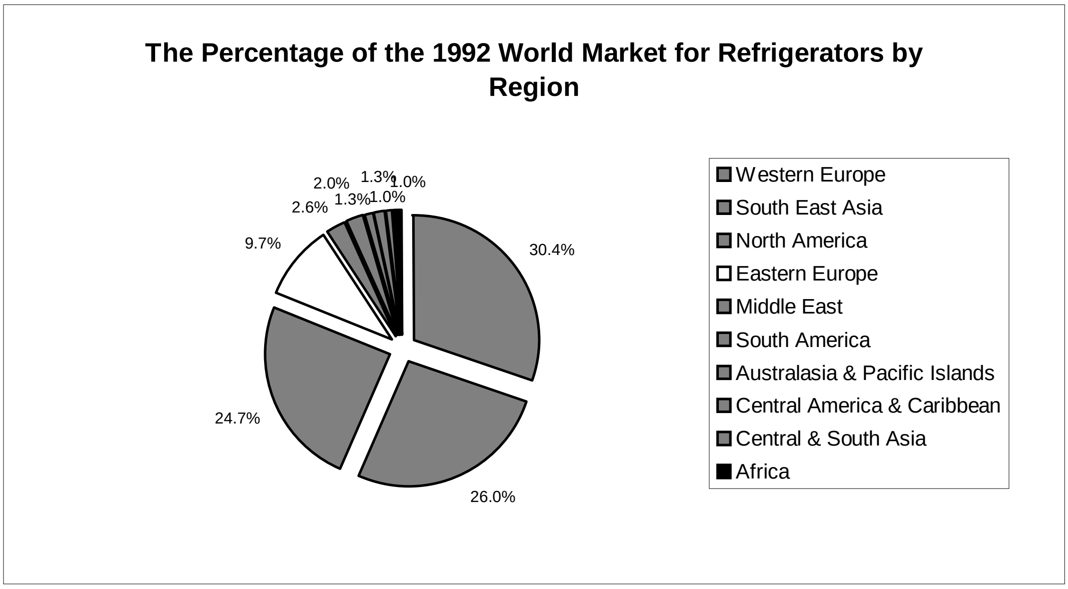


Source: IEA data 1996. Note: much of the data for CEE are either missing or very uncertain (0 values 1960 to 1970 are due to missing data).

Refrigerator/freezer market trends

Approximately 73 million refrigerators are manufactured and sold each year around the world. The global refrigerator market has three dominant regions: western Europe, southeast Asia and North America. Together, these regions account for over 80 per cent of world-wide sales by value. The same three regions and the CIS/eastern Europe region are the major centres of production, accounting for 91.6 per cent of all new refrigerator units manufactured in 1990 (IEA 1996).

Figure 6: The world market for refrigerators by region (1992)



Source IEA 1996

Demand for refrigerators is expected to continue to grow. The greatest growth rate during this decade is expected in southeast Asia, eastern Europe, and South America. The percentage shares of demand for North America and western Europe are expected to decrease, since these markets are already saturated (IEA 1996). In the United States, the average size of new refrigerators remained at around 600 litres (19 to 20 cubic feet) from 1978 to 1994, with some shift towards larger side-by-side refrigerator/freezers offset by the diminishing size for compact refrigerators. In western Europe, the trend is towards larger units, combined refrigerator/freezers, and energy intensive no-frost units. In Russia, refrigerators are only owned by 311 per 1000 households. In the scenario work for this study, the refrigerator stock in eastern Europe is assumed to grow by 20 per cent between 1995 and 2020, with a trend towards more efficient but larger refrigerators (CENEf - Technical Annex). In central European countries, over 90 per cent of households own refrigerators, so the level of ownership is likely to increase over the period, and the type of appliance bought is expected to move towards more refrigerator/freezer combinations.

At present, there is a clear distinction between the type of refrigerators available in different regional markets. In Japan, for example, most refrigerators have both fresh food and freezer compartments and there are almost no stand alone freezers. New models have as many as six doors and compartments, sometimes including a zero degree compartment for raw fish. In the United States, refrigerators are much larger than in other countries, and often include features such as “through the door ice,” which add significantly to energy consumption. In Europe, refrigerators tend to be smaller, with fewer compartments and features (IEA 1996)

Because of these wide differences in product types, even companies which operate in more than one region have shown little interest in selling the same models on more than one regional market. Instead, they manufacture separate products for and within each region. Nonetheless, there is a tendency toward greater inter-regional component sourcing, as well as increasing inter-regional transfer of technology, and this trend is expected to continue. At least two companies, Electrolux and Whirlpool, have developed into trans-global concerns, have established leading positions in both the North American and European markets, and have also begun to establish themselves in non-OECD markets (IEA 1996).

Office Equipment

For office equipment, voluntary energy efficiency standards are planned or have been set in Denmark (the obligation to set standards was legislated in 1994, but they are not yet implemented), and Switzerland. Energy efficiency labelling has been established in Sweden and Switzerland and it has been proposed for Japan and the United States (voluntary Energy Star labels).

Office equipment energy efficiency

Office equipment consumes nearly 80 TWh/year of electricity in OECD countries and is the fastest-growing electrical load in the commercial sector. The largest energy end-uses in the commercial sector are space conditioning and lighting, but office equipment is a rapidly growing energy end-use and may represent 5 per cent to 20 per cent of electricity consumption in the sector. (IEA 1989, p. 36). Unlike refrigerators, the product characteristics and energy efficiency of office equipment is likely to be very similar in all countries, because the market for office equipment is world-wide (McMahon *et al* - Technical Annex).

Personal computers and monitors each consume over one-fourth of the total office equipment energy use. Copy machines are the third largest energy consumer, and printer energy use is almost as large, but is decreasing because of power-management features in most of today's laser printers. Fax machines now account for nearly 8 TWh/year in OECD countries compared to less than 0.01 TWh/year in 1985. By most estimates, total energy use by large computers (mainframe and mini-computers) is greater than that used by personal computers and monitors (Piette, 1994). However, it is difficult to characterise the energy use of large computers because of the large variation in products, and they have not been included in this study. The inherent energy efficiency of palmtop, laptop, and portable personal computers makes energy efficiency standards for these products less important. (McMahon *et al* - Technical Annex)

There are conflicting trends in energy use for personal computers. Requirements for total personal computers power have fluctuated over the years as more powerful (but more efficient) computing technologies have emerged. During the mid-1980s, overall personal computers energy use increased. Increased power requirements for new chips suggest power use is rising. In addition, personal computers users are buying larger, higher resolution colour CRTs, which is driving up energy use requirements for monitors. At the same time, lower-voltage systems drive power use down. Despite the tremendous increase in computing power of today's personal computers, their energy requirements are lower than that required by the first generation of personal computers (Norford *et al*, 1990, McMahon *et al* - Technical Annex).

Many improvements in energy efficiency for computer electronics are achieved by increasing computing power while reducing internal heat. The most important development in personal computers energy-efficiency is related to technologies to slow or shut down various components after some user-defined idle time, which was originally developed to save battery power in laptops. Future computers are likely to require entirely new designs (large bandwidths will make the most common current personal computers architecture obsolete). This presents the opportunity to build power management into future technologies. In the future, voltages may also be lower than the current 3.3V system in the United States, which will reduce power use. It is expected that increases in storage density will not require more power (McMahon *et al* - Technical Annex).

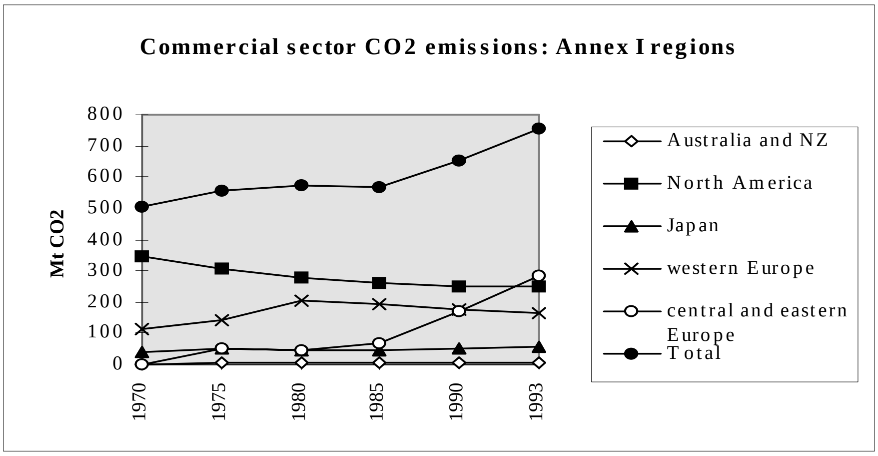
Power requirements for copiers have been decreasing slightly in recent years, though a more dominant trend is the increase in the number of copiers in use and average copying rate (Acquaviva and Hartman, 1993). Energy use of copiers is related to the number of hours the equipment is on, the number of copies made, copier speed, plus time spent and power requirements in various modes of operation. Several other factors influence energy use per page, such as whether duplexing is used, or the size of the copy job. Single-page jobs are the most energy intensive on a per copy basis. Many copiers (40 per cent of today's medium-speed copiers) have energy-saving features to reduce standby power by 20 to 40 per cent (Dandridge, 1994), but often this feature is not enabled, so the energy savings are not realised. Users may be unaware of the energy-saving modes or they may not be willing to wait during warm-up periods that may require several minutes before copying can proceed. Many copiers are shipped with the energy-saving mode disabled, or set at large delay times (McMahon *et al* - Technical Annex).

Two trends have caused a large increase in the energy used for printing. First, there has been rapid change in the last decade from impact printing, such as daisy wheel and dot-matrix techniques, to non-impact printing, dominated by energy-intensive laser printing. Laser printing is relatively energy intensive because of the heat and pressure requirements for the electrographics. Most of the energy is consumed while the printer sits idle keeping the rollers warm. Second, as with copiers, paper use has increased. A third trend, the emergence of colour printing, will also increase energy use for printing, but colour printing is still a small share of the printer market. (McMahon *et al* - Technical Annex)

Facsimile machines are the newest technology among the significant energy-consuming office equipment. Over the past decade there has been a shift from thermal to laser fax technologies which has increased annual energy use for fax machines. (McMahon *et al* - Technical Annex)

Commercial sector CO_2 emissions

Figure 7: CO_2 emissions from electricity: commercial sector

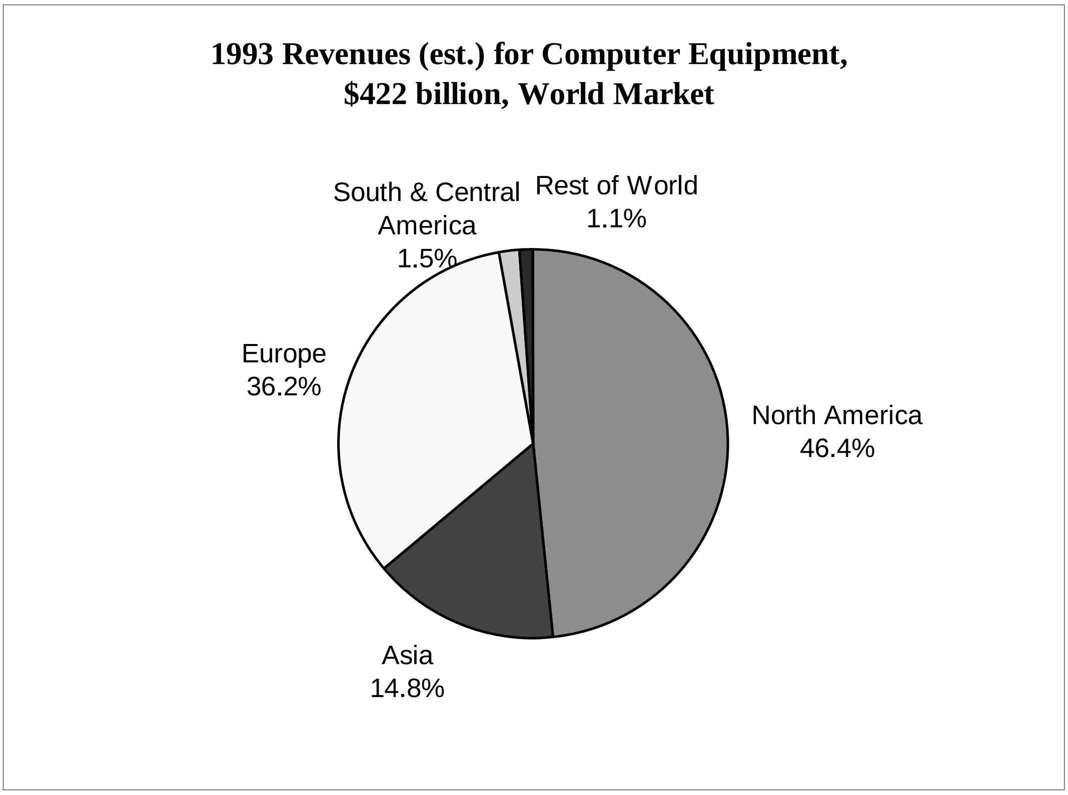


Source: IEA data 1996. Note: much of the data for CEE are either missing or very uncertain(0 values 1960 to 1970 are due to missing data).

Office equipment market trends

The world-wide market for computer equipment in 1993 is estimated at $422 billion in revenues, of which the North American market (Canada, United States, Mexico) comprises 46 per cent and the Western European market, 36 per cent.

Figure 8: 1993 revenues for computer equipment



The leading manufacturers of personal computers (IBM, Apple, Compaq, NEC, Dell, and AST) are from Annex I countries. These companies account for around 50 per cent of all revenues. There are a large number of additional manufacturers. Sales of personal computers are booming as they become all-purpose information appliances. Americans purchased $9 billion of personal computers for home use during 1994. The penetration of personal computers in Europe is currently one third that of the United States, and is expected to increase from 8 per cent penetration today to 50 per cent by 2000. The home market may become the biggest personal computers market by the year 2000, but is small at present and has not been included in this analysis.

The geographic distribution of 1993 estimated revenues of $78 billion for business equipment manufactured in the United States is similar to the distribution for computer equipment. North America represents 50 per cent, Europe 36 per cent, Asia 10 per cent, South and Central America 4 per cent, and the Rest of World, 1 per cent.

4. RATIONALE FOR COMMON ACTION

Advantages and disadvantages

Any form of common action on product standards that achieved similar levels of energy efficiency in all Annex I regions would increase the consistency and strength of market signals to consumers, manufacturers, and retailers, and improve market transparency.

Common action to harmonise test protocols would reduce the cost to manufacturers of testing products and facilitate more open markets. Refrigerator manufacturers universally cite concern over the differences in testing protocols in different regions, the main reason being that different protocols can present barriers to international trade because of the time and resources taken to comply with testing and certification processes (IEA draft, 1996). Manufacturers with a presence in more than one major market, and those wishing to expand to other markets, would benefit from harmonised test protocols or standards as the current multiplicity of tests and standards required by national programmes is very costly for manufacturers wishing to sell in more than one market. However, since manufacturers have already set up testing facilities and institutes to suit the different existing test protocols, any change would involve short-term cost. Common action on test protocols may also make it simpler to assess how foreign models might be expected to function under different countries' local conditions. Harmonisation of tests and standards would discourage protectionism. Moreover, reducing the number of test requirements might make greater improvements in efficiency possible. By sharing data and analytical tasks, governments and utilities could reduce the cost of developing test protocols.

Common action to monitor and share information on the efficiency levels of product standards, for example, would improve the comparability of information from market to market and provide better information about technological capabilities and limits. This would improve the ability of governments and utilities to work with manufacturers to encourage the development of more efficient products, and facilitate the design of programmes that promote the most cost-effective available technologies for their markets. Common action of this type could assist governments and utilities in their efforts to design, implement, and monitor standards programmes, and sharing analytical results could simplify the task of analysing the costs and effectiveness of energy programmes.

An example of countries working towards common action on testing protocols is the "Action Program for Energy" of the Asia Pacific Economic Co-operation (APEC), which is working towards common action on standards and test protocols. One of the main rationales for this work is to achieve trade benefits for the Asia Pacific region.

> "Major trade and economic gains will arise from: clarifying production and marketing requirements in all member economies against recognised and agreed benchmarks, increasing certainty among market suppliers in terms of production planning, agreeing test protocols, with the potential for reduced testing and retesting requirements (and hence costs) in multiple; and increasing certainty among regulators on accreditation procedures and quality assurance process, further reducing technical and administrative requirements and costs."

Common action to adopt the same standards (which would require common test protocols) would decrease the number of tests needed and decrease product design costs. Distributors and consumers would benefit, too, as it would be simpler to keep up with rapid technological and design changes and there would be less confusion from conflicting claims among manufacturers using different test protocols. Conditions for trade and technology transfer would be improved among countries with similar standards, which would enlarge the energy efficient segments of product markets - not only for the products themselves, but for the component technologies, as well. Larger markets would allow greater economies of scale and lower prices for efficient products and component technologies, and would increase the incentives for manufacturers to develop them.

Common action on procurement programmes could also improve the energy efficiency of products. For example, Annex I-wide government procurement programmes (possibly including the World Bank, the UN, the OECD/IEA and other institutions) would increase the size of bulk purchase contracts and the level of “prize” available in innovation procurement programmes, such as Golden Carrot contests. With a vastly increased market and contract size, the number of potential suppliers that would compete for them would increase. A greater level of competition could generate a wider variety of product and technology choices from which to choose the most cost-effective for the particular market being served.

Several issues are likely to make negotiation of common action on product standards complex. Firstly, measurement differences and differences between established national standards and testing protocols may be a problem for refrigerator/freezer standards. North America uses cubic metres to measure refrigerator volume (and their standards do not cover compact refrigerators), while European and other countries use litres. Eastern European standards do not use the concept of adjusted volume, but have separate requirements for every make of refrigerator produced (however, their test protocols are the same as ISO and CEN). Differences in energy testing protocols could be difficult to resolve, particularly given their correspondence to actual *in situ* energy use under different operating conditions in different countries. Secondly, different electricity prices and discount rates make the value of energy saved lower (and so less worthwhile) in some countries than others.

Lastly, regional, national or sub-national structural differences in manufacturing and retail sectors, differences in consumer preferences about product characteristics, different safety and environmental standards, and different voltage systems (which affects energy efficiency but also electrical safety) may also create difficulties. For example, energy-volume relationships of refrigerator/freezer models vary widely because of different consumer preferences (this is not a difficulty for office equipment). In addition, some producers of lower efficiency products could have some export markets closed to them as discussed in trade section below.

