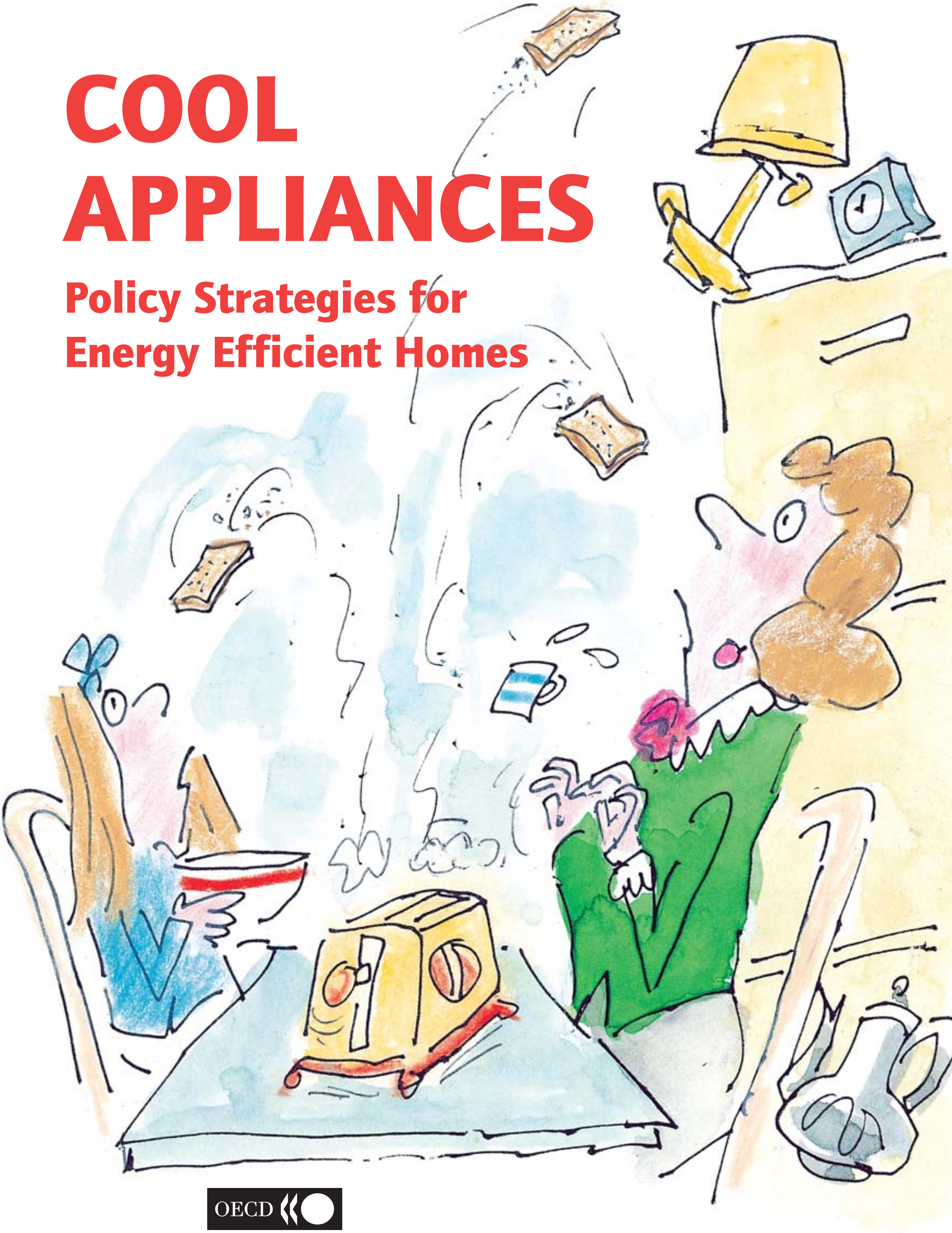
INTERNATIONAL ENERGY AGENCY

COOL APPLIANCES

Policy Strategies for Energy Efficient Homes



ENERGY EFFICIENCY POLICY PROFILES

OECD

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INTERNATIONAL ENERGY AGENCY
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The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-six* of the OECD's thirty Member countries. The basic aims of the IEA are:

- to maintain and improve systems for coping with oil supply disruptions;
- to promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations;
- to operate a permanent information system on the international oil market;
- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use;
- to assist in the integration of environmental and energy policies.

** IEA Member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, the Republic of Korea, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The European Commission also takes part in the work of the IEA.*

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

- to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973), Mexico (18th May 1994), the Czech Republic (21st December 1995), Hungary (7th May 1996), Poland (22nd November 1996), the Republic of Korea (12th December 1996) and Slovakia (28th September 2000). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

PREFACE

Almost one third of all the electricity produced in IEA Member countries ends up in our domestic refrigerators, dishwashers, ovens, lamps and other common household devices. The energy efficiency of this equipment has a major impact on how much electricity we need to produce and, depending upon the mix of fuels used for power generation, how much greenhouse gas is emitted to the atmosphere.

This publication describes, for the first time and in substantial detail, the electricity consumed in IEA member countries by each residential end-use. It assesses how many greenhouse gas emissions, and how much electricity, could be saved if more ambitious policy settings were introduced. It also examines the impact of current policy settings. Finally it explains and discusses the policies and strategies that could cost-effectively deliver additional savings.

The governments of the IEA Member countries are making renewed efforts to enhance energy security and combat climate change, and they are seeking the most cost-effective strategies to achieve these goals. In the residential appliance sector alone, we find that up to 24% of projected electricity consumption could be avoided by 2010, and up to 33% by 2030, with the rapid introduction of stronger but still cost-effective energy efficiency policies. Energy efficiency could be the largest single energy resource for fuelling our residential electricity needs in the future. As this publication only models those energy efficiency improvements that are cost effective, the resulting greenhouse gas reductions are obtained at negative cost.

This book should be of considerable value to policy makers to introduce, strengthen, and expand energy efficiency policies and programmes. The approach should benefit not only IEA Member countries but also any other country, especially in the developing world.

Claude Mandil
Executive Director

ACKNOWLEDGEMENTS

Cool Appliances: Policy Strategies for Energy-Efficient Homes is the fruit of a two year effort undertaken by the Office of Energy Efficiency, Technology and R&D under the direction of Marianne Haug. Benoît Lebot, of the IEA, managed this programme, with the support of the Head of the Energy Efficiency Policy Analysis Division, first Carmen Difligio and then Phil Harrington. The work benefited greatly from the substantial input and expertise of Mr Paul Waide of PW Consulting in UK and Mr John Newman, a private consultant from the USA.

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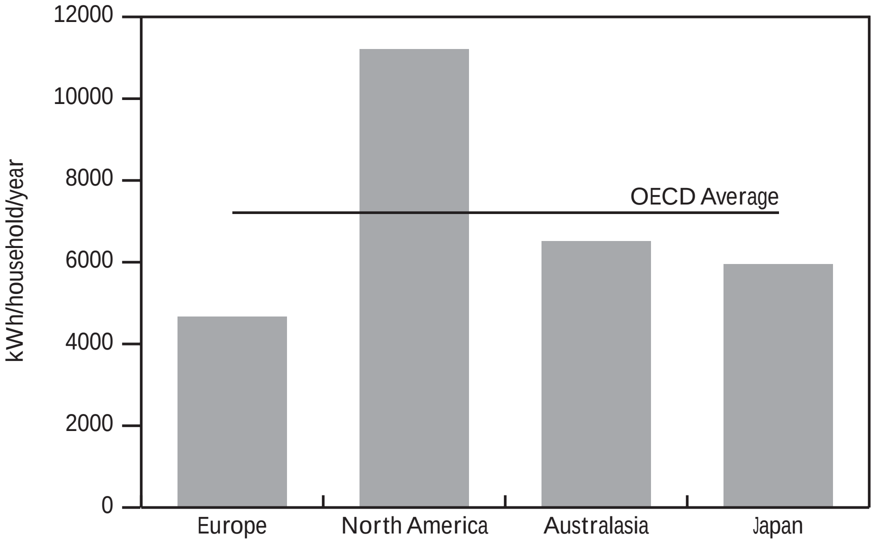
EXECUTIVE SUMMARY

Residential appliances and equipment contribute greatly to our quality of life. Appliances and energy-using equipment in the home keep us warm in winter and cool in summer. They provide us with the food, music, and mood lighting for our evening meals, and they wash the dishes afterwards. They allow us to surf the Web and telephone our colleagues from the home office while our clothes are being washed and dried in the laundry. For the most part, we think about appliances only when they break down or need replacing. How should we connect them to global issues such as climate change?