Extent of commonality

In general, the advantages of common action listed above would be strongest at Annex I or on a broader level for traded products. However, national standards, standards among a small group of countries, or even state or provincial level standards, can have important catalytic effects on the likelihood and political acceptability of standards at a higher level of commonality. Unilateral action to implement standards, although it differentiates the market and can create a barrier to trade, can spur multi-lateral agreements. In the United States, government standards provided the incentive for federal standards to be set to reduce trade distortions between States. Further, the Energy Star labelling scheme for computers in the United States has influenced the efficiency of computers sold world-wide because the United States is such a large market. Standards could be also be effective at a national level within a general international agreement to improve energy efficiency.

Regional international agreements can also stimulate national action; a multi-lateral commitment can facilitate politically difficult national reforms. For example, the motor vehicles exhaust emission standards first drawn up in the 1960s by the UN Economic Commission for Europe were subsequently applied in many countries. Standards which are effectively non binding “technical specifications” can also be drawn up by an international body such as the International Organisation for Standardisation (ISO) or the International Electrotechnical Commission (IEC), and then adopted at national level. Manufacturers participate in international standards organisations, as they generally find it in their interests to avoid proliferation of testing protocols and standards.

5. POSSIBLE PARTICIPANTS AND VEHICLES FOR ACTION

National level

The implementation of product standards is most likely to occur at national levels, regardless of the form of common action that might be agreed at Annex I level.[5] Participants and vehicles for action on product standards at national levels depend on how the standards are implemented. Mandatory energy efficiency standards could be introduced by formal legislation, which would take the form of an Act of Parliament (or Congress). Standards or technical specifications which set methods for monitoring, measuring and testing the energy efficiency performance of products could be introduced in regulations drawn up under broad enabling legislation. Technical specifications could be developed by national standardisation bodies, in consultation with industry and other interested parties. Although minimum efficiency standards are usually mandated by law or regulation, they are sometimes based on voluntary agreements negotiated with manufacturers. Voluntary approaches could be used to implement energy efficiency standards through industry agreements (if industry has a commercial interest in applying common standards), or government/industry agreements where the government may use voluntary agreements as a flexible policy tool to supplement, or take the place of, legislation. Another implementation tool is government procurement requirements. If some or all Annex I governments undertook to purchase energy efficient office equipment, as the United States government has, there could be significant impacts on energy efficiency and greater incentives for the development of innovative technology.

Instruments that influence consumer behaviour can achieve the same effect as standards. For example, the use of education campaigns or labels can have such far reaching implications on consumer demand that producers will often be forced in practice to adapt the design of a product. Economic instruments (e.g. carbon tax on energy) can also be used to increase consumer concern about product energy efficiency.

Taking each of these methods of implementation into account, at the national level possible participants are: Federal (and in some countries State) governments; manufacturers; and consumer groups. Possible

[5] Some countries, such as Canada and the United States, have provincial or state level governments with the power to set standards. In the United States, federal standards take precedence over state standards, but in Canada, the national government can only govern inter-provincial affairs, not the manufacture and sale of products within a province.

vehicles for action are: Legislatures or Parliaments; the executive branch of government, or government departments; national standardisation bodies; industry associations; or individual industry representatives. In addition, consultation may be required with a much broader range of interested groups; for example, including appliance manufacturers, national administrations (mainly industry and energy ministries), retailers, utility companies, consumers, standard bodies, researchers and other experts.

Regional Level

Possible participants at the regional level are: European Union (EU) countries, North America Free Trade Agreement (NAFTA) countries, Asia Pacific Economic Community (APEC) countries, multinational industries; and industry associations. Possible vehicles for action are: the EU, the ISO, the IEC, OECD council decisions, IEA implementing agreements, and industry associations. In addition, consultation with other groups would be needed. The European Commission, for example, consulted appliance manufacturers, national administrations (mainly industry and energy ministries), retailers, utility companies, consumers, standard bodies, researchers and other experts when developing the EU proposed standards.

Annex I-wide or Broader Level

The main non-governmental international standardisation bodies (ISO and IEC) would be important participants. Other possible vehicles for action could be the UNFCCC, the OECD, IEA, UNECE, ECMT.

The Technical Barriers to Trade (TBT) Agreement of the GATT (discussed more fully in the trade section below) emphasises the importance of international standards and the participation of developing countries in international standards. One commentator has suggested that the GATT’s environmental working group could develop an environmental code, the violation of which would be actionable under Article XX (Charnovitz 1992). Presumably, energy efficiency could be included in such as code.

The TBT Agreement contains provisions on technical assistance for developing countries to prepare technical regulations, establish standards institutions and participate in international standardisation bodies, and establish regulations, certification bodies, and legal frameworks to make membership or participation in international or regional agreements possible. In addition, the UN Industrial Development Organisation (UNIDO) is already involved in channelling UNDP assistance to developing countries for institution building in these areas. It is possible that a useful role could be played by the UNCTAD/GATT International Trade Centre (ITC) in identifying and executing projects to facilitate the internationalisation of standards. Appliance demand is growing fastest in developing countries, and that is where the greatest opportunities for energy use reduction lie. Because of the trade advantages of common standards, non-Annex I Parties may be interested to participate. Internationally accepted analytical methods, test protocols, and standards, could be a model that non-Annex I countries could use to develop their own efficiency programmes. The model not only would be a useful starting point for programme development and implementation, but also would increase the likelihood that such programmes are pursued in the first place.

6. EFFECTS OF REFRIGERATOR/FREEZER STANDARDS

Greenhouse Gas Emissions Reduction Potential

Approach

Since the regions have different refrigerator product types and use different energy testing protocols, a formula for converting minimum energy efficiency standards for refrigerators between the regions was used. This conversion technique is described in detail in the Technical Annex. This type of conversion formula would not be appropriate to compare the energy efficiency of specific models, but is necessary to enable broad comparisons to be made between very diverse markets, as we are attempting to do here.

A separate spreadsheet model was developed for each of six Annex I sub-regions, taking into account different regional starting points, policies, energy efficiency and products. Each model uses a similar approach, but different assumptions on key parameters that were considered most accurate for their region (documented below). For each region, the annual electricity consumption is calculated for a base case, a scenario of “introductory” standards, assuming the current European Commission proposed standards are announced in 1996 and implemented in each region in 2000, and a scenario of “more rigorous” standards, assuming the NAECA standards (which will probably be adopted in the United States in 1998) are announced in 1996 and implemented in each region in 2000.

For the purposes of the regional scenarios summarised below, *mandatory minimum energy performance standards* were assumed to be implemented in all Annex I countries. However, the standards from which the “introductory” and “more rigorous” levels of energy efficiency were derived for this analysis are not necessarily mandatory. The models account for the changes in overall refrigerator energy use and CO_2 emissions as new refrigerators are purchased over the period to 2020. The scenario results are summarised below.

Assumptions

The main assumptions that affect the greenhouse gas reduction results are presented in the Table and discussed below.

The autonomous energy efficiency improvement (AEEI) can strongly affect the results and is one of the most uncertain factors in the regional analyses. The regional analysts have used very different AEEI assumptions according to what they judge best reflects autonomous energy efficiency developments in their region. In Japan, for example, the analysts consider that there has been no AEEI in recent years, so they have used a low value (0.4 per cent) for the AEEI in the base case they consider most realistic. The Japanese analysts do consider it possible, however, that competition from other manufacturers could make the AEEI as high as 1 per cent per year in the future - which is reflected in their second baseline scenario (see Figure 11). In the United States, too, the AEEI is expected by the analysts to be very low or zero in the future (although historical rates were much higher) because the market has already experienced two rounds of standards (in 1990 and 1993) and energy prices are not expected to increase in the future. The alternative base case presented in the North American result in Figure 10 (see below) as a sensitivity analysis shows that increasing the AEEI to 0.5 per cent per year has a large effect on the savings from each standards scenario compared to the base case. In both western and central Europe, in contrast, much higher AEEI values were used: 1 per cent for central Europe, and 1.25 per cent for western Europe (see Figures 9 and 12). In Russia, there was no estimate of the AEEI, so it has effectively been valued at zero (see Figure 13). For Russia and other CIS countries, factors affecting the AEEI, such as price, electricity tariff, income dynamics were considered too complicated to be incorporated accurately in this study. The analysts for each region used a constant AEEI for the whole period to 2020.

Table 3. Key assumptions for refrigerator/freezer analysis

Region	**AEEI** % per year	**Product lifetime** years	**Refrigerator diffusion** % households	**Growth in population*** 1991-2020 %pa	**Fuel mix** gCO_2/kWh
West Europe	1.25	12 to 16	100+%	0.3%	400
CEE	1.00	15	90+%	0.6%	700
Russia/CIS	0	10+	30%	0.3%	326
Japan	0.4 alt base 1 base case	8.5	120%	0.3%	400
North America	0.0 (refrigerators) 0.2 (freezers)	19	120%	0.6%	608-622 US 180 Can

Source: regional analysts - see Technical Annex
* Source World Energy Outlook 1994 Edition p. 231

Almost every occupied household in OECD countries possesses at least one refrigerator, and diffusion levels have been fairly stable for a number of years (IEA draft 1996). Accordingly, the majority of world refrigerator sales are for replacement models (although separate freezer units still have a significant potential for sales growth). Because the market for refrigerators in most Annex I countries is saturated (except central and eastern Europe), assumptions about product lifetime largely determine the rate at which more efficient products enter the refrigerator stock. All analysts used a single average value to reflect product lifetime, although for western Europe, fairly sophisticated data is available which shows different product lifetimes for each product category. The product lifetimes used in different regions varied widely from 8.5 years in Japan, to 19 years in the United States. This variation is largely due to the extent to which second-hand markets operate for refrigerators/freezers. In Japan, for example, there is no significant second-hand market for refrigerators, and space considerations make it less likely that people will continue to use an old refrigerator once they have bought a new one. In the United States, there is a market for second-hand refrigerators and freezers, and people often move an old refrigerator to the garage “to keep the beer cold” when they buy a new one.

Assumptions about future composition of the appliance stock are another uncertainty in the analysis. The price and income effects of energy efficiency measures such as standards (often called rebound effects) may counteract the expected emission reduction, and thus reduce the net emission reduction effect obtained. The scenarios in this study generally assume that consumers will not buy larger refrigerators or more energy intensive, frost-free models with the money they save from more efficient appliances. In western Europe, consumers choose not to buy larger models for reasons other than cost, so this assumption may be appropriate, but it will not necessarily be true for consumers in countries with economies in transition, where lack of income may be have more influence on the size and type of appliances purchased. This is taken into account to some extent in the analysis for eastern Europe, which assumes that more consumers will demand larger refrigerators with automatic defrost features in the future, as income rises. In the central European analysis, a gradual change in the type of appliance demanded is assumed.

Refrigerator energy use is another uncertainty. In the absence of data from at least a sample of individually metered refrigerators/freezers that are in use, it is necessary to assume that test results of energy consumption correspond to actual consumption, which clearly is not accurate in many cases, for example, a refrigerator in a cold kitchen or one that is opened frequently will consume more energy than one in a warm kitchen that remains closed for much of the time.

Estimates of CO_2 emission coefficients also vary. Differences are mainly due to different fuel mixes, but also arise from varying assumptions used by the analysts about weather conditions (a hot summer increases the coefficient in Japan because peak cooling is met by fossil fuel power), and whether average electricity load or peak load emissions are assumed. One approach (average saving approach) is to estimate greenhouse gas emission reductions from the projected average fuel mix for baseload electricity production, including assumptions about efficiency of electricity production. Another approach (marginal saving approach) is to estimate the greenhouse gas emissions saved from the new baseload generating capacity that will be displaced by the introduction of standards. The analysts in this study have all used the average saving approach, which takes into account the savings from existing capacity. This approach is more accurate while existing capacity is being used. The marginal saving approach is probably more relevant for later years, in the period to 2020, when new capacity will be required.[6] To use the marginal saving approach, assumptions on the fuel mix of new capacity over the period and the load factors of each type of plant would be required.

Western Europe scenarios

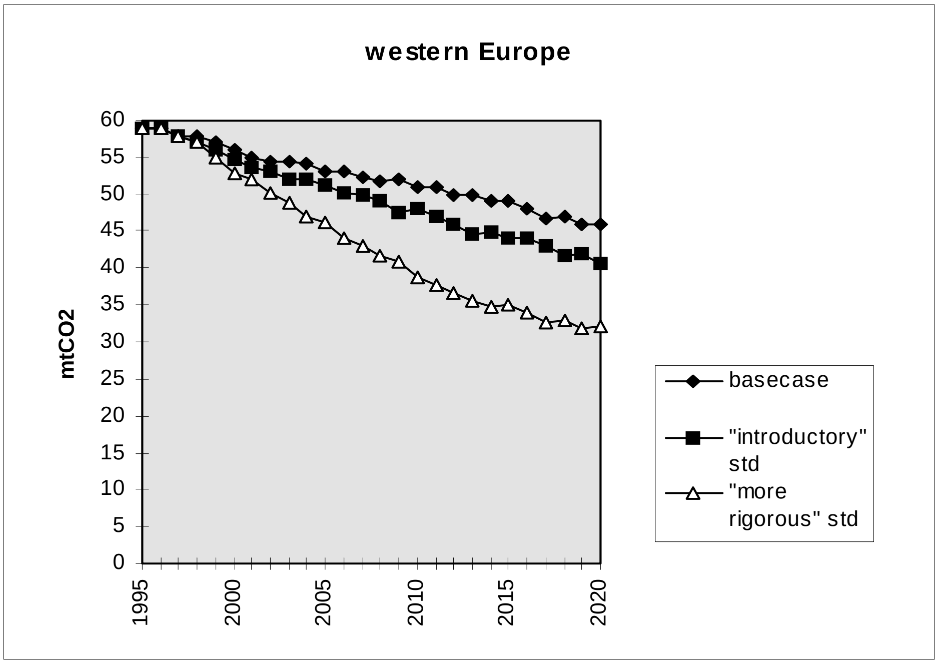
The base case and two energy efficiency scenarios were developed for refrigerators, refrigerator/freezers, and freezers for each Western European country. The scenarios were developed using a spreadsheet model based on the Group for Efficient Appliances 1993 model. The electricity savings calculated in the model are translated into CO_2 emissions reductions based on the fuel mix of each country. The electricity and CO_2 savings are then aggregated over the whole Western Europe region, and over all three categories of product. (Waide - Technical Annex).

In Western Europe, base case emissions fall throughout the period. CO_2 emissions are 3 $MtCO_2$ lower than base case in 2010 for the “introductory” scenario - a 6 per cent reduction, and 12 $MtCO_2$ lower than base case in 2005 for the “more rigorous” scenario - a 24 per cent reduction. These CO_2 reductions are roughly proportional to the energy savings (although for some countries, such as Norway and Iceland, no CO_2 emission reductions would derive from energy savings because they use little or no fossil fuel to produce electricity).

6 The IEA World Energy Outlook scenarios project that fossil fuel-based generating capacity in the OECD will grow faster than total capacity because of the limited expansion of power from nuclear and hydroelectric sources and the limited economic viability of other renewable sources. In the CEE, too, the IEA scenarios assume that solid fuels (coal) will continue to generate over half the CEE region’s electricity in 2010, although their share of the total electricity fuel mix will drop from 62 per cent to 53 per cent. The use of gas for electricity generation is assumed to grow at a faster rate than solid fuel in Annex I countries overall, although it is possible that solid fuels will continue to meet incremental demand in CEE over the period (IEA, 1994, p.221).

In western Europe, the market for refrigerators/freezers is saturated and population growth is expected be low. Consequently energy use and the CO_2 emissions associated with the energy use are projected to fall steadily in the base case as older appliances reach the end of their life and are replaced with new more efficient ones. The base case uses a lower autonomous energy efficiency improvement (AEEI) than historical trends imply (but much higher than the AEEI used by other regions), and does not incorporate the effects of the EU labelling scheme and various other initiatives which might increase the energy efficiency of refrigerators/freezers. The scenarios may consequently over-estimate the energy and CO_2 savings from product standards (a higher AEEI would result in lower savings under the standards scenarios compared to the base case).

Figure 9. CO_2 emissions scenarios for refrigerators/freezers in western Europe

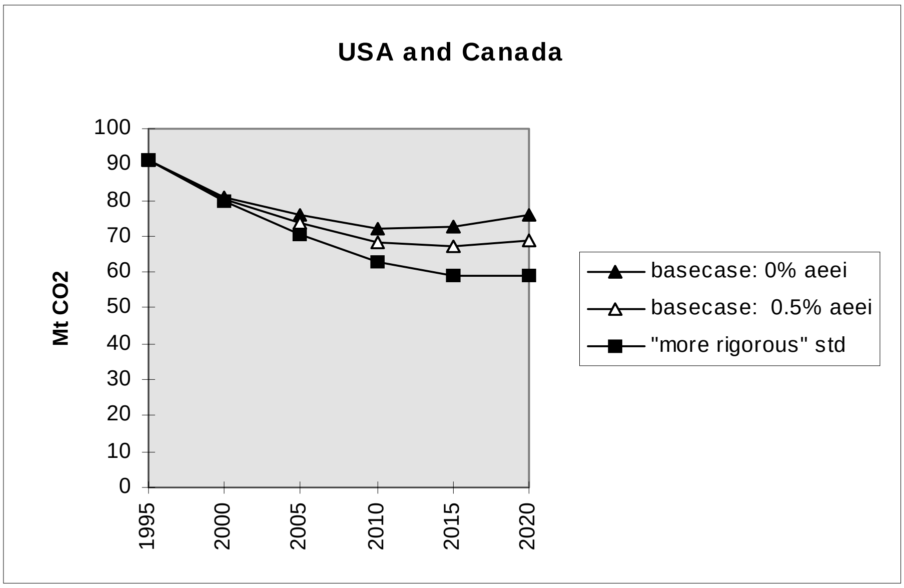


The “introductory” standards are projected to produce annual energy savings in the total Western European cold appliance stock in 2020 compared to the base case scenario of 11.1 per cent for refrigerators, 12.1 per cent for freezers, and 7.7 per cent for refrigerator-freezers. The “more rigorous” standards imply energy efficiency improvements compared to the average 1992 West European stock of 24 per cent for refrigerators, 37 per cent for freezers, and 49 per cent for refrigerator-freezers. The unevenness in the energy efficiency improvement by product type for the “more rigorous” standard reflects the fact that the United States standards were developed for refrigerators of a different typical size range. For example, European style refrigerator-freezers would be obliged to make much larger energy efficiency improvements than other refrigerator product categories to satisfy the United States standards.