Residential appliances and equipment are a major source of energy demand and greenhouse gas emissions in OECD countries. Residential appliances and equipment use 30% of all electricity generated in OECD countries, producing 12% of all energy-related carbon dioxide (CO_2) emissions. They are the second largest consumer of electricity and the third largest emitter of greenhouse gas emissions in the OECD. Since 1973, primary energy demand in the residential sector in the OECD has grown by more than all sectors other than transport, and in terms of electricity demand growth, it has outstripped all but the commercial buildings sector over this same period.

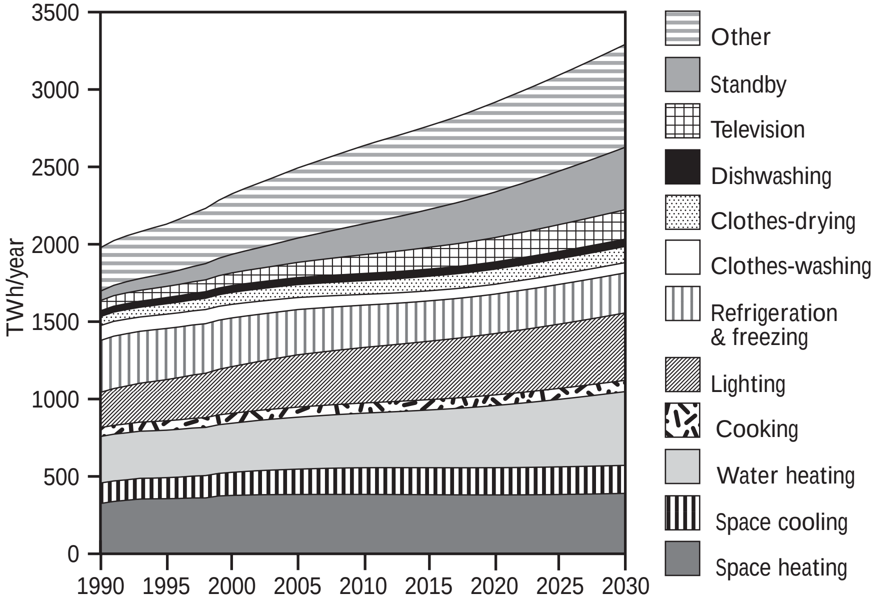
Household energy consumption varies markedly across the OECD. There is a significant variation in household electricity consumption by region, with, for example, OECD North America consuming 2.4 times more per household than OECD Europe in 2000. Also, the rate of growth in household electricity consumption was almost three times higher in Japan in the 1990s than in OECD Europe over the same period. Separating these differences by underlying cause – such as variation in income, energy costs, house size, climate, appliance ownership, patterns of use, consumer and producer preferences and underlying energy efficiency – remains a challenge for a future analysis.

Figure ES.1 **Residential electricity consumption in four major OECD regions, 2000**



With few exceptions, the demand for energy to power residential appliances and equipment does not appear to be slowing down. With rising incomes and fewer persons per household, we are owning and using more and more appliances in the home. We project that, even with a continuation of all existing appliance policy measures, appliance electricity consumption in the IEA will grow by 13% from 2000 to 2010, and by 25% by 2020. Oddly enough, the fastest growing appliance electrical end-use is projected to be standby power consumption, or the consumption of electricity by appliances that are turned "off" or, more strictly, that are in a "non-active mode" (standby, sleep, etc.). By 2020, 10% of total appliance electricity consumption in the OECD could be for standby functionality, which is currently unregulated in all OECD countries (see Chapter 1). In contrast, electricity consumption for clothes washing – an early target of efficiency policy – declined by 9% over the 1990s.

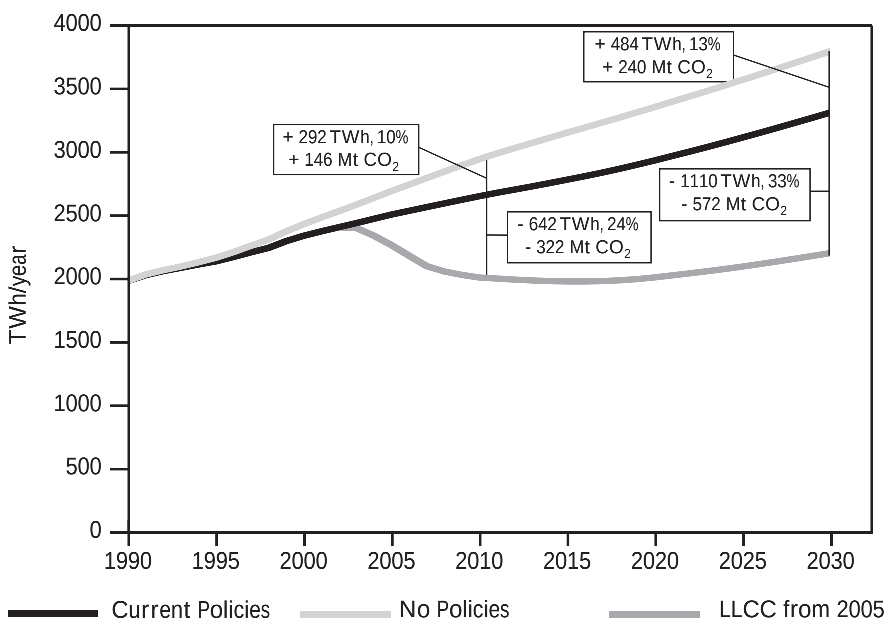
Figure ES.2 **Projected IEA residential electricity consumption by end-use with current policies**



The IEA's *World Energy Outlook 2002* "…depicts a future in which energy use continues to grow inexorably, fossil fuels continue to dominate the energy mix and developing countries fast approach OECD countries as the largest consumers of commercial energy… (T)he projections in the *Outlook* raise serious concerns about the security of energy supplies, investment in energy infrastructure, the threat of environmental damage caused by energy production and use and the unequal access of the world's population to modern energy". Even in the *WEO*'s Alternative Policy Scenario – which "analyses the impact on energy markets, fuel consumption and energy-related CO_2 emissions of the policies and measures that OECD countries are currently considering" – CO_2 emissions in the OECD stabilise only towards 2030, while global emissions continue to rise strongly. The WEO concludes that, "More rigorous policies and measures than those so far adopted will be needed for the industrialised countries to meet their emission reduction commitments under the Kyoto Protocol". This publication seeks to rise to this challenge, providing one model of how more rigorous policy can indeed reduce energy consumption and greenhouse gas emissions further and faster than existing policies – and even further and faster than those policies being "currently considered" by OECD countries – while remaining highly cost-effective.

There is substantial potential to reduce electricity consumption and greenhouse gas emissions from residential appliances and equipment cost-effectively. By using efficiency policy to target the most cost-effective level of efficiency (established through a life-cycle cost analysis and aiming at the technology improvement set at the least life-cycle cost) for appliances from 2005 onwards, IEA Member countries could save more than 642 TWh of electricity or some 322 million tonnes (Mt) of CO_2/year by 2010, when compared to what they will save under existing policy settings. In terms of greenhouse gas emissions, this would be equivalent to taking over 100 million cars off IEA roads, or doing without nearly 200 gas-fired power stations. These results are quite robust in the face of varying assumptions, such as the level of energy prices, and are in line with other published sources. However, this publication is unique in drawing together an IEA-wide picture.

Figure ES.3 **Residential electrical appliance electricity consumption under No Policy, Current Policy and Least Life-Cycle Cost 2005 scenarios in IEA countries, 1990 to 2030**



Cost-effective appliance energy efficiency policies can make a major contribution to meeting Kyoto Protocol – and future – greenhouse gas emission targets. Targeting the least life-cycle cost for residential appliances could achieve up to 30% of OECD Member countries' targets under the Kyoto Protocol on climate change. By 2030, a policy of targeting the least life-cycle cost for residential appliances (from 2005) would avoid more than 1,110 TWh/year of final electricity demand or 572 Mt CO_2/year, equivalent to taking over 200 million cars off OECD roads.

Most importantly, these savings can be achieved at negative cost to society. This is not to say the savings are *free*, but rather that the extra costs of improving appliance energy efficiency are more than offset by savings in running costs over the appliance's life. In the US, each tonne of CO_2 avoided in this way in 2020 would save consumers around $65; while in Europe, each tonne of CO_2 avoided would save consumers some €169. Significant savings appear to be available in all IEA regions despite widely diverging situations, although data limitations prevent the savings being costed in a similar manner for Japan and OECD Australasia.

Appliance energy efficiency policy has already proven itself to be a reliable and cost-effective way to reduce energy consumption and greenhouse gas emissions. Appliance policies in IEA Member countries over the 1990s reduced greenhouse gas emissions by some 46 Mt CO_2/year in 2000, avoiding the need for at least 25 gas-fired power stations. Even without further strengthening, these same policies will go on to reduce emissions by 146 Mt CO_2/year by 2010 as more efficient equipment replaces less efficient equipment in the stock. Given their proven track record, the risks in strengthening these policies are much smaller than for many alternative abatement policies.

Additional policy action is required to capture these benefits. Existing policies in IEA Member countries, while cost-effective, do not capture all or even a significant proportion of the cost-effective savings available. In fact, there is significant variation in the coverage, stringency and design and implementation of appliance energy policy. For maximum impact, appliance energy policies would need to be strengthened and broadened in coverage. In some cases, they would need to be redesigned, supported with an adequate legal and institutional framework, given adequate resources and appropriately administered. As discussed in

Chapter 4, a comprehensive basket of policies supported by an active and effective institutional framework, with voluntary and partnership measures building upon a solid foundation of minimum energy performance standards and labelling, is likely to be the most effective approach. Different policies may be required for different end-uses and markets, therefore policy must always be designed on the basis of real market information.

New challenges – and potential opportunities – for appliance energy efficiency are rapidly emerging. One of the strongest trends is the rapid growth of "information and communication technologies" in the home – computing equipment, communications equipment, multimedia devices, entertainment and audio systems. These devices – many of which continue to use power when switched "off" (or in standby mode) – are projected to account for the most rapid growth in residential energy demand and greenhouse gas emissions in IEA Member countries over the next 30 years. Up to three-quarters of this demand could be eliminated at very little cost and without loss of functionality by redesigning these products for maximum efficiency in all modes. At the same time, advanced monitors, meters and controls, as well as active power management, have the potential to save energy directly, and to enable broader changes in lifestyles that could in turn save energy. These savings are not guaranteed; therefore, at a minimum, governments should carefully monitor developments in this area.

International collaboration and co-operation on appliance policy are becoming increasingly important and require additional support. With increasing globalisation of appliance and technology markets, international collaboration and co-operation on appliance energy policy are becoming an essential element of product markets. This is particularly the case for information and communication technologies, where the rate of innovation and product development is such that traditional appliance energy policy instruments (regulatory or economic in nature) may be too slow or ineffective and where there is a high degree of product uniformity globally. Greater transparency and comparability in appliance energy performance standards, test procedures and labelling would bring benefits for producers, consumers and governments alike.

KEY FINDINGS AND CONCLUSIONS

■ *By cost-effectively improving the energy efficiency of residential appliances – or more precisely, by using efficiency policy to target the least life-cycle cost for appliances from 2005 onwards – IEA Member countries could save some 322 million tonnes (Mt) of CO_2/year by 2010, compared to what they will save under existing policy settings.*

■ *In terms of greenhouse gas emissions, this would be equivalent to taking over 100 million cars off IEA roads. By 2030, this same policy would avoid nearly 1,110 TWh/year of electricity or 572 Mt CO_2/year, equivalent to taking over 200 million cars off OECD roads.*

■ *This measure alone would achieve up to 30% of IEA Member countries' targets under the Kyoto Protocol on climate change.*

■ *These savings can be achieved at* negative *cost to society, since the extra costs of improving energy efficiency are more than offset by savings in running costs over the appliance's life. In the US, each tonne of CO_2 avoided in this way in 2020 will save consumers $65; while in Europe, each tonne of CO_2 avoided will save consumers €169 (reflecting higher electricity costs and currently lower efficiency standards in Europe). Significant savings are available in all OECD regions despite widely diverging situations.*

■ *Additional policy action is required to capture these benefits. Existing policies in IEA Member countries, while cost-effective, do not capture many of the cost-effective savings available. For maximum impact, appliance policies would need to be strengthened and broadened in coverage. In some cases, they would need to be redesigned, supported with an adequate legal and institutional framework, given adequate resources and appropriately administered.*

■ *Appliance policies have already proven to be a cost-effective option for energy and greenhouse gas savings in IEA Member countries. By 2000, these policies had reduced greenhouse gas emissions by some 46 Mt CO_2/year, avoiding the need for at least 25 gas-fired power stations. Even without further strengthening, these same policies will go on to reduce emissions by 146 Mt CO_2/year by 2010.*

■ *New challenges for appliance energy efficiency are emerging in the rapid growth of information and communication technologies in the home – computing equipment, communications equipment, multimedia devices, entertainment and audio systems, many of which continue to use power when switched "off" (or in standby mode). Up to three-quarters of this demand could be eliminated at very little cost and without loss of functionality.*

■ *International collaboration and co-operation is becoming increasingly important in the field of appliance policy. This is particularly the case for information and communication technologies, where the rate of innovation and product development is such that traditional appliance policy instruments (regulatory or economic in nature) may be too slow or ineffective. Greater transparency and comparability in appliance energy performance standards, test procedures and labelling would bring benefits for producers, consumers and governments alike.*

RECOMMENDATIONS

- *IEA Member countries should take steps to strengthen their residential appliance and equipment policies to target – as a minimum – the least life-cycle cost for each appliance class.*

- *Policy measures should be extended to all end-uses equipement as rapidly as possible, subject to a test of cost-effectiveness.*

- *While many policy instruments may be used to achieve these targets, mandatory minimum energy performance standards and comparative energy labelling stand out as the most effective, reliable and cost-effective approaches. Wherever possible, these instruments should form the basis of appliance policies in IEA Member countries.*

- *To encourage producers and consumers to go beyond minimum requirements, other policy instruments such as information initiatives, certification, voluntary agreements, technology procurement programmes and economic incentives may be effective complements to standards and labelling.*

- *Since markets and technologies change continually, including in response to past policy settings, the stringency of policy settings should be updated on a regular basis (typically on a three to four year cycle), and technological progress should be anticipated in setting future standards.*