North America

A base case and two energy efficiency standard scenarios were developed using the Lawrence Berkeley Laboratory Residential Energy Model (LBL-REM) for ten separate product classes of refrigerators/ freezers for the United States and Canada. The base case is equivalent to the 1993 United States energy efficiency standards (these were adopted in Canada in February 1995). The LBL-REM model uses detailed assumptions about the number of occupied households in future years, new house building, energy efficiency of each category of refrigerator/freezer stock, future disposable income per household, and energy prices (see McMahon *et al* - Technical Annex). For North America, base case emissions fall until the year 2010 as old appliances are replaced by new, more efficient ones, then rise again as population growth and consequent increased demand for refrigerators outweighs increases in efficiency.

Figure 10. CO_2 emissions scenarios for refrigerators/freezers in North America



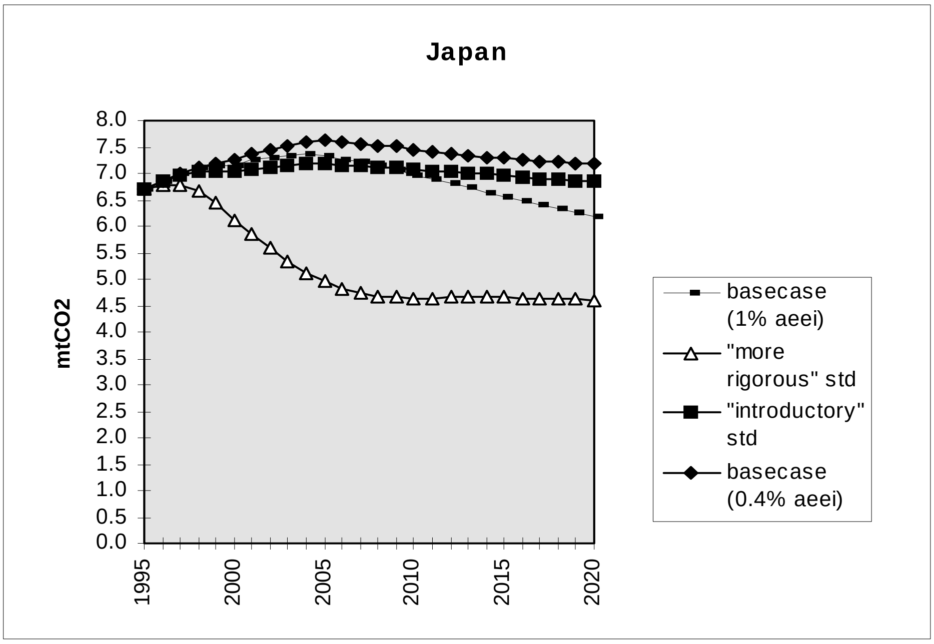
The 1993 United States efficiency standards that are already in place are more rigorous than the European Union standards. It is not possible under United States law to reduce the stringency of standards. Consequently, no effect would be achieved in North America by implementing the "introductory" standard. The more rigorous standards would have a significant effect, reducing emissions by 10 $MtCO_2$ by 2010, which is a 13 per cent reduction compared to the "base case 0 per cent AEEI" in the year 2010. If a higher AEEI of 0.5 per cent per year is used (the middle line in Figure 10 above) the effect of the standard is over 40 per cent lower. The North American analysts consider the 0 per cent AEEI assumption the most realistic one - as discussed in section 5.

Japan

Two base case scenarios (using two different AEEI assumptions) and two energy efficiency scenarios were developed for Japan. These base cases show the sensitivity of the results to the AEEI assumption. Both base cases use AEEI assumptions that are considered feasible for Japan. The base case AEEI assumption of 1 per cent reflects what could happen if Japanese manufacturers respond to competitive pressures that are thought likely to emerge in the future. The alternative base case AEEI assumption of 0.4 per cent reflects the possibility that the AEEI will be very low in future, since the AEEI has been zero in recent years. Both base case scenarios assume a significant shift towards non-CO_2 emitting sources of electricity over the period. The amount of new nuclear and other generating facilities that come into the fuel mix over the next 25 years is a key uncertainty in the scenarios, as lack of public acceptance may make the planned increases in nuclear power infeasible. This analysis is based on information in a recent (1995) forecast by MITI which assumes a much smaller increase in nuclear power than previous forecasts. In order to assess products that are compatible with the standards that are assumed to be set, two categories of refrigerator/freezers are assessed for the "more rigorous" scenario (compact and non compact) and one category of refrigerator for the "introductory" scenario (4-star refrigerators with a frozen food compartment). For Japan, base case emissions increase to 2005 and then fall to close to 1995 levels by 2020.

The reductions in energy use for the "introductory" scenario are very small (compared to the baseline using 0.4 per cent AEEI which the analysts consider is more realistic). Emissions are 0.5 $MtCO_2$ lower than base case in 2010 for the "introductory" scenario which in percentage terms is a reduction of 7 per cent. The reduction for the "introductory" scenario is non-existent compared to the baseline using 1 per cent Autonomous Energy Efficiency Index. Significant energy reductions result from the "more rigorous " scenario, however, around 3 $MtCO_2$ lower than base case in 2010 for the "more rigorous" scenario which is a 37 per cent reduction.

Figure 11: CO_2 emissions scenarios for refrigerators/freezers in Japan



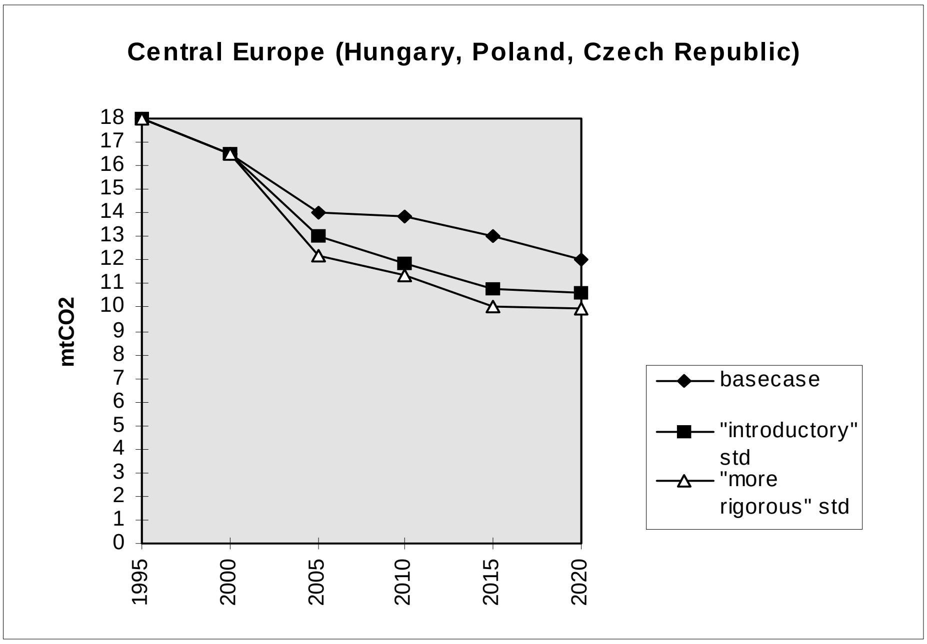
Source: OECD

Central and Eastern Europe (CEE)

The base case and two energy efficiency standards scenarios were developed for refrigerators, refrigerator/freezers, and freezers for the Czech Republic, Hungary, and Poland. Scenarios were not developed for Slovakia due to lack of data, but by 2000, the amount of fossil fuel used for electricity in Slovakia is expected to be negligible if nuclear power plant construction goes ahead as planned, so no CO_2 reductions would be achieved through standards on appliances using electricity. Other CEE countries, such as the Baltic states, were not included in this analysis. Calculations were made for these countries in the CIS analysis in section 5, but it is likely that the results shown in Figure 12 below are more representative for countries such as Estonia than the CIS results shown in Figure 13.

The base case scenarios assume the European labelling scheme will be anticipated from 1995, and adopted in legislation by 2000, since most Central European refrigerator stock is imported from EU countries. The new refrigerator brands are assumed to be similar to those in Western European countries, and the way people operate the appliances, and room temperature is also assumed to be similar to Western European operating conditions. The existing stock has been modelled on average representatives of three main appliance categories. Uncertainties in the analysis include the assumed mix of refrigerator/refrigerator-freezer/freezer stock, consumers' reactions (it is assumed they do not buy bigger appliances with the money saved), and assumptions on economic development and integration into European structures.

Figure 12. CO_2 emissions scenarios for refrigerators/freezers in central and eastern Europe



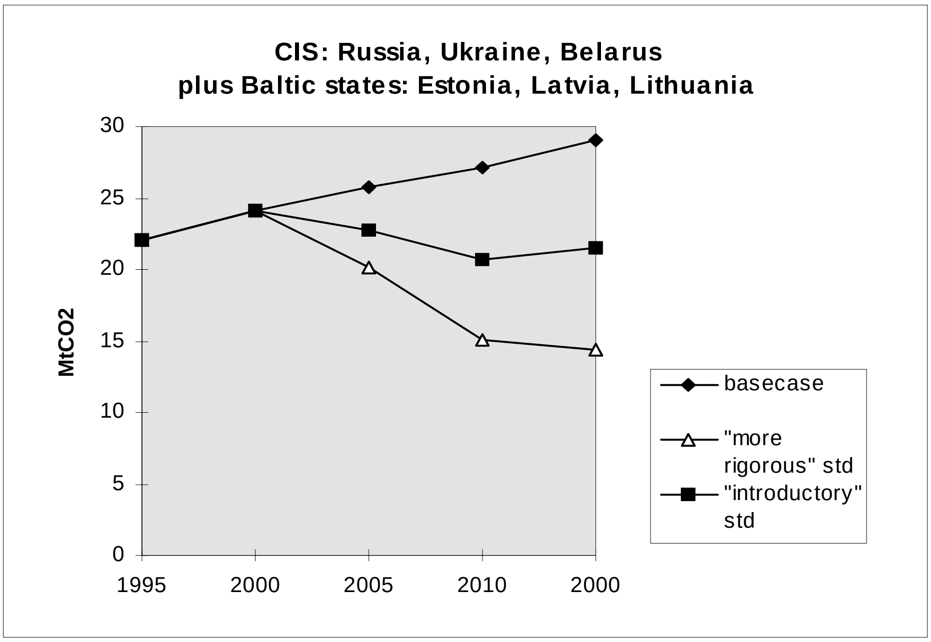
Source: OECD

For Central Europe, base case emissions decrease throughout the period, due to replacement of inefficient appliances by more efficient ones. In the year 2010, CO_2 emissions are estimated to be 2Mt lower than base case in the "introductory" scenario - a 14 per cent reduction. Under the "more rigorous" scenario, CO_2 emissions are estimated to be 2.5 million tons lower than base case in the year 2010 - an 18 per cent reduction. In the "introductory" scenario, which the analysts consider more feasible than the "more rigorous" scenario for the Czech Republic, 42 per cent of the expected annual electricity consumption of refrigeration appliances in 2020 could be saved, with reductions in annual electricity consumption of 53 per cent for refrigerators, 25 per cent for refrigerator/freezers and 53 per cent for freezers.

Commonwealth of Independent States

A base case and two energy efficiency standards scenarios were developed for six categories of refrigerator/freezer for Russia, Ukraine, Belarus. Several Central and eastern European countries (Latvia, Lithuania, and Estonia) were included in this analysis, but, as noted above, for at least some of these countries, the analysis in section 5 may be more appropriate. Refrigerators manufactured in the CIS currently have much higher energy consumption than the levels of standard assessed in this study, and unlike other regions, base case emissions in this region are expected to rise significantly throughout the period as the eastern European economies recover and disposable income rises. More households are expected to purchase refrigerators (the market is not yet saturated), and consumers are expected to demand larger refrigerators with features such as automatic defrost, which uses more energy.

Figure 13: CO_2 emissions scenarios for refrigerators in CIS



Source: OECD

Very large energy savings and related CO_2 emissions reduction can be achieved from implementation of higher standards. (Even making the existing voluntary energy efficiency standards mandatory would lead to energy demand reduction). In the year 2010, the “introductory” standard reduces CO_2 emissions by 2 million tons, a 23 per cent reduction compared to base case. Under the “more rigorous” scenario, the CO_2 reduction in 2010 is 3 million tons, compared to base case, a reduction of 45 per cent.

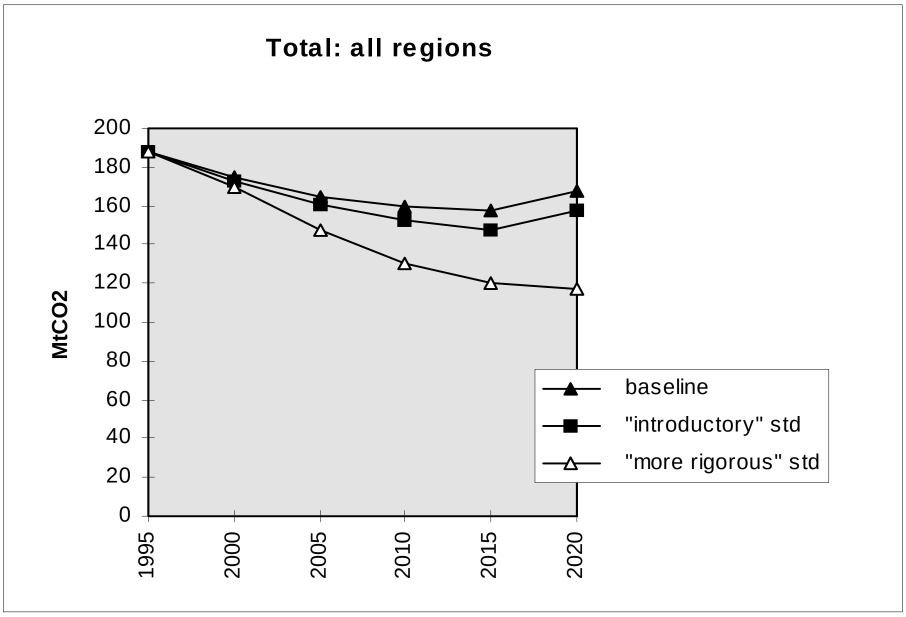
For some product categories (for example, some types of refrigerators with very low efficiency), the scenarios require minimum energy performance levels between 1.5 times and 3 times higher than the current performance of new products in those categories, so that all of the models currently in that product category would be removed from the market under the new standards. To meet the “more rigorous” standard, energy efficiency would have to be improved by over 100 per cent in four of the six product categories considered.

Uncertainties in the analysis include the base case assumption that refrigerator saturation per 1000 inhabitants will increase by 8 per cent over the period (energy consumption would be 6.3 per cent lower if saturation remained at 1993 level), population growth (±0.1 per cent change from base case would result in ±2.7 per cent change in electricity demand), and the assumption of substantial changes in stock composition towards more efficient but larger refrigerators with features such as automatic defrost (if stock composition remained static electricity demand would be 1.3 per cent lower).

Total potential: all regions

Total CO_2 emissions from refrigerator/freezers in 1995 are 188 $MtCO_2$ in the combined regional scenarios.

Figure 14: Combined CO_2 emissions scenarios for refrigerators/freezers for all Annex I regions



The regional results have been added together for the graph above. The refrigerator/freezer scenarios may not be directly comparable because different products were assessed in different regions, and differing assumptions (described above) were used. There were also many uncertainties in the analyses (described above), and 6 Annex I countries have not yet been included in the analysis: Australia, New Zealand, Slovakia, Bulgaria, Romania, and Iceland. Source: OECD

In the combined base case scenario, CO_2 emissions fall to 160 $MtCO_2$ in the year 2010 and rise again to 168 $MtCO_2$ in 2020 (mainly because of the expected United States pattern of emissions).

The combined scenario results suggest that in the year 2010, around 7 $MtCO_2$ could be saved from implementation of the “introductory” standards in all Annex I countries - a 5 per cent reduction. This result is in addition to the 30 $MtCO_2$ emissions reductions that are expected to occur in any case without the standards; i.e. in the base case. The “more rigorous” combined scenario results suggest that in the year 2010 around 30 $MtCO_2$ could be saved from implementation of the “more rigorous” standards in all Annex I countries - a reduction of 18 per cent compared to the emissions that are expected to occur without the standards.

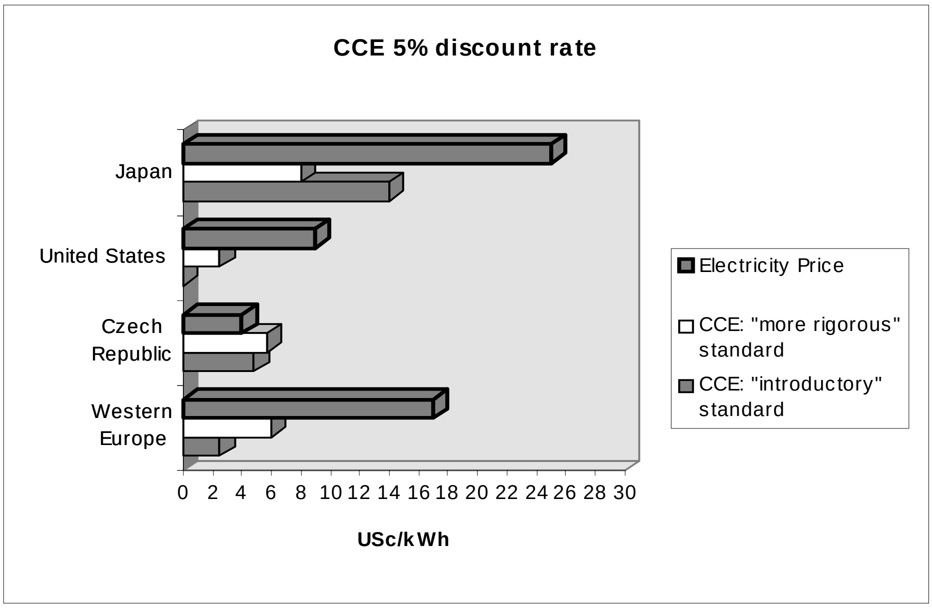
Economic effects (costs and benefits)

Cost to consumer

For each region, the cost of conserved energy (CCE) for refrigerators/freezers was calculated. The method used was to estimate the increase in product price under a standard and divide this by the physical amount of energy saved, discounted over the lifetime of the products at two discount rates - 5 per cent and

10 per cent[7,8] If the CCE is less than the electricity price, the investment is assumed to be cost-effective for the consumer. The CCE results from the regional scenarios are shown in Figure 15 below, with electricity prices for comparison.