- *In policy development and administration, governments should seek open communication and close working partnerships with relevant business and consumer groups. Where not already in place, countries should support their appliance policies with a clear and effective regulatory framework and adequately empowered institutions with sufficient resources. Particular care should be given to the quality and integrity of the supporting technical analyses, which are the foundation of all equipment energy policy measures. It is well worth investing in high quality data and analysis to enable equipment energy efficiency policies to be optimised.*

- *IEA Member countries should address the rapid growth of energy consumption in residential information and communication technologies (computers, power supplies, entertainment and multimedia equipment, etc.), including the standby power consumption of this equipment.*

■ *With the rapid globalisation of appliance products and component markets, international collaboration on appliance policy is more important than ever. Greater efforts should be made to harmonise internationally product test protocols, standards and labels. International collaborative efforts to transform particular markets, such as those for power supplies, should be considered. International support should be offered to major developing country economies, particularly appliance producers and exporters, to encourage them to adopt rapidly best-practice appliance efficiency measures.*

INTRODUCTION

Through its electricity consumption, an average refrigerator in an IEA home generates every day a volume of CO_2 equivalent to its loading capacity. An energy-efficient model can halve this consumption while maintaining the same level of service. As the savings on the electricity bill will compensate the possible extra cost for purchasing a more energy-efficient model, the reduction of CO_2 emissions is obtained at a negative cost to both the consumer and society. Refrigerators run all year round and for many years. They are found in every single household. Overall, domestic cold appliances are responsible for 2% of the total energy-related CO_2 emissions in OECD countries. With the natural turnover of the appliance stock, up to 50% of such CO_2 emissions can be abated when energy-efficient units replace old appliances within a 15 year framework. This is just one example of how significant electricity and CO_2 savings can be achieved with energy-efficient end-use equipment.

Results from a major end-use metering project in four European countries recently assessed that on average more than 1,000 kWh per year can be saved in every one of the 400 households monitored when existing equipment is replaced with the most energy-efficient available on the market. These measured findings correspond to a reduction between 20 to 35% of total electricity consumption, depending on the country.

The challenge is to find ways to realise the energy and greenhouse gas savings from this known potential, and to do so across the whole residential sector.

OBJECTIVES

This book is aimed to assist policy-makers to design and implement strong appliance policies by:

- Profiling the energy use, CO_2 emissions and the cost-effective potential for efficiency gains for 12 appliance types and four OECD geographical regions.

- Analysing the strengths and weaknesses of existing appliance policies across the IEA and identifying best practices.
- Describing the challenges arising from evolving technologies and future appliances.

CONTEXT

Electrical appliances in the built environment are the fastest growing energy users, after automobiles. Electricity demand in the residential sector is experiencing continuous growth. In many ways, our modern lifestyle depends heavily on the availability of devices, systems and equipment fuelled by electricity. Through the 1950s and 1960s, domestic appliances were designed to save time and to free users from manual labour. With the advent notably of television during the 1960s, domestic appliances were increasingly designed to provide entertainment and communication services in the home, culminating today with multimedia platforms, personal computers, telephone, video games and the Internet.

At the same time, electricity production contributes a significant portion of greenhouse gas emissions world-wide. IEA countries are developing policies to reduce such emissions in order to meet the target set by the Kyoto Protocol, to limit the risk of climate change. In this context we can ask, Is the growth of electricity demand from the residential sector inevitable? If each appliance were manufactured and used to consume less energy – while providing at least the same services as before – could the growth of emissions from the residential sector be slowed or even reversed? What are the key technologies associated with residential emissions, and what key policies can be put in place to deliver sufficient savings to abate in absolute terms the amount of greenhouse gas emissions associated with the production of electricity? This publication aims to provide concrete answers to these questions.

AMBITION

This book shows how current appliance energy efficiency policies in OECD Member countries are already generating substantial energy savings compared to a world without such policies. But it also identifies for policy-makers the extra electricity savings and associated CO_2 emissions that could be avoided in the coming decades if all cost-effective opportunities were implemented. Significant incremental reductions of greenhouse gas emissions exist and are achievable with known and proven policy measures, which at the same time would deliver net financial savings to consumers. The book proposes policy options and packages, based on current best practices, that can be used to deliver these savings. With appliances and equipment markets becoming increasingly globalised, this work pays special attention to the international dimension of appliance energy efficiency policies, and the benefits of enhancing international collaboration.

PROCESS

The book comprises two distinct sets of analysis: a detailed quantitative analysis aimed at assessing realistic figures for appliance electricity demand, CO_2 emissions, growth trends and projections; and a thorough policy analysis to identify best practices in appliance energy efficiency policies.

To understand the present situation, the book relies extensively on literature, surveys, published data, statistics, research publications available on residential electricity in OECD countries. Historical and cost data were collected and organised into a full stock model to represent the complete disaggregation of electricity by end-use in all OECD countries. Projections are made of the evolution of the electricity consumed by each end-use family and the level of ownership and use. The model is then used to analyse a range of policy scenarios.

Data for the Czech Republic, Hungary, Turkey and South Korea were unavailable for inclusion in the model and hence the results of the analysis presented in the whole report concern the following 22 IEA Member countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

For each end-use, the improvements that are cost-effective under current economic circumstances are identified, analysed and projected. The aggregated electricity savings are translated into the associated greenhouse gas emissions.

IEA APPLIANCE STOCK MODEL METHODOLOGY

A stock model was built to organise the collection and analysis of historical energy data (up to the year 2000) for 12 appliance types and four OECD geographical regions. Data on three primary underlying drivers: 1) the average appliance ownership level per household, 2) the number of households and 3) the average unit energy consumption of each appliance, were compiled for each appliance and region. Future energy consumption projections assumed smooth progressions from historical levels of ownership and household drivers, and used three scenarios concerning the unit energy consumption driver. The three scenarios investigated were:

No Policies *– an estimate of the efficiency trend that would have occurred had no policies been implemented from 1990 onwards.*

Current Policies *– assumes that existing programmes are maintained into the future, but that their ambition levels are not altered in any way.*

Least Life-Cycle Cost (LLCC) from 2005 *– assumes that all electrical equipment sold from 2005 onwards attains the LLCC efficiency level for each product type and in each economy. The concept of Least Life-Cycle Cost is introduced, described and discussed in Chapter 3. In determining the efficiency level associated with the LLCC, there is no constraint imposed on the maximum length of the payback period for higher efficiency equipment (i.e. it is only necessary for the LLCC efficiency level to produce the lowest total cost of purchasing and operating the appliance discounted over its normal lifetime).*

For reasons of simplicity, the LLCC from 2005 scenario assumes that there is no competition for current electricity end-uses from other fuels and hence does not consider the economic trade-offs of future heating applications (such as space and water-heating, cooking and clothes drying) being provided by alternative fuels such as gas or solar energy; however, in reality these options do exist. Nor does the scenario consider the potential impact of micro- or district cogeneration, nor the impact of passive solar or other residential building efficiency measures. Instead the scenario is confined to the consideration of technical options which would raise the electrical efficiency of residential electricity end-uses in a cost-effective manner, without influencing the manner in which the equipment is used or the quality of service provided.

***World Energy Outlook (WEO) Alternative Policy Scenario** – The above scenarios are compared with the Alternative Policy Scenario in the IEA's* World Energy Outlook 2002. *This scenario examines the projected impact, on energy demand and greenhouse gas emissions, of policies currently under consideration in IEA Member countries but not yet introduced.*

OUTLINE

The first chapter summarises the data collection and the aggregated figures of the energy consumed by appliances in the residential sector. For the first time, a picture, as comprehensive as possible, is presented for electricity demand in the IEA residential sector. Each end-use, one after the other, is discussed. This extensive and thorough discussion is indispensable to set the basis for the rest of the analysis.

The second chapter comprises a critical review of current appliance programmes enforced in IEA Member countries. Analysis of some policy details appears as important as the presentation of the general policy context.

The third chapter presents the findings of the policy scenario to assess the electricity, CO_2 and cost savings potentially achievable in the next decades from cost-effective appliance energy efficiency programmes. To assess the impact of current policies, two detailed residential electricity consumption end-use scenarios have been produced for each of the IEA Member country regions: the No Policies and Current Policies scenarios. The sole difference between them is that the former has a slower rate of efficiency improvement, based on the best estimate of the efficiency progressions by end-use which would have occurred had none of the current policies been implemented from 1990 onwards. Satisfaction with the apparent success of the policies already introduced is tempered when compared with the scale of the remaining untapped cost-effective efficiency savings and the consideration that in all OECD regions total residential electricity consumption is still set to rise. The scale of untapped future savings is evaluated. The costs of CO_2 abatement are discussed in detail. The main results are compared with existing ones available in literature.

Chapter 4 draws the lessons learned from both existing policies and projected savings obtained with the model developed in the previous section. It presents an attempt to design an optimal appliance policy.

Chapter 5 explores the challenge created by future appliances: can energy efficiency be promoted in the new generation of electronic appliances?

Finally, a last chapter discusses the benefits of international collaboration in appliance energy efficiency programmes.

The book concludes that appliance energy efficiency programmes deserve recognition, merit attention, and should be widely reinforced and encouraged. The successes of some appliance energy efficiency programmes in IEA Member countries are remarkable. However, the successes still to be captured are much more remarkable again. International collaboration will help to enlarge and accelerate the benefits of appliance energy efficiency programmes.

ELECTRICITY DEMAND AND CO_2 EMISSIONS OF APPLIANCES

KEY MESSAGES

- *Residential appliances and equipment are a significant source of energy demand and greenhouse gas emissions in OECD countries.*
- *Household energy consumption varies markedly across the OECD.*
- *With few exceptions, and in the absence of energy efficiency policy intervention, the demand for energy to power residential appliances and equipment is likely to keep growing.*

This first chapter summarises the data collection and the aggregated figures of the energy consumed by appliances in the residential sector. For the first time, a picture, as comprehensive as possible, is presented for electricity demand in the IEA residential sector. Each end-use, one after the other, is discussed. This extensive and thorough discussion is indispensable to set the basis for the rest of the analysis.

CURRENT ENERGY USE AND CO_2 EMISSIONS

Residential electricity use is one of the largest and fastest growing sectors of energy use in OECD countries. In 2000, residential electricity accounted for 30% of total electricity use and 6% of total final consumption of all energy types. When the relevant energy conversion and transmission losses are factored in, residential electricity accounted for 12% of the OECD's primary energy use and 12% of its energy-related CO_2 emissions in 2000. Overall, in terms of end-use energy consumption, the residential sector accounted for 30% of electricity use, 37% of natural gas use, 10% of coal use and 7% of oil use in OECD countries in 2000. When the relevant energy conversion and transmission losses are included, the sector accounted for 22% of the OECD's primary energy use and 21% of its energy-related CO_2 emissions in 2000.

Table 1.1 **End-use energy consumption profile of OECD countries, 2000** (Mtoe)

	Coal	Oil	Natural Gas	Electricity	Heat	Total
Residential		131	260	214	20	689
Commercial and Public Services		71	123	199		407
Industry	114	346	287	280	25	1,086
Transport		1,186	21			1,219
Agriculture		55				70
Total Final Consumption	**133**	**1,908**	**707**	**710**	**56**	**3,612**

Figures less than 20 Mtoe not shown.
Source: IEA Statistics.

From 1990 to 2000 residential electricity demand grew by 524 TWh from 1,967 TWh to 2,490 representing an average annual growth rate of 2.4% in all OECD countries. The associated CO_2 emissions grew from 1,267 Mt in 1990 to 1,449 Mt in 2000. Despite this, the rate of growth in residential electricity demand in the 1990s was slower than in the preceding two decades. This occurred partly as a result of a slowing rate of growth in equipment ownership but mostly because of rising equipment efficiency levels.

Residential electricity demand is comprised of an aggregation of demands by individual end-uses, the most important of which are space heating, food refrigeration and storage, lighting, sanitary water heating, space cooling, consumer electronics (home office equipment and entertainment), home laundry and cooking. Each of these end-use services is provided in IEA homes by specialised appliances most of which can only practically be powered by electricity. The electricity consumption of each end-use is the product of two key drivers: the number of appliances in use and the average annual energy consumption per appliance. The number of appliances in use is itself the product of the average ownership level per household and the number of households. The energy consumption per appliance is affected by the inherent nature of the energy service provided, the efficiency and capacity of the equipment, the level and manner of use of the equipment and the operating environment. The various end-uses often have quite different characteristics in each of these aspects between countries.

Significant efforts have been made within OECD countries to estimate the consumption of each electrical end-use in the residential sector and to understand the state of each of the primary drivers; nonetheless, there remain some more or less significant uncertainties that affect the overall confidence in the estimations. To understand the overall importance of each end-use across the OECD, a bottom-up equipment energy consumption stock model has been developed and used to estimate historical demand by end-use and project future residential electricity demand under a variety of scenarios. This model draws upon published data from a wide variety of sources (see references at the end of book) and represents an attempt to pool and apply the best available information on appliance energy consumption in the OECD. The model distinguishes between the following four regions with similar equipment markets: OECD Europe, OECD North America, OECD Australasia and Japan. Data for the Czech Republic, Hungary, Iceland, Mexico, Poland, Turkey and South Korea were unavailable for inclusion in the model and hence the results of the analysis presented in this Chapter and the next concern the following 22 IEA member countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

ENERGY CONSUMPTION BY END-USE

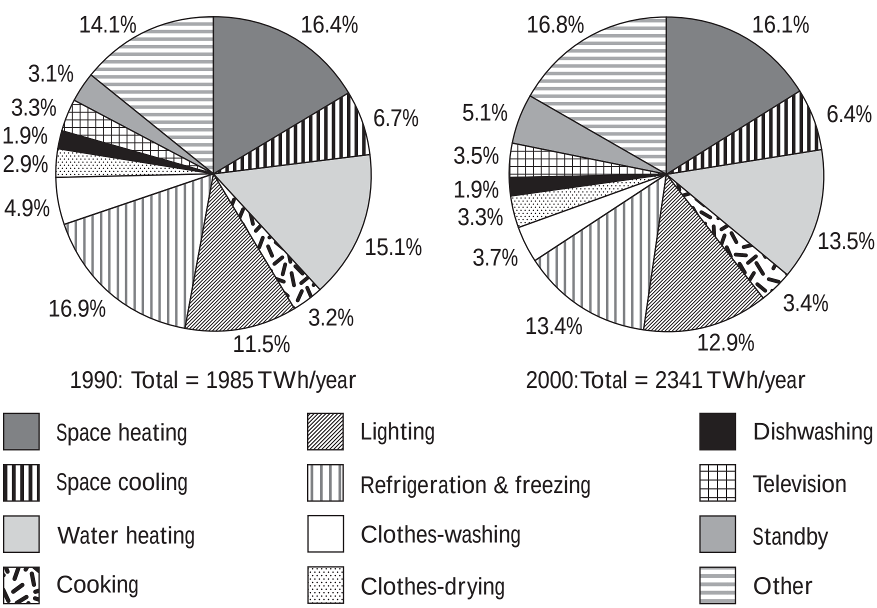
Notwithstanding the fact that the energy consumption of some end-uses is better known than others, Figure 1.1 present the share of residential electricity consumption by major end-use in 22 IEA member countries in 1990 and 2000.