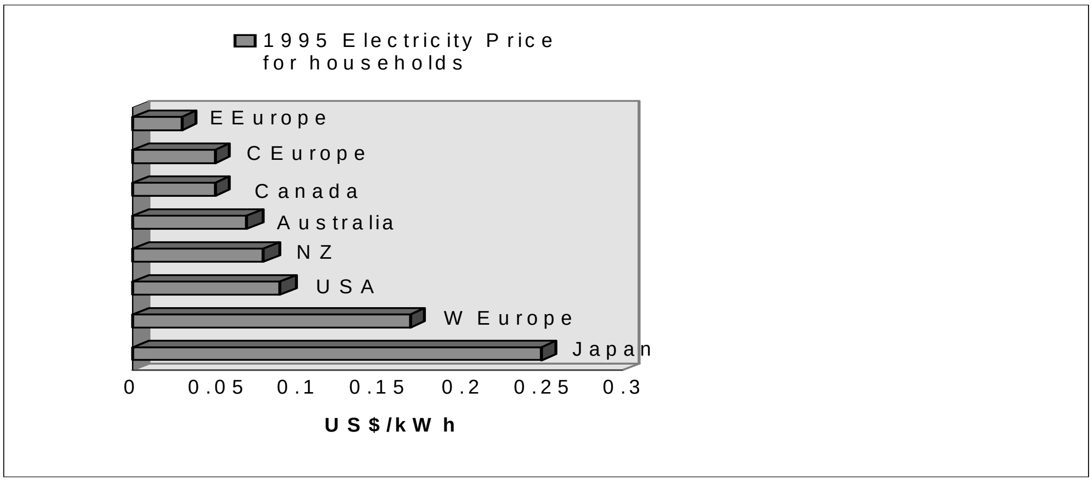
Figure 15. Cost of conserved energy for refrigerators/freezers, at 5 per cent discount rate



Source: OECD

Electricity prices vary greatly between countries, depending on the cost of fuel and subsidies. The electricity prices from a number of Annex I countries are presented in Figure 16 below:

Figure 16. Electricity prices



Source: OECD

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7 The formula used is: $CCE = \delta C/\delta E[(1/i)[1-(1+i)^{-t}]$ where δC is the increased first cost of the appliance to the consumer, δE is the physical energy saved (kWh) compared to base case, $[1-(1+i)^{-t}]$ is the formula for discounting the physical energy saved, i is the discount rate, and t is the lifetime of the product.

8 To reflect a societal perspective that values the future more highly than current market rates do, much lower discount rates could be used for the CCE calculations, such 0 to 5 per cent. To reflect typical rates demanded by consumers, much higher discount rates than the 5 to 10 per cent could be used.

The regional scenario results suggest that improving the efficiency of refrigerators and freezers can be very cost-effective in many Annex I countries if electricity prices are above about 5 to 8¢/kW ,according to the estimates presented in Figure 15 above. However, it must be emphasised that the assumptions on cost increases for manufacturers made by the regional analysts are very uncertain in some regions, due to lack of data (e.g. Japan, central Europe). No cost estimates were made for eastern Europe for this reason. Changes in the assumptions on increase in costs to the manufacturer would significantly alter the CCE results, but it is likely that the CCE results here are likely to be too high (see discussion in section 5).

In western Europe, the CCE is estimated to be 6¢/kWh for the "more rigorous" standard, and 2.5¢/kWh for the "introductory" standard compared to an average residential energy price (including taxes) of 17¢/kWh in Europe. In North America, too, the highest CCE of 4¢/kWh for the "more rigorous" scenario is less than half the average residential electricity price of 9¢/kWh. For Japan, the CCE is much higher, between 8 (for the "more rigorous" standard) and 17¢/kWh (surprisingly, for the "introductory" standard), mainly because of a very high assumed increased first cost (for the "most rigorous" standard) and very low assumed energy savings for the "introductory" standard.[9] However, the Japanese CCE is still well below the residential electricity price of 25¢/kWh (average price including taxes in 1994). Thus, for OECD countries in the Annex I group, energy efficiency standards provide a net economic benefit for the consumer: the value of electricity saved more than repays the increased first cost of more efficient refrigerator/freezers.

However, for countries with economies in transition, product standards may not be cost-effective for residential consumers who purchase more efficient appliances at present residential electricity prices. The cost-effectiveness analysis in these countries is complicated by the fact that residential electricity prices are still subsidised (although prices for industry have been raised towards market levels). The cost to society of producing electricity in these countries is therefore likely to be higher than the cost to the residential consumer. Unfortunately, no data are available on the cost of electricity supply in central and eastern Europe. For the Czech Republic, the CCE is between 5 and 8.4¢/kWh, and residential electricity prices are still very low - on average, 4¢/kWh in 1995. The result is that even at the "introductory" level, product standards would not be cost-effective to the consumer. The relatively high CCE for the Czech Republic is also a result of the price differential between more efficient products and current products.[10] The CCE presented in Figure 15 for the Czech Republic may not be representative of other CEE countries that have not made as much progress in their transition towards a market economy and suffer high inflation rates and other structural economic problems.

Low residential electricity prices in eastern Europe (2 to 3¢/kWh for residential consumers compared to 9¢/kWh for industry) are likely to yield a similar result for these countries.[11] Product energy efficiency standards may become more cost-effective for residential consumers in countries with economies in transition if electricity prices rise sufficiently. For example, for the Czech Republic, the regional analysts advise that residential tariffs could rise to 7¢/kWh by 2000 and to 9¢/kWh by 2020 if planned reductions in cross subsidies are implemented.

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9 It is interesting that for Japan, the "introductory" level of standard is estimated to would have a higher CCE than the "more rigorous" level, because although the cost of the appliance increases less under the "introductory" standard, the energy savings from this standard are estimated to be very small. The incremental cost estimates for Japan, were however, very uncertain as manufacturers' estimates of the cost were not available.

10 The estimates take into account expected reductions in the price differential in future.

11 Unfortunately the data needed for the Eastern European CCE calculation could not be collected in the time available for this study.

The main uncertainties in the CCE calculations are the additional first cost of more efficient products, assumptions about product lifetimes, and discount rates (see assumptions for each region next page). Increased first cost of products, in particular, may be much lower than assumed in these calculations, based on information on the costs of previous standards in the United States.

The CCE results show that the cost-effectiveness of product standards are different in different countries. The levels of energy efficiency assessed here would be very cost-effective in many Annex I countries when the increased product price is compared against the value of the energy that the consumer is expected to save over the lifetime of the product. However, these energy efficiency levels are either not cost-effective or are certainly less cost-effective in some countries. The factors that influence the cost-effectiveness of energy efficiency standards are:

- current and future energy prices (which determine the value of the saved energy);
- preferred technology types (refrigerator features differ significantly between regions);
- manufacturing costs.

Countries with low energy prices (such as residential electricity prices in countries with economies in transition), and/or have high manufacturing costs are less likely to find energy efficiency standards cost-effective. Given the wide range of energy prices, fuel mixes and levels of energy efficiency in Annex I countries, no single level of energy efficiency will be ideal for all from a cost-effectiveness perspective. It would be optimal for each country to assess the extra cost of various technical options for improving energy efficiency, and compare the value of the energy savings that would result over the lifetime of the products if the technical options were implemented. The lowest extra cost with the highest energy savings would be optimal, and this will differ by country. However, it may be necessary to accept less than optimal levels of energy efficiency in terms of cost-effectiveness for the sake of achieving trade gains from adopting the same levels of energy efficiency within regional sub-groups of Annex I countries (discussed in Section 3 as a "rationale for common action").

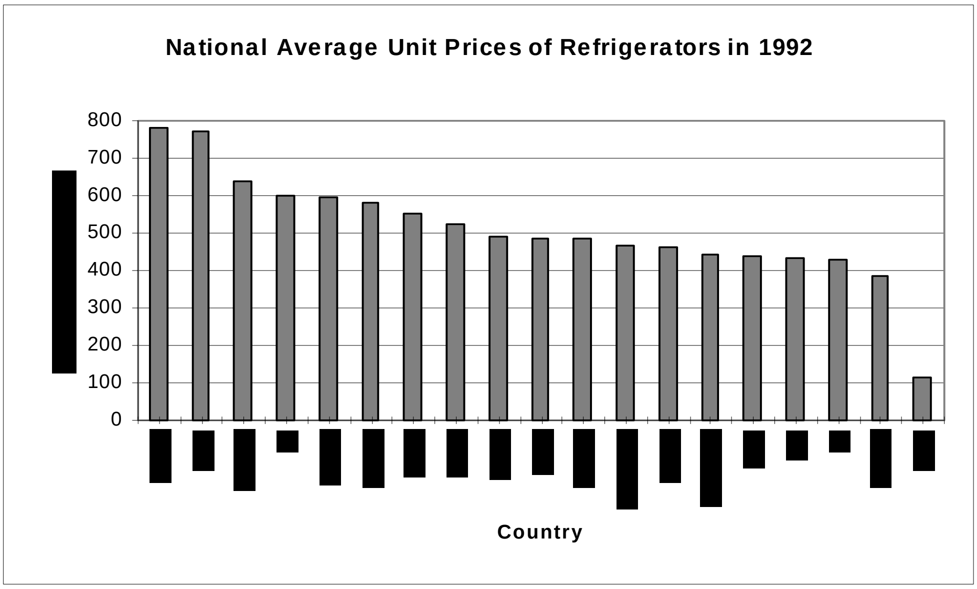
Effect on prices and cost to industry

It is difficult to predict the impact that common action to adopt product standards would have on prices faced by consumers. Increases in first cost are not necessarily fully reflected in increased prices: manufacturers may choose to reduce profit margins so the price increase is lower than the cost increase, or if the cost is fully passed through to retailers, the retail outlets may put a simple percentage mark-up on the products so that the price increase could be higher in absolute terms than the cost increase.

Retrospective analysis of the United States 1990 and 1993 refrigerator standards has shown that consumer prices increased less than had been expected before the standards were introduced. The latest research indicates that quality-adjusted prices continued to decline over time, consistent with historical trends, after the implementation of standards in the United States in 1990 and 1993. This suggests that the standards did not have a discernible effect on prices. Amenities, such as volume of refrigerators, defrost type, and shelving configurations, were not diminished, and for some product classes, amenities actually increased after standards. Consumers received the expected efficiency increases and energy savings at lower costs, together with higher levels of cold food storage services (McMahon *et al* - Technical Annex). This experience suggests that the *ex ante* CCE estimates prepared for this report could be too high.

Refrigerator prices vary considerably for the same model sold on different markets and are often as much a function of what the retailer believes the market is prepared to pay for a given product as they are a reflection of the cost of manufacture.

Figure 17. Prices for refrigerators



Source: IEA 1996[12]

It is possible that under common action on standards, some highly priced manufacturers would face increased competition and would have to lower their prices, in which case, the cost to the consumer would actually fall. However, people in different regions tend to like different features in their refrigerators/freezers, so the effect of competition between regions may be limited.

The United States 1993 standards are higher than the "introductory" level, which is modelled on the proposed European Union standards, but lower than "more rigorous" level. As prices did not increase when the 1993 level standards were implemented in the United States, it is likely that prices from "introductory" level standards will not rise in western Europe, either. Waide indicates that under the EU proposal (the "introductory" standard scenario) the increase in first cost of refrigerator/freezers to European producers is likely to be minimal (see Technical Annex). The European Union proposal aims to achieve an overall 15 per cent improvement in energy efficiency (both old and new stock), compared to the 1992 average. Development of new technologies is not necessary to achieve these gains in average efficiency. The proposed European Union standards are considered likely to lead to only a small number of appliances being removed from the market because during the period of four year notice, most suppliers would have replaced about one third of their model range and most refrigeration appliance models which would still fail to comply with the proposed minimum efficiency standards would only require minor design changes to comply.[13]

In central and eastern Europe, the increase in first cost is likely to be higher under the "introductory" level of standard than in the United States or western Europe because existing standards are lower. Moreover, in the context of very low monthly incomes in central and eastern European countries, even a small increase in price would be a burden to consumers. In Russia the price of a refrigerator at the end of 1994

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12 Since the introduction of the European Union labelling scheme, prices have dropped by 20 per cent on the Danish market (personal communication, Peter Karbo) - and the same may be true of other western European refrigerator prices.

13 Reference: Proposal for a European Parliament and Council Directive on energy efficiency requirements for households electric refrigerators, freezers and their combinations, European Commission, COM(94) 521 final; (cited in Gusbin 1995).

was 941 thousand roubles, which is more than twice the average monthly salary (CENEf 1996 - Technical Annex). In the Czech Republic, refrigeration appliances typically cost between one and three times the average monthly salary (SEVEn 1996 - Technical Annex).

The levels of standards proposed and the time frame for implementation are not expected to create major difficulty for EU manufacturers (European Commission, 1994). In fact, if the standard were higher, the potential effects on innovation (reinforced by those from the labelling Directive) could actually increase their competitiveness. A US Department of Energy study on refrigerators/freezers standards in the United States also found that in the long run, the refrigeration appliance industry as a whole is more likely to experience an increase in profits than a decrease when efficiency standards are imposed, even in case of high performance levels such as under the “more rigorous” scenario (US DOE, 1989).

Another possible cost to industry is the cost of complying with technical documentation and accompanying test reports required under the self assessment procedure. Quantitative information on this cost is not available, but the cost of documentation is likely to be reduced if test procedures are harmonised among countries.

The figures used by the regional analysts to calculate the cost of conserved energy were generally derived from manufacturers’ estimates of the increased cost of producing more efficient products. The assumed increases in product cost (and product price) in the regional scenarios are shown in the table below:

Table 4. Key assumptions for refrigerator/freezer analysis

Region	Product price $US 1995	“introductory” extra cost $US per appliance	per cent increase	“more rigorous” extra cost $US	per cent increase
North America					
Refrigerators	730	not applicable	0%	58	8%
Freezers	443	not applicable	0%	16	4%
Japan	1000	30	3%	120	12%
western Europe					
Refrigerators	533	7	1.3%	21	4%
Refrigerator/freezers	770	0	0%	135	18%
Freezers	480	2	0.4%	56	12%
central Europe					
average	400 to 500	90	18%	130	

For the U.S. 1998 “more rigorous” level standards, the $58 extra cost to consumers in North America is an 8 per cent increase in average refrigerator purchase prices (which is expected to be around $730 in the year 2000). For freezers, the $16 increase is only a 4 per cent increase over freezer purchase price (expected to be $443 in 2000). For other regions, such as Japan, western Europe and central Europe, the cost to manufacturers of changing to the US 1998 “more rigorous” level of efficiency is probably higher because the gap between current efficiency and the level of the standard is greater. However, if standards are announced well in advance, so that industry can change product lines at the time that it is most cost-effective, and if product lines become larger through implementation of common product standards, the cost to industry should be small. Again, it should be noted that based on the United States experience, efficiency improvements have empirically been found to be much cheaper when analysed after implementation, than assumed before implementation.

Technical Potential

The technical potential of refrigerators/freezers depends on both the energy intensity of the technology (kWh/litre/year) and the size and features (such as separate freezer compartments, and through-the-door ice) of the appliances. Some refrigerator models available today use one half or less electricity than other models within the same type and volume category, and are not necessarily more expensive (Gusbin 1995). The energy intensity of new models today ranges from 1 to 4 kWh/litre/year (see section 5). The best commercially available technology requires only about 90 kWh/year, or 0.45 kWh/litre/year (IEA 1989, p.113).

7. EFFECTS OF OFFICE EQUIPMENT STANDARDS[14]

Approach

The study develops a base case and two energy efficiency scenarios for the United States, Canada, Western Europe, Japan and Australia/New Zealand. Regional scenarios for office equipment were developed using a spreadsheet model that explicitly treats changes in power and energy use for five categories of equipment. The emissions of carbon dioxide associated with the electricity use from office equipment was estimated for each region by year. These scenarios have only been taken to the year 2010 because the expected rapid evolution of office equipment technology makes it impossible to draw conclusions very far in the future based on the type of office equipment available today.

The “introductory” scenario assumes that the US Energy Star program requirements are implemented in each region, taking effect in 2000, in accordance with a most likely estimate of the market penetration of the technologies. This penetration rate is expected to be reasonably accurate for the other regions, as well, because the market for office equipment is global. In fact, the voluntary Energy Star energy use levels and labels are now being used by most major manufacturers of office equipment in North America, and their use is rapidly expanding outside North America, as well. Implementing international standards at Energy Star levels would only accelerate a process which is occurring already. The “more rigorous” scenario assumes that Swiss and proposed Danish standards, which are the most rigorous standards that are expected to be implemented in the near future, are implemented in each region, taking effect in the year 2000.

The five categories of office equipment are: personal computers, monitors, printers, copiers, and fax machines. These categories are briefly explained below and defined in detail in the Technical Annex.

Personal Computers. Desktop and deskside micro-computer systems with a central processing unit (CPU), basic storage, keyboard, and monitor are included in the analysis. Laptops, personal computers servers, or mainframe, and minicomputers are not included (nor are home computers).[15]

Monitors. This product category covers display terminals using cathode-ray tube (CRT) displays, including those used with personal computers, mainframes, and mini-computers. Features such as colour, resolution, and size influence power requirements. Today's personal computers users are buying larger, higher resolution colour CRTs, whereas the typical monitor five years ago was a smaller (14 inches) monochrome. Flat-panel displays used with today's laptop computers use far less

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14 The full report by Jim McMahon, Mary Ann Piette et al is in the Technical Annex, available on request from the OECD.

15 Omitting laptops could be significant, as these products are a large part of the market. However, these products are inherently energy efficient, so only very small gains in energy efficiency could be made. Home computers could also be a significant omission because this market is expected to grow rapidly in future. However, at present, this part of the market is small and there is very little information on the hours of use, which is a key assumption in the analysis.

power than CRTs, but their high cost currently limits their use to the laptop arena, although this may change in the future. There are three types of flat-panel displays: liquid crystal (LCD), plasma, an electroluminescent emission (EL). Colour LCDs are likely to increase their share of the monitor market.