Space heating accounted for 377.2 TWh in 2000 – up 16% from 1990. Space cooling is estimated at 149.2 TWh in 2000 – up 12.9% from 1990. Electric water heating energy is estimated to be 317.1 TWh in 2000 – up 5.5% from 1990. Lighting electricity consumption rose by 32.4% from 1990 to reach 301.7 TWh in 2000. Food refrigeration and freezing accounted for 314.6 TWh in 2000, which is a decline of 6.2% from 1990 levels. Clothes washers energy consumption declined by 9% to 87.6 TWh in 2000. Conversely clothes drying energy consumption rose by 32.7% to 77.1 TWh in 2000. Dishwashing energy consumption rose by 19.2% to

44.1 TWh in 2000. Television electricity consumption increased by 24% to reach 82.1 TWh in 2000. The electricity consumed by other uses increased by 49.3% to 511 TWh in 2000 of which an estimated 120 TWh is for standby[1] (Figure 1.1).

The average OECD North American household used 11,209 kWh of electricity in 2000 compared with 6,508 kWh per household in OECD Australasia, 5,945 kWh/household in Japan and 4,667 kWh per household in OECD Europe. In North America and Japan there was a general upward trend over the last decade while in Europe and Australasia there was a very slight fall. These figures come against a backdrop of an increase in household numbers and a decline in the average number of people per household in all OECD regions.

Figure 1.1 **Share of residential electricity consumption by major end-use in 22 IEA Member Countries in 1990 and 2000**



1. This figure does not include standby power consumption associated with the other major end-uses already discussed.

ENERGY CONSUMPTION AND EFFICIENCY OF SPECIFIC APPLIANCE TYPES

Space heating

An estimated 377.2 TWh of electricity was used for space heating in 22 IEA Member countries in 2000, up from 325.1 TWh in 1990. The majority of this energy was used by electric resistance heating with a heating efficiency of close to 100% but an estimated 16.6% was consumed by heat pumps. In general, when households have access to natural gas, gas is preferred as the primary heating source due to the lower running costs. When piped gas is not available, most IEA Households are heated by oil or electric heating. Electric heating is particularly commonplace in regions where electricity tariffs have traditionally been very low, as in Norway where most electricity is from hydroelectric sources; when there is no access to a gas main, as is common in many remote communities and some whole regions; and when there is a low annual heating demand. This latter case often occurs in regions with warmer temperate climates with roughly comparable space cooling and heating demands. These conditions tend to favour the installation of heat pumps as a single-shot heating and cooling system.

Between 15% and 42% of households in the IEA were using electric heating as the primary heating source in 2000. The lower figure is the proportion of IEA homes using resistance heating while the upper figure includes the 27% of IEA homes that have heat pumps, of which about 85% are equipped with individual room heat pumps. Heat pumps are particularly prevalent in Japan and some parts of the US, but much less so in OECD Europe. As heat pumps exploit ambient thermal energy to provide a large component of the delivered heat they are typically between two and three times more efficient than electric resistance heating although the real difference in operating efficiency is sensitive to the local ambient conditions as well as the type and efficiency of heat pump used.

Demand for space heating is very sensitive to local conditions depending on: the difference between the outdoor temperature and typical interior set points, which can be expressed in a simple manner through the number of degree days or hours; the thermal performance of the building stock; the quantity and volume of occupied space to be heated; occupancy patterns; ambient energy gains (solar energy gains); internal energy sources (heat from people and other equipment); and the system control, i.e. the extent to which the heating is delivered to the occupied spaces in response to demand. Most North American and European electrically heated households either use central electric heating (be it heat pump or resistance heating based) or have room heaters in all the spaces with high occupancy levels. In Japan and some parts of OECD Australasia, central or all house electric heating is relatively rare and heating is generally delivered on a room-by-room basis.

Given the complexity of the factors driving demand for electric space heating, there is considerable uncertainty about the total electric space heating load within most OECD countries and for the OECD as a whole. In the US, for example, estimates of national average electric space heating demand for electrically heated households vary by a factor of 1.6 and were set from 4,600 to 7,400 kWh/year per household depending on the source. The certainty in estimated space heating electricity consumption appears to be no greater in Europe and Japan, suggesting that there is a need to exert a more systematic effort to gather reliable data on this end-use.

Electric heating technologies

Electric resistance heaters come in a variety of types but can generally be divided into room heaters such as mobile radiant or convection heaters, or fixed heaters such as wall storage heaters, etc., and central heaters linked to a heat distribution system. The latter usually use heated air or water as a vector to transport heat to the point of demand; they include "furnace" heating systems, which are commonly found in North America but not the rest of the OECD, wherein air is heated in a central location and circulated through ducting around the building. The efficiency of the distribution system is an important component of the overall system efficiency for this type of equipment and can significantly increase the system losses. Among room heaters the coincidence of the heating and demand are an important determinant of overall efficiency. Storage electric and water heating, which take advantage of favourable tariffs for off-peak electricity have traditionally been promoted by some European utilities to maximise capacity factors for inflexible generation plant; however, storage heating is inherently less efficient than instantaneous heating due to the weaker overlap of heating supply and demand. In Japan, reversible room air-conditioners are the usual electric heating technology and can have exceptionally high efficiencies, for example the Top Runner[2] target coefficient of performance for reversible room heat pumps has been set at 5,2 W/W (520%) when measured under standard test conditions.

Dissimilarities in demand

A comparison of electric space heating energy consumption across OECD countries when normalised for dissimilarities in heated household numbers, household floor area and heating degree-days (DD) shows some stark dissimilarities. The average electrically heated household in the four most populous European countries (Germany, the UK, France and Italy) used 27.7 Wh per square metre per degree day[3] per year in 1994. The equivalent figures in other OECD countries were 13.6 Wh/m^2-DD in Australia, 14.1 Wh/m^2-DD in the US and 7.7 Wh/m^2-DD in Japan. When expressed on a per capita, rather than per unit area basis, the figures are 971 Wh/person-DD for the EU-4, 792 Wh/person-DD for the US, 590 Wh/person-DD for Australia and 289 Wh/person-DD for Japan. The more than five-fold difference in normalised per capita electric heating consumption between European and Japanese households is not explained by changes in the thermal performance of the building stock because, if anything, the European supply is better insulated. It is rather the result of cultural characteristics, wherein less occupied space is heated, and perhaps to lower average set points in Japan, and significantly due to the far higher efficiency of heat pumps compared to resistance heating. This latter result suggests that substantial energy saving would be expected through the substitution of resistance space heating by heat pumps.

Food refrigeration

Despite a long history of ownership of refrigerators and freezers in the IEA, the stock of these appliances has continued to rise throughout the last decade from an estimated 315 million refrigerators[4] and 91 million freezers in 1990 to 391 million refrigerators and 115 million freezers in 2000. The capacity of refrigeration appliances has also been increasing, albeit at a slow rate. In spite of these trends, the energy consumption of

2. Chapter 2 gives a discussion of the Top Runner programme.

3. Calculated to an 18°C base.

4. Here used to mean pure refrigerators, refrigerators-freezers and other combinations of food preservation compartments excluding pure freezers.

the stock of refrigeration appliances has stabilised and is now in decline in most OECD countries. The reason for this is a significant improvement in efficiency from the early 1970s to the current time, which has been largely policy driven. Refrigeration accounted for 335.3 TWh of residential electricity demand in IEA countries in 1990 and is estimated to have accounted for 314.6 TWh in 2000, a decline of 6.2%. As a result, food refrigeration accounted for 16.9% of OECD residential electricity use in 1990 but just 13.4% in 2000. There are significant differences in the features and storage temperatures of refrigeration appliances across the OECD, which are reflected in the different nature of the national test procedures, that makes comparison of equipment efficiency between regions difficult. The average household in OECD Europe consumed 700 kWh/year of electricity for food refrigeration in 2000 compared with 1,034 kWh/year in Japan, 1,216 kWh/year in OECD Australasia, and 1,294 kWh/year in OECD North America.