Photocopiers. The majority of photocopiers in the commercial sector use heat and pressure technologies to fix an image to paper. Several factors influence energy use per page, such as whether duplexing is used, the size of the copy job, and speed. Many copiers have energy-saving features to reduce standby power by 20 to 40 per cent.

Printers. There has been rapid change in the last decade from impact printing such as daisy wheel and dot-matrix techniques, to non-impact printing, dominated by energy-intensive laser printing. We are primarily concerned with laser printers, including colour and high speed printers. Like copiers, printer energy use is generally linked to print speed. Energy use is also strongly related to volume. Most of the energy is consumed while the printer sits idle keeping the rollers warm.

Fax Machines. Facsimile machines send and receive information from printed documents or electronic files over telephone lines. Three common types of fax machines are: direct thermal, laser, and inkjet. We restrict our discussion to the laser fax, which has the broadest market share and uses the most energy. The fax machine was little known a decade ago, but is widely used in office's today. It is likely that this technology will change quickly again in the next decade. Fax cards used with computers suggest the possibility of a future with reduced paper communication by eliminating the need to print a document before sending it.

Greenhouse Gas Emissions Reduction Potential

The base case scenario (see Figure 18) shows a steady increase in office equipment energy use from 1995 to 2010. This base case assumes that today's technology is used to the year 2010. Technology change in office equipment is occurring very rapidly, but it is not possible to foresee these changes or judge their impact on energy consumption. The main factor driving the increase in energy use is increased equipment densities per unit of office space, especially personal computers and monitor densities. Printer and fax machine densities are assumed to rise over the period. Copier densities are expected to increase only slowly. Office equipment energy use nearly doubles from 59 TWh in 1995 to 94 TWh in 2010.

The "introductory" standard scenario assumes that standards equivalent to the current voluntary Energy Star levels are announced in 1996 and implemented in 2000, so some impact is felt from the standard before it is implemented. Results from the "introductory" standard scenario show that the growth that is expected in the base case is held in check. Energy use increases only 8 TWh between now and 2010 in the "introductory" scenario. Although active power requirements are the same as in the base case, improved power management (e.g. suspend and standby modes), is expected as a result of the "introductory" level standards. In the "more rigorous" scenario office equipment energy use actually declines between now and 2010, although there is some growth between energy use in 2005 (31 TWh) and 2010 (35 TWh) because increases in equipment densities are expected to dominate over decreases in equipment power per device.

In 1995, the five categories of office equipment were responsible for nearly 30 million tons of carbon dioxide. The greenhouse gas emissions from office equipment energy use differs from the energy savings estimates by country for each scenario because of the different fuels used for electricity generation. CO_2 per kWh is highest in the US, where in 1995 emissions from office equipment accounted for over 75 per cent of total emissions from the countries included in the analysis. CO_2 per kWh is lower in Japan, and therefore accounts for a smaller percentage of the CO_2 emissions from office equipment. Figures 18 shows the CO_2 emissions reduction estimates for the baseline, "introductory", and "more rigorous" scenarios, and Figure 19 shows the distribution of the emissions reductions by region.

Figure 18. CO_2 emissions from office equipment

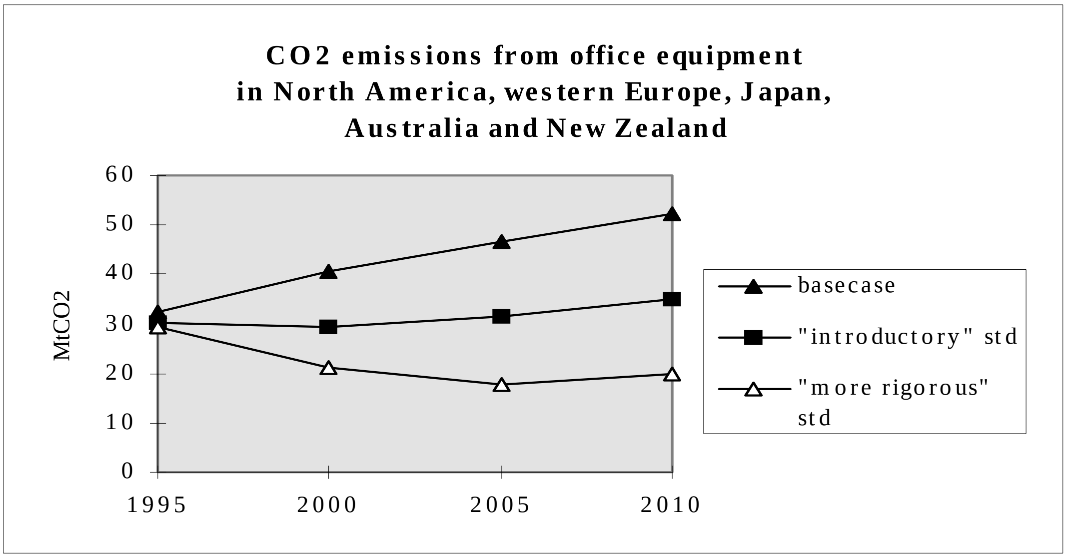


Figure 19. CO_2 emissions by region

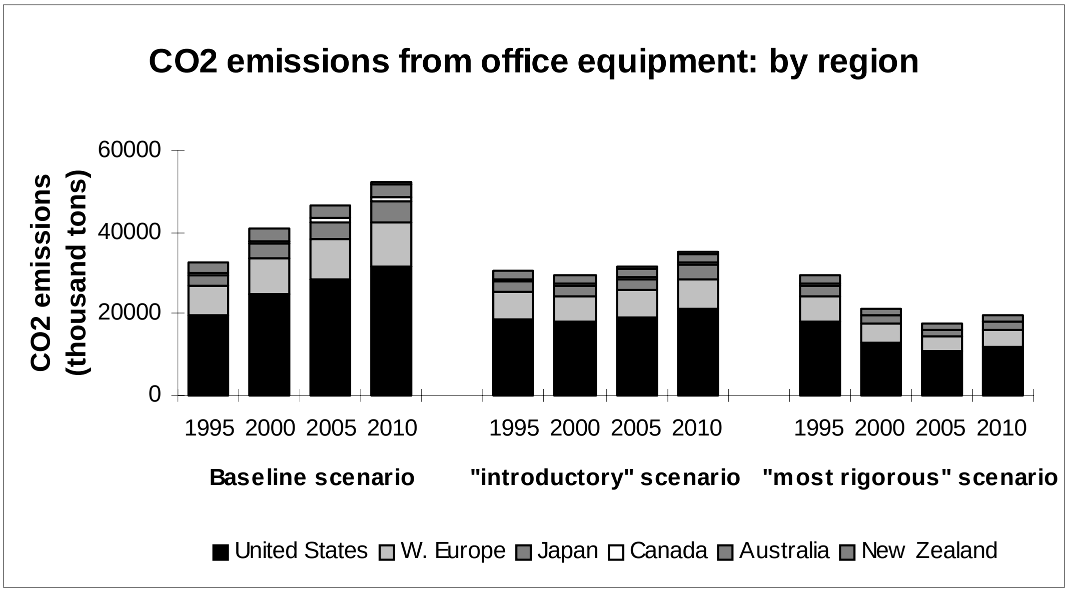
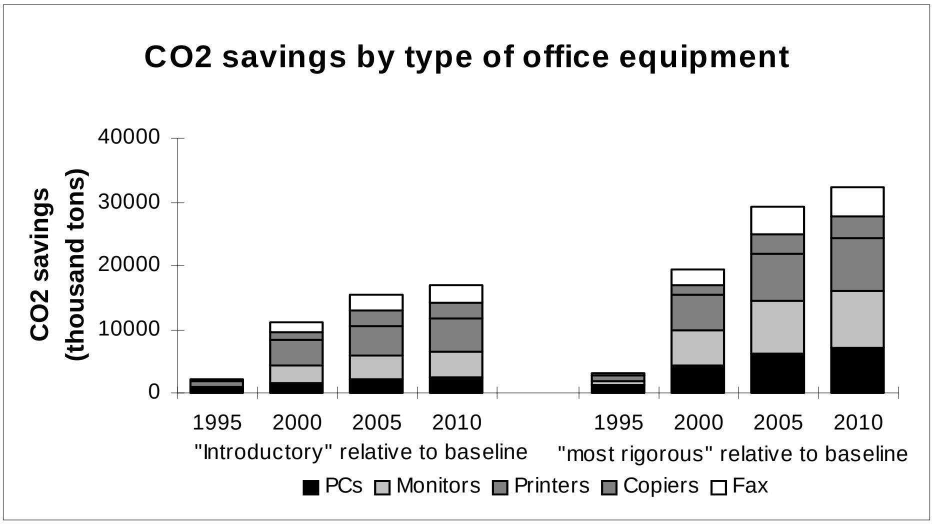


Figure 20. CO_2 reductions by equipment type



The greatest CO_2 savings compared the baseline scenario are from printers in 2000 (7 TWh), and from monitors in 2005 (8 TWh) and 2010 (TWh). In taking the next step to the "more rigorous" standards, energy savings from advanced power-management in monitors continues to be the most important, followed by energy savings from personal computers and printers.

Assumptions

Energy use by region is derived from commercial floor space estimates. Estimates of office equipment by building type have been made for each region. Density of office occupancy is assumed to be 28 square metres (300 square feet) per person. Occupant density is changing over time as information technology continues to redefine the nature of the workplace, so any such estimate is inherently uncertain. Growth rates in equipment densities were estimated from industry forecasts of equipment sales, and estimated lifetimes for each type of equipment. Equipment density is assumed to saturate at just under one per person in 2050. Power levels are estimated from measured data, trade press assessments, personal communications from industry participants, and the Energy Star requirements. No assumption is made about autonomous energy efficiency improvements. The analysts advise that autonomous improvements have been found not to be relevant or plausible in modelling energy use trends in office equipment, because office equipment is changing too quickly to compare products over time.

The majority of assumptions on the penetration and performance of the office equipment in the US are assumed to be representative of the European and Japanese conditions as well. Commercial floor stock by region was provided by regional analysts, but the density of office equipment is assumed to be the same as US equipment density in all countries that are included in the analysis. This is a simplification, and a source of uncertainty. It is unlikely that equipment densities in the US are the same in other countries, but estimates of commercial floor space and office equipment stocks are difficult to compile. The problem may be mitigated to some extent, however, because although the US may have higher penetrations of office equipment per occupant, it is likely that the average US office is larger. Even taking this into account, however, it is likely that the baseline energy use and savings estimates shown by the scenarios may be over-estimated.

Table 5. Commercial Floor Area (million m2)

	US	Canada	Japan	W. Europe	Australia	New Zealand
1995	6390	642	1495	3117	439	131
2000	6723	676	1599	3225	468	154
2005	7003	704	1743	3329	499	207
2010	7286	733	1887	3434	533	214

Table 6. CO_2 Emission Factors by Region (g/kWh)

	US	Canada	Japan	W. Europe	Australia	New Zealand
1995	611	180	369	450	975	131
2000	608	180	359	450	970	154
2005	622	180	369	450	964	207
2010	621	180	366	450	932	214

Table 7. Amount of time in use, for each product category, by mode

	PCs and Monitors	Copiers	Printers	Fax
Fraction of year active	9%	4%	1%	4%
Fraction of year standby	13%	14%	4%	96%
Fraction of year suspend	13%	29%	30%	0%
Fraction of year off	65%	53%	65%	0%
Daytime diversity	76%	100%	76%	100%
Night-time and Weekend diversity	18%	20%	18%	100%
Weekend diversity:	20%	20%	20%	

Table 8. Average lifetimes for office equipment

Device type	Lifetime (years)
PC CPUs	4
Monitors	4
Laser Printers	6
Copiers	6
Fax machines	6

The equipment lifetimes in the table above are estimates of the average economic life of the equipment from the U.S. Internal Revenue Service's Depreciation Tables, which show "lives" of dozens of classes of commercial and industrial equipment (IRS 1989). These lifetimes, in combination with projected equipment sales, are used to calculate the equipment stock in any year. Lifetimes are used in the forecast by assuming that equipment put in service in a given year is all retired at the end of its average lifetime. This approach, while crude, is a reasonable approximation in the face of the rapid turnover of the office equipment stock. The lifetime estimates are uncertain. In particular, it is not known what fraction of the equipment actually lasts longer than these lifetimes, in particular, how many appliances "retired" by their first owners are used in other institutions. Somewhat longer lifetimes would reduce the speed at which new equipment penetrates the existing stock, but probably only by a year or two. Office equipment becomes obsolete so quickly that actual lifetimes are unlikely to significantly exceed those in the table above, so these lifetimes can be seen as a conservative assumption. In western Europe, the only figure available for lifetime of office equipment was seven years, but this is close to the top end of the range of figures used (Jacques Roturier, personal communication).

Only commercial sector office equipment is included in this study. The home computing stock is growing, but there are large uncertainties in the estimates of home computing stock and operating patterns for the home user are less well defined. A recent forecast of 1995 personal computers CPU stocks for residential use is 11 million, with 2 million for industrial applications. Commercial sector use is much larger (41 million - Dataquest, 1993).

The market penetration of each type of office equipment is another important assumption. The market penetration values assumed are shown in the table below. For both energy efficiency standards scenarios, all devices sold are assumed to meet or exceed the standard by the year 2001. Copier and fax machine penetrations reflect the later start dates for the Energy Star programs affecting these device types, but these programs ramp up rapidly. The laser printer market has seen extremely high adoption of power-management in accordance with the Energy Star program, which explains the aggressive market penetration estimates. The fax program is also popular, while the copier program is just underway and subject to the greatest uncertainty.

Table 9. Estimated sales of Energy Star-compliant equipment (per cent of sales)

	PC	Monitor	Laser Printer	Copier	Fax
1992	0%	0%	0%	0%	0%
1993	15%	15%	10%	0%	0%
1994	26%	26%	50%	0%	0%
1995	38%	38%	90%	10%	10%
1996	49%	49%	100%	20%	50%
1997	61%	61%	100%	40%	100%
1998	72%	72%	100%	80%	100%
1999	83%	83%	100%	90%	100%
2000	95%	95%	100%	100%	100%
2001	100%	100%	100%	100%	100%

One of the key uncertainties to the energy savings from Energy Star and other standards for office equipment is that only a small fraction of Energy Star CPUs and monitors that are equipped with the power saving features are properly enabled for saving energy. LBNL estimate that only 50 per cent of the personal computers and 70 per cent of the monitors have their power management properly enabled in the United States. This problem has been documented in a series of recent case studies monitoring the energy savings from actual equipment (Nordman *et al*., 1995). In Europe the percentage of personal computers and monitors supplied or operated with these features enabled is very small[16]. Fortunately, the number of personal computers and monitors that are properly enabled is likely to increase. Most of the early

16 Jacques Roturier, University of Bordeaux, comment on early draft.

technical issues surrounding Energy Star equipment should be overcome by 2000, and energy saving features will be built into the equipment as a matter of course.

Office equipment scenarios such as those carried out in this study are far more uncertain than the scenarios on appliances such as refrigerators or freezers. In reviewing work in progress for this study, Dr. Jacques Roturier described some of the key uncertainties:

1. One of the main uncertainties lies in changes in the technical features of office equipment. The continuing rapid improvements in microelectronics and related applications are likely to result in completely new forms of office equipment. Technology improvements are happening rapidly (new products are often developed and brought onto the market several times a year), and it is difficult to foresee the functions, technology or energy use patterns of emerging equipment. For example, it is unclear whether emerging multi-function devices that include printing, copying, and faxing will increase or decrease energy use. It is also unclear how quickly these devices will penetrate into today's marketplace. A second example of technological advances that could greatly influence energy use is the strong possibility that in the future low power flat panel displays (liquid crystal displays like those with laptops) will replace the present CRT (Cathode-Ray Tube) monitors.

2. Another major uncertainty in the analysis is user behaviour. As mentioned above, it is unclear whether users will override the energy saving features of office equipment.

3. Additional assumptions such as market saturation, hours of use and GDP growth (which drive the assumptions about commercial floor space and saturation of office equipment) are also subject to uncertainty. There are also problems with the floor space and stock data. For example, western European floor stock data shows total commercial floor space as less than half of the United States estimate for commercial floor space, but western European office equipment stocks are estimated to be larger than United States equipment stocks. Even given the fact that the commercial floorspace per capita in the U.S. is higher than the commercial floor space per capita in Europe, it is likely that the western European floor space estimates are underestimated. Because the scenarios are based primarily on floor space estimates, the energy savings for Europe may be underestimated. Similar difficulties may arise for other regions because U.S. estimates for equipment per metre squared of commercial floor space is only a rough proxy for actual office equipment stock numbers in other regions.

4. Saving energy in office equipment will also affect space conditioning. The issue is a complex one because these effects vary regionally and by building type. This study has not included extra savings that may occur from cooling energy reductions. Preliminary analysis of cooling savings from lower energy use in large offices shows additional savings of 10 to 25 per cent on top of the energy savings estimated in this analysis could be possible in the United States climate. Savings will be less in other building types and climates. There can actually be a heating penalty in cold climates.

Economic Effects (costs and benefits)

Cost to consumer

Cost-of-conserved energy estimates have not been developed for office equipment standards because of the uncertainties associated with evaluating the cost increases of power-managed office equipment. A discussion of the economics of power-managed office equipment is provided instead.

There has been little analysis of the manufacturing cost of developing energy efficient office equipment (McMahon p. 59). Some of the more advanced energy efficient products have considerably higher prices than common Energy Star equipment, but for the standards in this study, significant cost and price increases are not expected. The US Environmental Protection Agency expects that there will not be any additional first costs for Energy Star copiers, for example. The opportunity cost to low standard producers (i.e. value of the alternative uses to which they could put the resources used to produce more efficient products) would be low, given the negligible extra costs incurred. A possible exception is the fastest copiers that are required to have duplexing as the default option, although this is not yet clear. (IEA draft 1996 McMahon p. 60). The office equipment market is competitive, and manufacturers are very sensitive to even small cost increases. For example, even the $5 cost to put sleep modes in desktop personal computers was considered by manufacturers to be too high to consider (McMahon p. 60).

Extensive discussions with manufacturers during the design of the program showed that Energy Star features could be added to personal computers CPUs and monitors at negligible cost to the purchaser (Johnson and Zoi, 1992). Examination of data from a recent trade article showed that there was no cost difference between colour monitors with power-management features and those without (Froning, 1994). Data on direct costs for other equipment types are not available. Because the Energy Star program is voluntary (unlike many standards), and because the office equipment industry is highly competitive, it is reasonable to believe that there is no increase in first cost to manufacturers as they would not subscribe to program requirements that will increase costs to consumers and place the manufacturer at a competitive disadvantage. If there is no increase in product prices as a result of the standard, consumers would gain the full value of the energy savings. These are shown below:

Table 10. Value of annual energy saved per unit compared to baseline, at 10 cents/kWh

"Introductory" standard	$/year
PC	7.7
Monitors	7.4
Laser Printers	14.5
Copiers	26.1
Faxes	16.9

The Swiss low-power targets are more aggressive and there may be significant cost increases in office equipment that meet the "more rigorous" low-power levels. However, there is no data available on the increased first cost to manufacturers expected from these targets. There is likely to be an increase in product prices as a result of the "more rigorous" standard, so consumers would gain only part or none of the value of the energy savings shown below:

Table 11: Value of annual energy saved per unit compared to baseline, at 10 cents/kWh

“More rigorous” standard	$/year
PC	10.1
Monitors	11.0
Laser Printers	20.2
Copiers	43.0
Faxes	23.6

The addition of the more advanced power-management required by the “more rigorous” level of standard would have to cost no more than a few dollars per unit to be cost effective given the short lifetimes of office equipment. The device for which the economics are likely to be most favourable are copiers, which also have a longer life.

In addition to the energy savings for lower energy use, the Energy Star copier program is designed to increase the use of duplex printing (the program states that duplexing should be the default setting). If this program is successful in increasing duplexing rates, consumers will benefit from direct cost savings with the use of less paper. Paper costs are about $0.005/sheet. The average medium speed copier (4 copies per minute) uses simplex copying for 89 per cent of their jobs, and 11 per cent for duplexing (Graff and Fishbein, 1991). An average 40 cpm copier produces about 140†000 images per year which amounts to 124†600 pages simplexed and 7†700 pages duplexed (15†400 images). Doubling the duplex rate to 30†000 images per year saves about 15†000 pages per year which is $75/year, which is nearly twice the dollars of the energy savings. In addition, there are energy savings associated with saving paper that should be taken into account, and external costs associated with electricity production will be lower. These potential impacts are not assessed here, but they make the policy more cost effective than it would be based simply on the expected direct dollar savings to business consumers.

Technical Potential

The main energy savings in personal computers are from improving power management in standby and “power down” features. The potential for low power use in power-managed personal computers is impressive. Power managed personal computers require only 0.9W in the “standby” mode, and the time taken to go from standby to active is less than one second (Dandridge, 1990). Powering down disk drives takes the personal computers into a deeper "suspend” mode, with power at 0.06 W, requiring only 3 seconds to power up to an active "ready" state. (IEA draft, 1996). Current non-Energy Star personal computers use 70W in both active and idle mode. Energy Star personal computers available today use 45W in active mode and 25W in idle mode (Piette, 1995).

Increased energy efficiency for photocopiers could be achieved by suspend power savings, auto-off feature and greater use of duplexing. Total energy use for photocopiers with all three strategies would be reduced by about 30 percent (Table 2-4). Further energy savings may be achieved in the future with high-resolution inkjet copying, highly focused light sources, and low-voltage chips.

The newest information processing technologies that could revolutionise image processing are multi-function devices. Multi-function devices may contain some or all of an integrated image processor, combining printer, fax, scanner, and copier functions. Multi-function devices have only recently begun to be marketed. Some of today's digital copiers can be used as faxes and printers. One multi-function product even includes a personal computer (Dandridge, 1994).

Dandridge reports that one machine that combines five capabilities costs $4 000, versus about $12 000 for each component (Dandridge, 1994). It is unclear whether these products will lead toward an increase in office equipment energy use, or a decrease. Energy use may increase if the machine is left on during all hours as a fax machine and standby power is high. However, power-managed multi-functional equipment could greatly reduce image processing power requirements since one machine could replace the use of three. Local area network (LAN) connected multi-functional devices could be optimally controlled to maintain lower power levels until a user requested a print or copy job.

8. OTHER ECONOMIC EFFECTS (COSTS AND BENEFITS)

Cost to Government

The cost to government will be low. In the United States, for example, the Department of Energy (DOE), Office of Codes and Standards had a budget of around $10 million in fiscal year 1995, and the cost of developing test protocols, performance specifications, and standards for any one product is a small fraction of the total budget, on the order of hundreds of thousands of dollars per year over several years (IEA draft, 1996). The proposed control and enforcement system of the EU proposed standards is not expected to lead to significant costs to government in the European Union (Gusbin 1995). The cost of other policy instruments that could be used to achieve higher energy efficiency levels varies widely. Voluntary actions and government procurement requirements are typically low cost measures, while public information and education can be expensive.

The cost to the government for running programs such as Energy Star is probably on the order of a few million dollars. This compares to expected direct dollar savings to consumers of more than one billion annually for the United States alone after the year 2000 (excluding paper savings). Adding these costs and benefits together reveals that the Energy Star program will save more than $1 billion annually after the year 2000 in the United States alone, at a cost to society of a few million dollars. (McMahon *et al* - Technical Annex) Hence, the net cost would be negative.

The cost of harmonisation of test protocols to both manufacturers and government is likely to be small, and mostly accommodated within normal activities. However, the political challenges of reaching agreement on test methods and protocols can be significant.

Macro-economic effects

Although no quantitative information exists on macro-economic costs of imposing refrigerator/freezer energy efficiency standards, if industry as a whole does not experience a decrease in profits, as suggested above, it is unlikely that the implementation of the proposed standards will have negative impacts on GDP and employment, and it is possible that standards could have positive impacts.

For both refrigerators/freezers, and office equipment, the costs to industry of meeting either standard is judged to be low. Preliminary work for the common action study found that the "introductory" level standard on refrigerators/freezers would not affect the competitive position of the EU manufacturing industry and commerce, and would not to lead to excessive costs for the European economy since they require relatively modest efficiency improvements, and they give industry a few years of lead time to adapt and to sell their lowest-standard stocks before the new requirements come into force (Gusbin 1995).

The macro-economic impact of standards in the United States has been projected in a variety of studies for the US Department of Energy, in the course of developing US standards. However, little retrospective analysis has been done to verify the projected results. The projections indicated that, for standards enacted to date, and for the proposed 1998 refrigerator standards, consumer prices were expected to increase, but not enough to seriously impact sales of appliances. The net impact on a prototypical manufacturers' profitability was projected to be small. The short-term impact on GDP would be small, while the long-term (positive) impact on GDP would be larger as a result of cumulative energy savings. (McMahon *et al* - Technical Annex)

The ratio of benefits (from reduced energy expenditures) to costs (increased purchase price) for the proposed refrigerator standards in the US, present valued at 10 per cent real, is 2.7, while at 5 per cent, the ratio is 4. The number of jobs that are expected to be created as a result of standards has not been estimated, but the net impact on employment is expected to be positive, as consumers reinvest their savings from reduced energy expenditures elsewhere (McMahon *et al*, Technical Annex).

9. ASSOCIATED MEASURES

Test protocols

Test protocols are used to measure the energy efficiency (and many other aspects) of products. At present, test methods and requirements vary greatly between countries. Common test procedures are a prerequisite for harmonised standards, although probably not essential for other types of common action on standards. Work to develop international test protocols has already been done under the International Organisation for Standardisation (ISO) and International Electrotechnical Commission (IEC). A number of countries follow the procedures set by the ISO to define characteristics and test methods.

Relevant ISO test standards are:

ISO 5155 Household refrigerating appliances - frozen food storage cabinets and food freezers - characteristics and methods

ISO 7371 Household refrigerating appliances - refrigerators with or without low-temperature compartment - characteristics and methods

ISO 8187 Household refrigerating appliances - refrigerators-freezers - characteristics and methods

ISO 8561 Household frost-free refrigerating appliances - refrigerators, refrigerator-freezers, frozen food storage cabinets and food freezers cooled by internal forced air circulation - characteristics and methods

ISO 14000 environmental management standards (not yet implemented).

ISO 9000 regulates production processes (partially implemented).

Most internationally agreed standards, such as ISO standards, do not reflect any particular technical energy efficiency level or characteristic. ISO standards generally provide a basic infrastructure for measurement, testing, sampling, definition, and analysis which facilitates the development of national standards in accordance with a common methodology. This approach is mainly due to differences between standards that have already been developed by different countries.

Internationally compatible test methods reduce the incompatibility of energy efficiency data from different countries and facilitate comparisons of the energy use of products in different countries. Internationally agreed test methods would also reduce the cost burdens that result when manufacturers are required to conduct several different tests to satisfy different requirements.

It is difficult and time-consuming to develop test procedures that are simple and robust. Test procedures must be specific and detailed enough to give reasonably accurate and reproducible results; a conversion technique of the sort used in this analysis to compare refrigerators tested under different protocols would not be adequate in a commercial environment. However, a balance must be struck between accuracy and simplicity to ensure that test procedures do not require excessive measurement precision. The development of standard terminology would also be helpful, as without this, it is difficult to understand power management functions and what sort of power reduction a device can achieve. There are many terms, for example, to describe low-power modes for office equipment: standby, suspend, coma, sleep, and energy-saver.

The complexity of test procedures differs from one product to another. Test procedures for both personal computers and monitors, for example, should account for significant differences in recovery-time to active mode for various levels of low-power modes; many proposed tests do not. Test procedures for products with shorter product cycle, such as personal computers or printers, may need to be updated more frequently than standards for products with longer product cycles, such as refrigerators or copiers.

Once test methods are established, test results on the energy efficiency of different products need to be disseminated. Different buyers, ranging from individuals buying a home computer to small businesses to large corporate and government purchasers (or contract re-sellers, system integrators, etc.), have different information needs. Test results could also form the basis for monitoring the effects of policies.

The cost of harmonisation of test protocols to both manufacturers and government is likely to be small (IEA, 1996). Many countries are already engaged in the development of or adoption of test protocols. In addition, much of the early work of developing draft harmonised protocols has been done, and there is already manufacturer interest in limiting proliferation of standards. In fact, it could be argued that harmonisation of test protocols will be less costly than uncoordinated and independent development for different test protocols and standards by different national or regional jurisdictions (IEA, 1996). However, harmonising test protocols could be complicated and lengthy because of the many different product types, measurement norms, and tests, and because industry will have already invested heavily in testing facilities to suit their own test requirements.

For refrigerators/freezers, it would be necessary to agree on the definitions of appropriate refrigerator categories, and harmonisation of energy and storage volume testing protocols. Significant differences exist between the major regional markets for categorisation of refrigerators/freezers according to such things as cooling service, layout, storage volume and auxiliary features. The international harmonisation of energy testing protocols would require that sufficient product classes be acknowledged to treat all fundamental refrigerator needs equally. The number of distinct refrigerator categories should be expanded to include all the basic types found on the world market, although it might be possible to reduce the number of categories by allowing similar categories to be merged

For most office equipment products, national tests and specifications are not yet in place, but several are under development, and proposed test procedures exist. As discussed elsewhere, for personal computers and monitors, the US Energy Star program is having international ramifications. Co-ordinated international action could either ratify those power levels and help spread compliance with them, or create an alternative paradigm. This presents an opportunity for development of international tests and specifications, in order to avoid the proliferation of different, and perhaps divisive, protocols. Product manufacturers, particularly those serving large segments of the world market, would like to avoid such proliferation. The key will be to identify a credible entity that could develop the international tests. Such an entity should be: representative of diverse regional interests, credible to manufacturers and to energy/environmental interests, and knowledgeable of the technologies and the services these products provide. In addition, some countries might need assistance to bring their laboratories of national supervisory bodies up to an appropriate level of performance so that mutual acceptance of test results from different national laboratories would be possible.

Work is already underway in the APEC's Energy Efficiency and Conservation Expert Group on "Acceptance of Equivalence in Accreditation and Increasing Harmonisation of Energy Standards", with the aim of reducing costs to both governments and business by both acceptance of equivalence in accreditation; and closer harmonisation of standards relating to energy products, appliance and services where cost effective. APEC believes that major trade and economic gains will be made if energy standards can be harmonised, or common protocols agreed. Major benefits will derive from the establishment of a harmonised network of protocols operating in member economies on basic product performance, methods of testing for determining energy consumption, accreditation systems, processes for laboratories, and quality assurance systems and procedures.

The European Free Trade Agreement includes inter-governmental agreements on recognition of tests, and there has been subsequent accession to these agreements by a number of non-EFTA countries. The GATT Technical Barriers to Trade Agreement; Article 5.2 requires parties:

> "to ensure, wherever possible, that their central government bodies: accept test results, certificates or marks of conformity issued by relevant bodies in the territories of other Parties; or rely upon self-certification by producers in the territories of other Parties even when the test methods differ from their own, provided they are satisfied that the methods employed in the territory of the exporting Party provide a sufficient means of determining conformity with the relevant technical regulations or standards".

Monitoring

Monitoring the effects of product standards through internationally agreed indicators and statistics at a relatively disaggregated level would facilitate international comparisons of the progress different countries are making and enable analysis of the effects of energy-related policies possible.

The most commonly used indicator to represent energy efficiency at present is the ratio of energy used (final energy consumption in total, by sector, and sometimes by end-use e.g. space heating) to Gross Domestic Product (GDP). Changes in this ratio are not necessarily due entirely to improved technical energy efficiency, since structural changes (such as shifts to or away from energy intensive industry), lifestyle and behavioural factors influence energy use (the numerator).

Product-specific energy efficiency indicators would facilitate reporting the effects of product standards (as recommended by Annex I Parties for national communications guidelines), comparison of progress between countries (at the product level), and understanding of how effective product standards are under different national circumstances. They would also enhance understanding of what is causing changes in the patterns of energy use. Detailed indicators of energy efficiency would also make it easier to target measures towards specific problems. For example, if the overall number of refrigerator/freezers is rising rather than energy consumption per litre, it may be more effective to encourage people to trade in old refrigerators/freezers than to improve the technical efficiency of the products through product standards.

In order to monitor the effects of product standards across Annex I countries, much more detailed information on the energy consumption of products would be needed. Collecting the necessary data would require considerable planning. Countries would need to agree at the outset on a standard form of the indicator that is both most useful for any particular purpose and achievable, in terms of data collection. With agreed indicators, it would be possible to target data collection to satisfy the agreed priority needs. For example, if the task is to monitor the effects of energy efficiency standards for a particular set of products, agreement might be reached on one or two standard indicators, such as average energy efficiency and size across the stock of existing equipment, and/or the average efficiency and size of the new stock of products sold annually.

At present, energy statistics in most countries do not generally include data on energy end-use by each category of end-use. Some end-use information is available from surveys of actual energy consumption and equipment used and from experiments where actual energy flows are metered to determine how much energy is used for specific end-uses (e.g. space heating). The sales and test data that are needed for product specific indicators exist, but are not always readily accessible. For example, it should be possible to use average results from standard test procedures to provide the data for such indicators, rather than actual measurements of energy use from each product (which would require household appliance metering), and product sales data could be used to estimate product numbers.

To make commercial sales data available, each manufacturer (and importer) would have to provide data on their sales and test data on the energy use of their products. To facilitate this, and to avoid concerns about release of commercially sensitive information, some countries may find it necessary to establish a neutral data collection agency that would collect detailed statistics but release only aggregated data. Some countries already have this type of system, with industry associations collecting data from individual companies and releasing aggregated figures.

To reliably monitor the effectiveness of a standards programme, data collection and analytical techniques would need to be established to determine purchases of products at various efficiency levels, assess changes in habits regarding the use of the products, and estimate how the market would have changed in the absence of the standards. In the European Union, self assessment and reporting by manufacturers is proposed to monitor the effects of standards. Under this procedure, manufacturers will be required to make a declaration of conformity with the standard and to draw up technical documentation and accompanying test reports in support of this.[17] However, this may be difficult to achieve, given industry concern about commercially sensitive data, and setting up a data collection agency might not be possible in the face of government budget constraints.

For climate purposes, information on the energy efficiency of new appliances from internationally agreed indicators (ideally using internationally agreed test procedures) could be reported to the national community in national communications under the Framework Convention on Climate Change. For consumers and retailers, information could be disseminated via international and national information programs, with participation from the industry and trade press, as well as manufacturers, large and small buyers, retailers and distributors, utilities, and others.[18]

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17 To inform consumers and deter firms from placing non-conforming refrigeration appliances on the market, a "CE" label will be put at a visible place on the appliances which meet the standards. However, the European Parliament has proposed a stricter enforcement system based on tests and market inspection similar to that of the United States. This system requires spot inspections and if necessary sanctions if non-compliance with the Directive is found.

18 Consumer information programmes have begun to a limited extent in Switzerland, Sweden, and the United States.

10. POLITICAL FEASIBILITY

Different National and Regional Contexts

Product standards have proven to be politically acceptable in many countries. The political feasibility of product standards in different countries will depend on the type of instrument used to implement the standards. If a legislative approach is used, a possible barrier may be arguments about the disadvantages of formal government regulation of products. This is a common debate, even in countries with a comprehensive body of environmental legislation. Government regulation of products may meet political and commercial opposition.

Product standards are static instruments which can be viewed as preventing more dynamic or creative options from being made. Energy efficiency (or performance-based) standards allow the manufacturers more flexibility to make technological choices than technology-based standards. If sufficient time is allowed between the announcement of the standards and their entry into force, the appliance manufacturing industry will have enough time to adapt in a flexible way. Mandatory standards can be designed so as not to be a "command and control " policy, for example, by taking a performance approach rather than rigid specifications, and by incorporating an explicit cost-effectiveness criterion, as the United States standards do. However, minimum performance standards may not provide incentives for innovation and diffusion of improved technologies, as they only give an incentive to improve the efficiency performance up to the minimum level (although this depends on how high the minimum level is).