These figures mask some appreciable differences in average per household storage capacities, the ratio of frozen to fresh food storage capacity, ambient temperatures and humidity, and food storage temperatures and control. European households will typically either have a refrigerator-freezer in the kitchen with perhaps an additional freezer or pure refrigerator, or they will have a pure refrigerator and a separate freezer usually both in the kitchen. The large majority of free-standing refrigeration appliances designed to be used in European kitchens will be 60 cm wide by 60 cm deep in order to fit into standardised European kitchen spaces. The maximum practical height of these appliances is 2 metres. These dimensional limits place constraints on the available internal storage space for any single appliance and influence the degree of total volume available for insulation and the refrigeration circuit. Similar constraints apply in Japanese households, where ownership of a single refrigerator-freezer is the norm, but are less pressing in OECD North America and Australasia. In these latter countries almost all households have a refrigerator-freezer but many will also have a separate freezer and occasionally a separate pure refrigerator.

Refrigeration technologies

Almost 100% of domestic refrigeration appliances sold around the world use a vapour compression refrigeration cycle to cool stored food. A small market share exists for gas absorption cooled appliances, which are used almost exclusively for hotel mini-bars due to their very low noise levels.

Table 1.2 **Average annual household energy use, appliance ownership and unit energy consumption, 2000**

	Average Household Energy Use (kWh/household/year)	Appliance Ownership (units/household)	Unit Energy Consumption (kWh/unit/year)	Average Household Energy Use (kWh/household/year)	Appliance Ownership (units/household)	Unit Energy Consumption (kWh/unit/year)
	Space Heating - Heat Pumps			**Space Heating - Resistance**		
Europe	83	0.03	2,500	1,020	0.14	7,089
North America	341	0.11	3,094	1,195	0.19	6,400
Australasia	-	0.18	-	330	0.23	1,450
OECD	209	0.27	773	970	0.15	4,040
	Space Cooling - Room Air-Conditionners			**Space Cooling - Central Air-Conditionners**		
Europe	31	0.02	1,714	0	-	0
North America	368	0.52	714	712	0.33	2,172
Australasia	125	0.24	52	-	0.03	
OECD	205	0.29	700	252	0.12	2,103
	Water Heaters			**Lighting**		
Europe	505	0.20	2,492	574		-
North America	1,824	0.48	3,823	1,519		-
Australasia	1,943	0.49	3,977	580		-
OECD	977	0.31	3,189			-
	Refrigerators			**Freezers**		
Europe	495	1.15	432	205	0.45	450
North America	1,099	1.29	850	195	0.32	611
Australasia	932	1.07	872	284	0.41	694
OECD	752	1.20	625	217	0.35	613
	Washing machines *(with electric water heating)*			**Clothes Dryers** *(with electric heating)*		
Europe	201	0.91	221	95	0.27	353
North America	367	0.38	955	480	0.58	833
Australasia	77	0.81	96	72	0.45	158
OECD	270	0.74	363	237	0.38	619
	Dishwashers *(with electric water heating)*			**Colour Televisions**		
Europe	109	0.37	295	184	1.48	124
North America	167	0.20	850	333	2.44	136
Australasia	67	0.24	281	343	1.67	205
OECD	136	0.28	488	253	1.91	132

There are also very small niche markets for thermo-electrically cooled appliances for camping and mobile home use. A typical refrigerator or freezer has a single compressor and condenser and one or two evaporators operating in series in a single cooling circuit. About 95% of European appliances use natural convective cooling to transfer heat to the evaporator and from the condenser, while almost all North American, Australasian and Japanese appliances use forced convection (i.e. use electrically powered fans). This difference is explained because natural convective cooling is efficient, low cost and convenient for appliances with small to medium cooling capacities and which operate in low humidity conditions. In higher humidity levels the frosting on the evaporator becomes a greater inconvenience to consumers. Active no-frost technology, where a fan circulates air over the evaporator, is usually preferred. This ensures the excess moisture is deposited on it as frost and a heating cycle is activated periodically to melt the frost which is removed through a drainage system. European natural convection appliances also have automatic defrosting of fresh food (refrigerator) compartments but these use a passive heating system wherein the evaporator temperature is allowed to rise above zero degrees Celsius long enough for the accumulated frost to melt and be drained away. This approach cannot be used in the frozen food compartment and so one of the real drivers determining whether no frost technology is needed or not is the level of frost build-up in the frozen food compartment given typical usage and humidity levels. The other key driver is the size of the appliance, as beyond a certain volume and height it becomes difficult to maintain appropriate internal temperature distributions without using a fan.

The energetic implications of using an active no-frost system are rather complex. On the one hand using a high-efficiency low-powered fan will improve the heat transfer at the heat exchangers, which lowers the temperature difference between the exchangers and surrounding space and can greatly raise the efficiency of the cooling cycle. On the other hand the fans require energy, which in the case of the evaporator fan is also deposited as heat inside the appliance, while the active heating system for the evaporator can use a substantial amount of additional energy. Whether the appliance is no-frost or cooled by natural convection its efficacy is greatly influenced by the quality of insulation, the efficiency of the compressor and of the heat exchangers and the quality of the control system. All of these have improved significantly over recent years. Ironically, the larger a refrigeration appliance, the easier it is to make it more “efficient” if efficiency is measured in terms of the inverse of the energy used per unit storage space at a given temperature. The reason for this is that the surface to volume ratio is lower for larger appliances thus the heat loss per unit volume is smaller, while the useful space available for insulation or cooling circuit components is larger, which has a bearing on their efficiency. Similarly, larger capacity compressors are inherently more effective than smaller capacity units and hence give an efficiency gain to appliances with inherently larger cooling capacities.

Lighting

An estimated 301.7 TWh of electricity was used for domestic lighting in the IEA in 2000, up by 32.4% from 227.9 TWh in 1990. The majority of this energy was used by low efficiency incandescent lamps which account for ~79% of residential lamp sales by volume and have a lighting output of ~10-15 lumen per watt of electricity used. The most popular incandescent lamps have rated power inputs of 60 W but a wide range of input power levels is available. Linear fluorescent lighting, which typically has much higher efficacy levels in the region of 60-100 lumen per watt, is estimated to account for an estimated 9% of residential lighting energy consumption and ~2% of lamps sales in the OECD. Compact fluorescent lamps (CFL), which were first commercialised in the early 1980s and provide a high efficiency and cost-effective alternative to incandescent lighting (with efficacy levels in the range of 60-80 lumen/watt) had from 0.3% to 4% of residential lamp sales by volume in 1998 depending on the region. The other main sources of domestic lighting are halogen lamps and reflector lamps, of which the former has efficacy levels in the range of 15-25 lumens/watt for low voltage lamps (Table 1.3) and accounted for ~5% of lamps sales in 1998 while the latter has highly variable efficacy levels and accounted for ~10% of lamps sales by volume in 1998.

Table 1.3 **Energy efficacy levels and useful life spans of various household lamps**

Lamp type	Luminous efficacy (lm/W)*	Lamp life span (hours)
Incandescent lamp	10 - 15	1,000
Halogen lamp	15 - 25	2,000
Compact fluorescent lamp (CFL)	60 - 80	10,000
Fluorescent tube	60 - 100	10-20,000

* Luminous flux/power dissipated expressed in lumens per watt (lm/W)

The large difference in average lamp life spans by lamp type means that the proportion of lamp sales by type is not the same as the proportion of lighting provided by each lamp technology. One study has estimated that the 4.3% share of the 1998 share of the European Union household lamps market by volume taken by CFLs implied 30% lower sales of incandescent lamps by volume due to the longer average life spans of CFLs (ADEME 2001).