Voluntary standards allow more flexibility for industry to adapt dynamically to technological advances in efficiency improvements, and can be implemented more rapidly, but are likely to result in only small improvements in energy efficiency. Lack of agreement over the level of energy efficiency to be achieved proved to be a barrier to implementing voluntary energy efficiency improvements in refrigerators in the European Union, for example. The European Commission investigated the possibility of EU-wide voluntary agreements with manufacturers to improve appliance efficiencies, but this option failed in 1993 because it was not possible to reconcile the requirements of the European Commission with those of appliance manufacturers. The European Commission went on to propose EU-wide mandatory efficiency standards.

In CIS countries, where refrigerator efficiency standards have effectively been voluntary since 1990, very few refrigerator models produced between 1990-1993 met the existing energy efficiency standards, and there has been no barrier to inefficient products being imported to eastern European countries (Cenef Technical Annex). Voluntary measures have not been effective in eastern Europe, given the low energy prices, low awareness of energy efficiency, lack of energy efficiency laws (or lack of enforcement), and absence of competition. A concern for central European countries, if they do not legislate mandatory standards, is that they may receive sub-standard products from western Europe once the proposed standards for refrigerators are implemented.

Most countries rely to some extent on a mix of legislation, technical specifications (such as, for monitoring and testing procedures), and voluntary approaches, but different administrative structures, existing legislation, and socio-cultural characteristics make certain instruments more feasible than others in different countries. Different approaches typically used in different countries to date were described in Section 3.

Barriers to Successful Implementation and Options for Addressing Them

Technological improvements to improve energy efficiency can influence the quality of the service provided. For refrigerators/freezers, extra insulation usually reduces the space available or increases the size of the appliance. The size of refrigerators/freezers and other appliances is standardised in many countries. Changes in thermal insulation that increase refrigerator size could reduce market penetration because of the additional instalment costs that would be incurred.

Monitoring and enforcement costs can be a barrier to mandatory standards, particularly given the large number of products subjected to regulations and the complex technical nature of many standards. Another barrier in some countries may be that the integration of product standards into existing environmental and energy legislation can be difficult.

The time allowed between announcement of the standards and their implementation can greatly affect the acceptability of standards to industry. If too short an interval is allowed, then opposition will be strong from manufacturers who are unable to sell their lower standard stocks and adapt their product lines before the standard is implemented.

11. TIME PERIOD

For the regional scenario analysis, it was assumed that common standards were announced in 1996 and implemented in 2000. It is likely that the effects of standards would begin to be felt from the year the standards are announced. However, the penetration rate of new, more efficient appliances is dependent on product lifetime. The full effects of the product standards analysed would be felt in four to six years (for office equipment) and eight to twenty years (for refrigerators/freezers) once current stock has reached the end of its life and been replaced by more efficient products. Thus, product standards on fairly long-lived products would have some effect on emissions in the short term, but much greater effect in the longer term. Office equipment standards would have greater effect, sooner, than standards on longer life products, such as refrigerators. Refrigerator/freezer standards in Japan (where the refrigerator lifetimes average 8.5 years) would have greater effect much sooner than in the United States (where refrigerator lifetimes average 19 years).

A tighter timescale (e.g. less than four years) for implementation would disadvantage manufacturers, particularly small and medium-sized firms, that would not be able to get rid of their low-standard stocks in time. Gradually increasing standards according to a schedule announced well in advance would minimise costs to manufacturers. In eastern Europe, standards that were introduced in 1987 were brought in gradually, with softer standards to be complied with from July 1988 and stricter standards from January 1991.

It is likely that common standards would take a long time to negotiate. They almost certainly could not be announced in 1996 (as assumed for the scenario analysis in this study). Negotiating common test protocols, which is a prerequisite if harmonised standards are desired, would be very time-consuming. According to one reviewer of an early draft of this study, for most appliances, a transition to world-wide harmonised standards would take 10 to 20 years.[19] Part of the reason for this is that industry has invested heavily in test laboratories, in equipment, buildings and training to be able to test according to local and regional standards, so it may be unwilling to participate in developing new test protocols until the old standards are obsolete.

On a national level, putting the necessary legislation, technical specifications or voluntary approach in place will take varying amounts of time in different countries, depending on the existing legislative or policy framework (e.g. Switzerland already has framework legislation in place, but in some countries the legislative framework for environmental protection is more complex and new legislation might be required). In some countries with major manufacturing sectors and well-established consulting processes, the necessary consultation with interest groups could be time-consuming. It is likely that in most countries a multi-year effort would be needed for developing test procedures, analysis of economic and technological impacts, public consultation or hearings, and publication of documents.

European Union experience suggests that the time needed for researching, planning, and negotiating common standards at Annex I level could be about five years (negotiations began in 1992 and standards should be adopted by 1997). According to the draft European Union Directive on refrigeration appliances standards, Member States should adopt and publish the laws, regulations and administrative provisions necessary to comply with the Directive within three years following the final adoption of the Directive by the Council and the European Parliament (which will probably be late 1996 or 1997). The standards will enter into force from 1 January 2000 at the earliest. In the European Union, even national product standards must be notified to the Commission, which can slow implementation considerably, as the Commission takes up to 18 months to consider the national initiative. The Commission then either rejects it, authorises it, or takes it up to be made into an EU wide proposal, in which case the time-scale for introducing the standard is lengthened still further.

Common action by Annex I countries could be implemented together in steps. For example, in early years, a reporting commitment could be made to gain information, then work could begin on developing common test protocols, and finally common standards could be negotiated. Graduated timing of commitments has a precedent in the proposed EU Directive, where the European Parliament intends to propose amendments to increase the effectiveness of the measure after it has been in place for four years, with possible stricter and faster implementation of the first set of standards and possible introduction of a second set of stricter standards. Alternatively, different steps could be taken by different sub-groups of Annex I countries. For example, central and eastern European countries may find it difficult to agree to the same level of standards as OECD countries, so could take on reporting commitments and contribute to development of test protocols, while OECD countries negotiated common standards.

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19 René Kemna, van Holsteijn en Kemna, Netherlands

12. OTHER POLICY GOALS

The main effects of energy efficiency standards on other policy goals are on environment policy. Energy efficiency contributes to reduced and therefore cleaner consumption of energy, reducing all emissions associated with production of electricity.

Other policy goals include: improvement of trade, economic growth, and reduced dependence on imported electricity. Energy efficiency product standards would also have effects on employment (these are expected to be small, as discussed in the section on macro-economic impacts), trade and foreign investment (discussed below).

13. IMPACT ON OTHER COUNTRIES, TRADE, AND GATT IMPLICATIONS

Impact on Other Countries

Energy efficiency performance standards could have impacts on energy efficiency, greenhouse gas emissions, foreign investment, and trade in non-Annex I countries and non-participating Annex I countries.

In analysis of the impact of the European Union proposed standards for refrigerators/freezers, it was concluded that the adoption of common EU standards would have large repercussions in neighbouring countries outside the EU. In particular, many countries exporting refrigeration appliances to the EU might adopt similar standards to avoid their market being flooded by low efficiency refrigerators banned from EU market, and also to encourage their manufacturing industry to produce more efficient appliances to compete in the EU. In addition, the adoption of minimum efficiency standards at multi-national level was expected to stimulate the diffusion of more efficient technology in several non-EU countries (Gusbin, 1995).

Because white goods are relatively low-technology appliances, there has been a tendency among Western manufacturers to move production toward low-cost production centres such as southern and eastern Europe and the Far East. Malaysia is being used as an off-shore centre of production for Japanese manufacturers seeking low-cost production sites. Thailand, too, is becoming an attractive option as a production base. Electrolux recently established production facilities in Thailand and aims to be one of the top three white-goods suppliers in South East Asia by the year 2000. This movement towards low cost production centres is having a positive impact on foreign investment in non-Annex I countries that can be expected to continue, with or without Annex I product standards.

It is likely that product standards in Annex I countries will increase energy efficiency and reduce greenhouse gas emissions in non-Annex I countries, through technology transfer and export of more efficient products from Annex I countries (where the number of low efficiency products manufactured would presumably decrease even if standards are not placed on exports), and through the influence on non-Annex I producers wishing to export to Annex I countries. United States standards that were implemented in 1990 and 1993 are thought to have already had spillover effects on product efficiency in Europe and other regions.[20] Standards on refrigerators/freezers and especially on office equipment in Annex I countries could have a beneficial impact in non-Annex I countries through reducing consumer energy costs and improving the environment (reducing local air pollution associated with electricity use, and reducing greenhouse gas emissions).

However, non-Annex I countries with lower standards could risk becoming “dumping grounds” for low energy efficiency products if Annex I countries were to adopt some form of common action on energy efficiency standards. Countries without standards or with lower standards would risk being the recipients of sub-standard products from countries with stronger standards, whose producers would seek to export the products they could not sell domestically.

In addition, non-Annex I country manufacturers could lose access to Annex I export markets if they did not to meet the higher standards, or face higher costs in order to meet the requirements of higher standards (although the extra costs of the standards assessed in this study are expected to be low). The proliferation of refrigerator energy efficiency initiatives, in particular, has raised the issue of whether some of these unilateral programmes might present barriers to international trade. The impact of product standards on trade flows is discussed in the following section.

Trade Impacts

The trade benefits of common action on standards is discussed in Section 11 as a rationale for common action. However, for countries not party to an agreement on standards, divergence between product standards can be a barrier to trade because producers serving markets with different specifications are prevented from gaining economies of scale that are available to producers serving just one market, or that would be available under harmonised standards. Producers who sell their products in markets where standards are lower have to make a choice between giving up the higher standards market (in which case, the standard has the same effect as prohibitive tariff or import ban), or making changes to their products to meet the higher requirements (again, having the same effect as a tariff).

Certification and approval procedures can also impose greater costs on foreign competitors than the domestic producers (e.g. it costs more for foreign companies to send samples for certification), and can form a barrier to trade if the certifying body acts in such as way as to prevent or hamper foreign competitors from receiving certification (e.g. charges high fees to foreign competitors or refuses to test their products). In the European Union, the Treaty of Rome (the European Union’s founding agreement) addressed this concern for its Member States by establishing that any good which is lawfully produced and sold in one Member State should be eligible to be freely transported and sold in all other Member States without being further modified, tested, certified, renamed or otherwise changed (Article 30).

If common action on standards were agreed to by Annex I countries, the export markets of weaker standard producers could be limited. For example, if the “introductory” standard were implemented in Annex I countries, products that were below the “introductory” standard would have the Annex I markets closed to them. If the “more rigorous” standard were implemented in Annex I countries, even fewer producers would be able to export to Annex I countries. Annex I countries might be able to export to countries with lower energy efficiency standards, but not vice versa, so there would be no weak standard

[20] Florentine Krause, comment on early draft.

product trade between Annex I countries and reduced trade between Annex I and other countries[21.] The following diagram illustrates the trade flows.[22]

Table 12. Illustration of trade flows

Countries outside agreement	Trade	Countries party to agreement	Trade	Countries party to agreement
weak standards	**weak standard producers trade both ways**	weak standards	**rigorous standard producers export to weak.**	rigorous standards
rigorous standards	**rigorous standard producers trade both ways**	rigorous standards	**rigorous standard producers trade both ways**	rigorous standards

Alternatively, weak standard producers could face increased costs to meet more rigorous standards in Annex I countries, both in terms of having to change their product specifications to meet the energy efficiency requirements, and providing documentation and test results to prove their products meet more rigorous standards.

The implications of Annex I refrigerator standards for non-Annex I countries would be small because at present, and presumably for the foreseeable future, the style, size and function of refrigerators/freezers differs tremendously from region to region and there is consequently very little trade in refrigerator models between regions. Nearly all the models sold within each region are also produced there. The prospect of any significant change in this situation over the near future is slim. However, the two trans-global refrigerator manufacturers, Electrolux and Whirlpool, and other trans-global manufacturers that may emerge would benefit from greater standardisation of energy efficiency requirements. Product runs would be larger if the market could produce a more products of the same efficiency in different regions. Providing documentation and test results would also be simpler if common action were taken to harmonise test protocols by all Annex I countries, as the number of different test protocols would be lower (IEA draft, 1996).

The implications for non-Annex I countries of common office equipment standards would also be small since at present the majority of producers are in Annex I countries. There are some non-Annex I producers, notably in Asia (e.g. Samsung in Korea). In any case, the United States' Energy Star label programme has already become the starting point for a *de facto* standard for office equipment world-wide, because any change in demand in the enormous United States influences producers world-wide.

The trade economics literature suggests that if product standards were implemented globally, trade flows would unambiguously increase, regardless of whether the standard were set at a high or low level.

21 An export restraint would probably not be feasible because of the harm this can do to domestic exports, but the Montreal Protocol broke new ground by mandating trade discrimination against countries not signing this treaty, both forbidding Members from importing CFCs from non-signatories not complying with the requirement to phase out CFCs, both imports of products containing CFCS *and exports to non-signatory countries* to prevent transfer of production to countries that might otherwise seek to specialise in environmentally harmful trade. So far, no disputes regarding the import or export trade controls of the Montreal Protocol have been taken to the GATT.

22 adapted from Hannsson, 1990.

Anything short of global standards obviously risks forming trade barriers to countries outside the agreement. The wider the coverage of the standard, and the lower the level it is set at, the lower the likelihood of any adverse impacts on trade will be. Common action on standards at the "introductory" level in Annex I countries can be expected to have few adverse trade impacts on non-Annex I countries, and should benefit trade between Annex I countries. Common action on standards at the "more rigorous" level in Annex I countries is more likely to have adverse impacts on trade. Of course, the environmental benefits of rigorous standards (reducing the risks of global warming) may offset the welfare loss from adverse trade impacts, but it is not possible to estimate the size of these benefits with any confidence.

From the trade optimisation perspective, only harmonisation at the "lowest common denominator" level by all countries would be unambiguously "no regrets" (although the cost of higher standards would need to be weighed against the trade and environmental benefits). This suggests that a possible Annex I-wide common action on standards could be harmonised test protocols and common standards at a low level, with individual countries opting to impose higher domestic standards where this is effective for them. Negotiating harmonised efficiency standards at multi-national level which are acceptable to all interested parties may lead to unambitious levels of energy efficiency and small emission reductions. It is possible that relatively weak harmonised standards could even have a negative impact on countries that have already adopted more stringent standards by removing the incentive to push for further improvements.

GATT Implications

One of the basic premises of the General Agreement on Tariffs and Trade (GATT) is that imported products should receive treatment

> "no less favourable than that accorded to like products of national origin" (Article III). Import duties or tariffs are the most obvious example of unfair treatment of imported products, but non-tariff barriers have drawn increasing attention. Product standards, technical specifications (and other similar measures) can form a "non-tariff barrier" to trade if they set at different levels in different countries. National standards, technical regulations, and the certification, testing and approval procedures which frequently accompany them, are "among the most complex and numerous" non-tariff barriers to trade, and "[t]hey are also the most difficult to quantify in terms of trade effects" (Middleton, 1980)

Under the GATT, a separate Agreement was negotiated to respond to the growing number of non-tariff trade barriers in the form of national standards: the Agreement on Technical Barriers to Trade (TBT Agreement). This Agreement covers both technical specifications and certification/testing procedures. The Agreement is designed to ensure that technical regulations and standards do not create "unnecessary obstacles" to international trade. The most relevant provisions of this Agreement are presented below:

- "... products imported from the territory of any Member ***shall be accorded treatment no less favourable*** than that accorded to like products of national origin". (Article 2.1)

- "...ensure that technical regulations are not prepared, adopted or applied with a view to or with the effect of creating ***unnecessary obstacles*** to international trade. For this purpose, technical regulations shall ***not be more trade-restrictive than necessary*** to fulfil a ***legitimate*** objective, ... Such legitimate objectives are, inter alia: ...***protection of human health or safety, animal or plant life or health, or the environment***." (Article 2.2)

- "Where ... ***relevant international standards*** exist or their completion is imminent, Members shall use them, ...as a ***basis for their technical regulations*** except where such international standards... would be an ***ineffective or inappropriate*** means for the fulfilment of ***legitimate objectives*** pursued, for instance because of fundamental ***climatic or geographical factors*** or fundamental technological problems" (Article 2.4)

- "... to ***harmonis[e] technical regulations on as wide a basis as possible***, Members shall play a full part, within the limits of their resources, in the preparation by ***appropriate international standardizing bodies*** of ***international standards*** for products for which they have either adopted, or expect to adopt, technical regulations." (Article 2.6)

Energy efficiency product standards, implemented as an Annex I-wide or regional common action, with the objective of reducing greenhouse gas emissions, would be in line with the provisions of the GATT as long as countries party to the agreement treated imports no less favourably than domestic products.

If some countries chose to set higher domestic standards than the internationally agreed level, an argument would have to be made that the international level of standard would be an "ineffective or inappropriate" means for fulfilment of global climate objectives and that higher standards were therefore necessary. Under the GATT, members can promulgate regulations that are "necessary to protect human, animal, or plant life or health" or "relating to the conservation of exhaustible natural resources", as long as the measures do not "arbitrarily discriminate" between countries or act as a "disguised restriction" on trade (Article XX General Exceptions). The Technical Barriers to Trade (TBT) Agreement affirms the right of governments to impose stricter requirements where the relevant international standard would be an ineffective or inappropriate means for fulfilment of "legitimate" objectives. The Treaty of Rome also grants European Union Member States the right to introduce national controls on the free flow of goods in the interest of protecting health, safety and the environment. It is worth noting, however, that before the European Commission proposed new standards for refrigerators/freezers, several Member States were on the point of adopting provisions relating to the efficiency performance of domestic refrigerators and freezers (e.g. Denmark and the Netherlands). The Commission suspended these initiatives in 1992 as a potential barrier to free trade of these products in the European Union, and because of the intention of formulating a proposal of harmonised standards at EU level to contribute to the implementation of the internal market.

A commitment to promoting international standardisation and certification "underlies virtually all sections of the TBT Agreement" (Middleton, 1980). The Agreement stresses "the important contribution that international standards and conformity assessment systems can make (to further the objectives of GATT) by improving efficiency of production and facilitating the conduct of international trade". Article 2.6 supports harmonisation of product standards at the broadest possible level through participation in ISO processes to develop international standards.

14. CONCLUSIONS

Common action on product standards can be broadly defined as international agreement of policy actions and measures to improve the energy efficiency of products. The analysis in this study has been limited to two very different products:

- refrigerators/freezers, which tends to be manufactured and traded within regions and has very different product characteristics in different regions; and
- office equipment, which is traded globally and has the same product characteristics world-wide.

This study shows that energy efficiency product standards on these products can yield cost-effective CO_2 emission reductions in most Annex I countries. The analysis of these products provides insights into factors that influence whether products could be good candidates for common action. However, the form that common action should take clearly depends very much on the characteristics of the product and on different national starting points. There are a number of products that could be analysed as possible candidates for common action on energy efficiency standards. The conclusions reached here for refrigerators/freezers and for office equipment should not be generalised for other products.

Type of Common Action

Common action on energy efficiency levels could take many different forms. The range of definitions for “common action” developed by the Annex I Expert Group on the UNFCCC is:

- specific policies and measures that could be implemented by a group of countries together under some form of agreement to increase the effect of the measures (e.g. trade partners remove subsidies);
- co-ordination of action to implement the same or similar measures together (e.g. harmonise standards or test protocols for products);
- agreement to take actions in a sector towards a given aim or target leaving the means of reaching the agreed aim to each country (e.g. x per cent improvement in fuel efficiency);
- successful policies and measures that could be replicated in other countries (e.g. countries might choose from a menu of measures).

This range of definitions indicates that a broad range of common actions could be considered from harmonisation of policies between countries, to different national actions towards a common objective leaving full flexibility on the type of policy instrument used.

While agreement on *energy efficiency levels* (either on simple absolute MEPS levels, or allowing different national levels based on an Annex I umbrella agreement) will yield benefits from common action in terms of emissions reductions and trade benefits, there is little advantage to an Annex I-wide agreement on the *policy instruments* that should be used to reach these levels. The example of European Union “directives” shows it is possible to offer flexibility in how a policy that is agreed at the regional level can be implemented at the national level. The approaches to the choice of instruments used by different countries for improving the environmental performance of products vary enormously. The political feasibility of achieving specified energy efficiency levels in different countries depends very much on the type of instrument used to achieve them. Efficiency standards are often implemented in the context of other national (or regional) actions such as consumer information, labelling, demand side management programmes, financial incentives to consumers, and incentives to industry which help promote innovation.

Implementation options vary from legislation of mandatory regulations drawn up under broad enabling legislation, to government procurement policies, voluntary approaches with industry, or energy efficiency labels. A high level of uncertainty is associated with many of these policy instruments. The effects of mandated, minimum energy efficiency performance standards can be assessed, but analysis of the effects of information and education, or voluntary energy efficiency improvements is much more difficult. Packages of measures will probably be needed if a non-mandatory approach is taken in order to achieve the desired results. In addition, policy instruments such as energy taxation, full cost pricing of electricity, and removal of subsidies to electricity producers and consumers (particularly in countries with economies in transition) would increase the cost-effectiveness of energy efficiency and would provide support for energy efficiency measures.[23]

Given the variety of national institutional and administrative structures, existing policies, and different preferences or requirements for legislation, approaches to implementation are likely to vary greatly among Annex I countries. It is also possible that different options could be agreed to by different countries at different times. Some countries with economies in transition, for example, may not be in a position to commit to adopt common standards within the same time-frame as other Annex I countries. For this reason, implementation will be more complicated in the central and eastern European countries than others.

Options for Common Action

Option 1: Cost effective energy efficiency levels

The cost-effectiveness of the energy efficiency standards analysed in this study varies from country to country because of different energy prices, and different manufacturing cost increases to improve products to the required level (influenced by base case level of energy efficiency, state of existing production capital, size of product runs, cost of labour, cost of capital).[24] Consequently, different levels of energy efficiency will be cost-effective for different countries. Although trade benefits would derive from common standards, from the point of view of cost-effectiveness, there is no reason that standards should be the same across countries.

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23 These measures are the subject of other reports under the study of Policies and Measures for Common Action.

24 The cost results in this study are very uncertain due to analytical difficulties and lack of data, however, the general result that “cost-effective” levels of energy efficiency will be different for different countries is robust.

An option for Annex I wide common action is for Parties to agree to target cost-effective energy efficiency levels in specific products. This would require analysis by national experts to assess the most cost-effective levels of energy efficiency, and agreement to implement these levels. Different methodologies for assessing cost-effectiveness and different definitions of "cost" are likely to be used by different countries. It would be interesting to try to agree on a common methodology for assessing costs and effects of measures, but different analytical approaches are likely to be unavoidable, in which case, the methodologies used and the results of these analyses should be transparently reported in national communications and subject to in-depth review by the UNFCCC.

This type of common action is likely to be simpler and quicker to negotiate than common minimum energy performance standards, and could be a first step towards a greater standardisation of product energy efficiency. At the same time, work on harmonisation of measurement procedures and testing protocols could be continued (and given greater impetus) in order to provide the foundation for standardisation of product requirements in the future.

Option 2: Minimum energy performance levels

Common minimum levels of energy efficiency would improve energy efficiency in some countries significantly, while making no difference to energy efficiency in countries that have already exceeded the minimum level. However, some CO_2 emissions reductions would result and there would be additional trade benefits if countries adopted the same levels of energy efficiency. Individual countries could adopt higher standards for environmental reasons without contravening GATT rules, as long as the standards do not present an unnecessary barrier to trade. Products that are traded widely are likely to be good candidates for agreement on common measurement techniques, testing protocols and standards, or energy efficiency levels that could be achieved through a variety of policy instruments. Such agreements will yield lower costs for manufacturers and facilitate trade in the products among countries that are party to the agreement.

Refrigerators and freezers are traded predominantly within regions, because consumers in different regions like very different product characteristics in their refrigerator/freezer appliances. For this reason, it seems likely that, while trade benefits would occur from regional common action, Annex I-wide common action would add little additional benefit and make the negotiations on test protocols and energy efficiency levels unnecessarily complex. Regional agreements on minimum energy efficiency levels could be considered among Annex I sub-groups that have similarity of refrigerator/freezer product types, i.e.:

- North America, Australia, and New Zealand;
- Europe (western, CEE and CIS);
- (Japan has no obvious Annex I partners with similar refrigerator/freezer characteristics.)

Office equipment is traded more widely than refrigerators/freezers and is much more uniform in type across Annex I (and other) countries, so it would be technically more realistic to realise Annex I-wide common energy efficiency levels. To some extent, multinational companies are moving toward common standards in facilities throughout the world, so that the need for common action on standards may be lower in the future for globally traded products such as office equipment. However, international co-operation to enhance the energy efficiency of office equipment would further facilitate trade, while promoting faster development of more efficient products. Rapid improvements in technology for office equipment mean standards would need to be continually updated and strengthened to remain effective. Energy efficiency standards for personal computers are already greatly influenced by the energy efficiency levels required to meet the United States voluntary Energy Star labelling scheme. Annex I-wide action could further improve the energy efficiency of office equipment.

Harmonisation of definitions, measurement and analytical techniques, and testing protocols is an important prerequisite for common action on energy efficiency levels or standards, but would not itself be expected to yield significant improvement in energy efficiency. Acceptance of test results from all countries is also a logical component of harmonisation of test protocols. Accreditation of testing laboratories may be required for this. Labelling schemes could complement product standards by stimulating the demand for appliances with higher energy efficiency.

Of the other products considered in an appendix to this study (air conditioners, electric space and water heaters, and electric motors), electric motors appear to offer very large cost-effective potential in all Annex I countries, and would be worth studying further as a possible candidate for agreement on improved energy efficiency levels or standards.

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APPENDIX A. AIR CONDITIONERS, HOME HEATING APPLIANCES AND ELECTRIC MOTORS

Approach

The aim of this section of the study is to assess the value of energy efficiency standards as possible common actions for three additional products: electric motors; air conditioners, and home heating appliances. It draws on a review of the literature and a survey of expert opinion. No new work was carried out to assess the possible effects of energy efficiency standards on these products.

Electric Motors

Current standards

Annex I countries have recently begun to consider to implement standards for electric motors. European countries do not have energy efficiency standards for electric motors. Energy efficiency standards for electric induction motors exist in Canada (from 1995), or are about to come into effect in Mexico and the United States (to be implemented in 1997). Canada is assessing the possibility of increasing their current standard for motors to the US 1997 level. There are plans to harmonise the Mexican motor standards with those of the United States and Canada. In the United Kingdom, there is a standard that provides a method for determining motor efficiency and energy losses.

Potential as measure for common action

Electric motors account for more than half of all electricity used by industry in most countries. They offer a larger potential for electricity savings than either refrigerators or office equipment. The potential for electric drive efficiency improvements in Europe and the United States has been estimated to be anywhere between 28 per cent and 60 per cent of total motor drive electricity (Krause, personal communication). High efficiency motors typically cost 10 to 30 per cent more than other models and reduce energy use by 2 to 15 per cent, depending on motor size. However, the annual operating cost of a motor often exceeds its purchase price so even small efficiency improvements are cost-effective. In the United Kingdom, higher efficiency motors are now becoming available at the same price as their standard equivalents. Electric motors are more or less the same in all IEA countries, but patterns in electricity end-use from motors differs widely between countries because of factors influencing demand such as climate, prices, regulations, and behaviour (IEA 1989 p.23).

Most measures to improve the efficiency of motors have a CCE of $0.03/kWh or less (Levine *et al* p. 30). However, many of these measures could not be achieved through energy efficiency standards because they are not directly related to the energy used in motor systems. Examples of other measures include the use of variable speed drives, optimal motor sizing, better motor repair and maintenance practices, use of induction motors, elimination of past rewind damage, correction of previous oversizing, electrical tune-ups, use of DC and synchronous motors, and drive-train lubrication and maintenance. Many of these other measures would require the education of industry.

A significant portion of the potential energy efficiency improvements in electric motors could be achieved by standards, but a package of these measures would probably be needed to achieve energy efficiency improvements most cost-effectively. Two options that have the potential for large cost-effective energy savings are:[25]

i. minimum levels of motor efficiency by motor type and size (although industry agreement on the minimum levels for each motor type and size may be difficult to obtain);

ii. a requirement for all manufacturers of motor driven machinery to equip their products with suitable variable speed and power factor controllers (although this could be more controversial than the first option because, for example, variable speed drives are not appropriate for all motor driven machinery).

The Good Practice Guide 2 of the Department of Energy of the United Kingdom provides useful information for further study and an EC project on “Energy Efficiency Actions for Electric Motors" is scheduled to be finished in June, 1996, and could provide the sort of information that would be required.[26]

Air Conditioners and Electric Home Heating Appliances

Current standards

Several Annex I countries have developed and implemented energy efficiency standards during the last decade. In the United States, minimum efficiency standards for room air conditioners became effective in 1990. In 1994, the DOE proposed revised standards for these products (Federal Register, 1994) and is now working on a final rule. For central air conditioners and heat pumps, efficiency standards became effective in 1992 and 1993 for split systems and single-package systems, respectively. The DOE is presently analysing central systems with the intent to propose new standards. Canada has labelling requirements and efficiency standards for room air conditioners, central type air conditioners and heat pumps. The Canadian regulations for these products are presently somewhat different than the American standards. However, there is an agreement to harmonise the efficiency standards for the United States and Canada. In 1993, Japan established new energy efficiency targets for cooling only air conditioners that will take effect October, 1997. Labelling is also required for air conditioners. There are also efficiency standards in Japan for heat pumps.

There are no energy efficiency standards in European countries for electric home heating appliances or air conditioners.

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[25] Florentine Krause, IPSEP.

[26] This project aims to provide an estimation of the electricity consumption of the different types of electric motor systems in the European Union by major types of equipment end-use, an assessment of potential energy savings from more efficient equipment up to 2010 and optimal selection and control of such equipment, and an investigation of ways in which these savings can be realised (e.g. energy labelling, efficiency standards, voluntary agreements, etc.), including cost-benefit analysis and impact on manufacturers.

In China, air conditioning is a major new electricity use for those households that can afford it. China has minimum energy efficiency standards for room air conditioners and for split system units. There is no labelling requirement. Korea has established efficiency targets for single package (window) and air conditioners. In Mexico, room air conditioner efficiency standards are the same as the American standards which took effect in 1990. In the Philippines, labelling and standards regulations apply to window type air conditioning units only (not to split systems which make up about 20 per cent of the units).

A heat loss standard for electric storage water heaters will be made mandatory by the Australian government in 1999. For electric storage water heaters of 80 litres and greater, it had been recommended that the heat loss limit be lowered to 55 per cent of the values in the existing, but non-mandatory Australian standard[27] (Australian Standard AS1056 Part 1). This would correspond to about 75 mm of foam insulation. However, the negotiated standard for 80 litres and above is 70 per cent of the existing heat loss standard (equivalent to 50 mm of polyurethane foam). The present thickness ranges from 25 to 32 mm. For tanks of less than 80 litres, it was recommended that the heat loss limit be also lowered to 70 per cent of the existing standard. Industry requested a limit of 100 per cent, and after extensive discussion between government and manufacturers, that limit was agreed to for small tanks.

As of February, 1995, Canada has established an energy efficiency standard for electric storage water heaters of volumes from 50 to 450 litres. The efficiency standard is in the form of a maximum allowable standby loss, as in Australia. Canada has also established energy efficiency standards for gas and oil water heaters. These are the same as the United States standards described below.

In the United States, water heater standards became effective in 1990. They were modified when the test procedure was revised in 1991. The US DOE proposed revised efficiency standards in 1994, but the future of those standards is uncertain. The proposed standards would require the use of heat pump water heaters to meet the minimum energy efficiency.

Potential as measure for common action

The share of electricity for space heating and cooling is generally small in Europe because electric home heating appliances and air-conditioners are not widely used. Use of air-conditioning is developing in the commercial and public sectors in Southern European countries, however. In North America air conditioners and heating appliances are widely used and in Asia their use is growing rapidly. Technologies for water and space heating differ greatly between regions (IEA, 1989, p. 23)

The most common electric heating technology is resistance heating, whose efficiency is close to 100 per cent (electric resistance heating systems directly converts electric power to heat). To improve on this energy efficiency, a switch away from electricity to other fuels would be needed (burning gas to produce electricity incurs losses of more than 50 per cent compared to using gas directly for heating). However, the use of electricity to produce heat is an extremely poor use of this high energy source. Energy efficiency policy interventions might therefore aim to limit or discourage the use of electricity for space heating or, alternatively aim to improve the efficiency of the production and transmission of electricity. Of course, energy efficiency policy interventions will only reduce greenhouse gas reduction in countries which use fossil fuels to generate electricity.

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27 G. Wilkenfeld, "Benefits and Costs of Implementing Minimum Energy Performance Standards for Household Electrical Appliances in Australia, Sydney, Australia, July, 1993.

The other basic technology for electric space heating is the heat pump, for which significant efficiency improvements are possible. Highly efficient heat pumps are available which are about 25 per cent more efficient than standard heat pumps. By using ambient heat, they can deliver 1.5 to 3 times as much heat per kWh as resistance heaters. They are often not as cost effective as resistance , but where they can be cost-effectively applied they can result in very large end-use energy savings (e.g. in situations where space cooling and heating are required or the heating season is long, but not too harsh). They are being used in large numbers in the United States and to some extent in Sweden and Japan. (IEA, 1989, p.54)

Electric heat pumps are not used in significant numbers in the residential sector of most European countries (and are actually losing market share due to the low reliability of existing equipment). Minimum efficiency standards for heat pump systems would therefore not result in significant reductions of total electricity consumption in Europe.

In the United States, upgrading the efficiency of a new electric resistance storage water heater from 82 per cent to 90 per cent through better insulation and use of heat traps is estimated to save about 300 kWh/year in a typical house, at a CCE of 0$0.013/kWh. The most efficient electric resistance water heaters in the United States in 1991 had efficiency ratings as high as 89 per cent (ACEEE 1991). High efficiency air conditioners are cost-effective for residential consumers in the United States as long as annual operating hours and the price of electricity are average or above average (Levine *et al*, p. 15). However, high efficiency air conditioning would not be a priority in most of Europe because it is not widely used.

In summary, improving the energy use of air conditioners and heat pumps is clearly an important issue for North America and Asia, but is perhaps a lower priority as a possible common action for Annex I countries because of the limited relevance for European countries. A study is being done at present on defining energy efficiency standards for water storage heaters in households, which could be used as a basis for studying water heater standards.

TECHNICAL ANNEX. CONSULTANTS' REPORTS

Available upon request from OECD

These papers were written under contract to the OECD, in support of the common action study. The opinions are those of the authors and do not necessarily reflect the opinions of any organisation.

1. **Guidelines for Regional Analysts on Modelling Inter-regional Refrigerator Minimum Energy Efficiency Standards**; Paul Waide (PW Consulting, France), 6 December 1995.

   This report contains the instructions for regional analysts to convert regional energy specifications for refrigerators/freezers to those used in the EU and US standards, so that regional refrigerator/freezer emissions scenarios for these standards could be developed.

2. **CO_2 Emissions Reductions and Cost-Effectiveness of Minimum Energy Performance Standards for Refrigerators in Japan**; Jyukankyo Research Institute, Inc. Tokyo, Japan; 4 March 1996.

   This report contains the regional refrigerator/freezer scenarios for Japan that were used to assess the effects and costs of standards.

3. **Refrigerator Energy Efficiency Standards in Eastern Europe**;
   I.Bashmakov, S.Sorokina, Center for Energy Efficiency (CENEf) Moscow, Russia, March 1996.

   This report contains the regional refrigerator scenarios for eastern Europe that were used to assess the effects of standards (freezers were not included in this analysis and costs were not estimated due to lack of data).

4. **Energy Efficiency Standards on New Refrigerator Appliances in the Central Europe**; Vladimír Procházka, Zora Voráèková; The Energy Efficiency Center (SEVEn), Prague, Czech Republic, March 1996.

   This report contains the regional refrigerator/freezer scenarios for central Europe that were used to assess the effects and costs of standards.

5. **Internationally Harmonised refrigerator Energy Efficiency Standards Analysis**, Paul Waide (PW Consulting, France), January 1996.

   This report contains the regional refrigerator/freezer scenarios for western Europe that were used to assess the effects and costs of standards.

6. Draft report: **Regional Analysis of Product Standards**; James E. McMahon, Mary Ann Piette, and Isaac Turiel, USA, March 1996.

This report contains the North American scenarios for refrigerators/freezers, and scenarios for all regions for office equipment, and a description of standards on electric motors, air conditioners and heaters for non European countries.

7. **Review of information on standards on electric home heating appliances, air conditioners and electric motors in European Annex I countries**; Dominique Gusbin COHERENCE, Belgium February 1996

   *This report contains a description of standards on electric motors, air conditioners and heaters for Europe***.**