The average IEA Household had 25 installed lamps in 1999 (Table 1.4) although there was a greater than two-fold difference between countries.

Table 1.4 **Use of compact fluorescent lamps in OECD countries, in 1999**

Country	Number of households (million)	Proportion of households with at least one CFL (%)	CFLs in use (million)	Number of CFLs per household owning a CFL	Average number of CFLs per household for all households	Average number of lamps per households
Australia	7.09	12	0.8	1.0	0.1	15
Austria	3.38	27	2.6	3.0	0.8	30
Belgium	3.85	29	4.3	3.7	1.1	31
Canada	11.7	5	0.5	1.0	0.1	27
Denmark	2.35	56	5.9	4.2	2.4	26
Finland	2.2	n.a.	n.a.	1.0	n.a.	n.a.
France	23.14	26	4.5	1.9	0.5	n.a.
Germany	36.03	53	86.0	4.3	2.3	28
Greece	3.65	4	0.3	2.0	0.1	14
Hungary	3.85	20				
Iceland	0.1	50	0,09	2.0	1.0	20
Ireland	1.4	21	0.6	2.0	0.4	20
Italy	22.69	55	21.8	2.0	1.1	20
Japan	41.37	100	40.8	1.0*	1.0	21*
Luxembourg	0.2					
Netherlands	6.51	60	15.6	4.0	2.4	36
New Zealand	1.26	8	0.2	1.5	0.1	23
Norway	1.93	77	n.a.	n.a.	n.a.	35
Portugal	3.66	n.a.	n.a.	n.a.	n.a.	
Spain	14.94	15	6.0	4.0	0.6	15
Sweden	3.97	10	1.6	4.0	0.4	40
Switzerland	2.98	75	11.0	4.3	3.2	n.a.
Turkey	15.09					
United Kingdom	21.93	23	16.8	3.0	0.7	20
United States	101.04	12	14.4	1.2	0.1	30
OECD	**386**	**33**	**246**	**2.2**	**0.8**	**25**

* Japan has an average of 11.8 linear fluorescent lamps per home

n.a. = not available

Table 1.5 **World CFL sales** (million lamps)

	1994	**1995**	**1996**	**1997**	**1998**	**1994-98**	**Estimated number for residential use**	**Estimated number for commercial use**
North America	55	61	65	45	50	276	14	262
Latin America	5	8	10	14	16	53	n.a.	n.a.
Western Europe	76	85	95	110	125	491	190	301
Eastern Europe	3	5	7	10	11	36	n.a.	n.a.
Japan	25	30	30	30	35	150	41	109
China	7	9	15	40	45	116	n.a.	n.a.
Rest of Asia Pacific	27	37	50	65	50	229	n.a.	n.a.
Rest of the world	6	7	9	12	13	47	n.a.	n.a.
Total	**204**	**242**	**281**	**325**	**345**	**1,98**	**n.a.**	**n.a.**

There are estimated to be an average of two linear fluorescent lamps in most IEA Households, with the notable exception of Japan where they account for about 56% of installed lamps. The number of linear fluorescent lamps per household appears to be quite stable. By contrast, the number of CFLs per household appears to be growing in OECD Europe and Japan, albeit at quite a slow rate. Table 1.5 shows the evolution of global CFL sales by region from 1994 to 1998 and the estimated number of lamps destined for use in the residential sector.

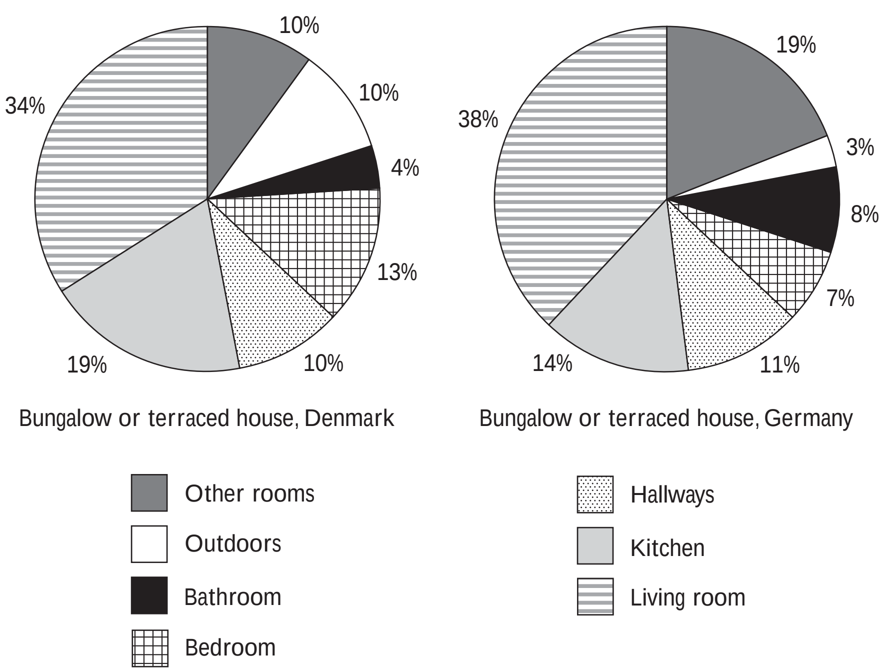
Across the OECD there were estimated to be an average of 0.8 CFLs in use per household in 1999, with ownership levels of just 0.1 CFL per household in OECD Australasia and North America rising to levels of up to 3.2 CFLs per household in OECD Europe.

The number of installed lamps per lamp-type is not necessarily representative of the overall proportion of lighting by lamp type as some studies have found that energy savings lamps such as CFLs are usually deployed in the rooms with the highest lighting use and hence account for a disproportionately high share of the total lighting load. Lighting in the living room and kitchen usually accounts for over 50% of total household lighting, while lighting in the bedrooms, bathroom and hallway accounts for most of the rest (Figure 1.2).

Like CFLs, halogen lamps have been in use since the 1980s and have captured a significant market share due to their intense light output levels. Halogens can be either low voltage dichroic and capsule lamps or high voltage lamps. The low and high voltage types have completely different energy consumption characteristics. Low voltage halogen lamps use a step down transformer, which can be associated with standby losses, but otherwise are an intermediate efficiency lighting source. High voltage halogen lamps have very high power ratings (300-500 W) and are generally used in torchiere uplighters to create high intensity mood lighting. Sales of high voltage halogen torchieres grew dramatically in OECD North America and Europe in the 1990s and in 1996 accounted for 10% of all lamps sales in the US. Sales in North America are believed to have declined steeply since that time due primarily to fire risk safety concerns but sales were still growing in Western Europe in 1998. At full power the halogen torchieres generally have efficacy levels of 15-20 lumen/watt but at partial power levels this falls to a paltry 2 or 3 lumens per watt. It has been estimated that high voltage halogen torchieres have increased lighting energy consumption more than CFL sales have lowered it in many OECD countries. Energy consumption for halogen torchieres has been estimated at 438 kWh/year per lamp in the US.

Overall, the 1990s saw a trend toward more lamps of all types per household with lower average lighting outputs per lamp across many OECD countries. In France, for example, many new residences do not have lamp fixtures hanging from the ceiling but rather are designed with numerous wall mounted side lights intended to create a mood lighting effect. The increased emphasis on mood lighting has caused average lighting energy consumption to rise across the OECD such that in 2000 the average household in OECD Europe consumed 574 kWh/year for lighting compared with 580 kWh/year in OECD Australasia, 719 kWh/year in Japan and 1,519 kWh/year in North America.

Figure 1.2 **Average proportion of household lighting energy consumption by room in typical Danish and German households**



Sanitary hot water

Unlike refrigeration and lighting, sanitary hot water is not an electricity specific end-use and is provided in most IEA Households by gas and to a lesser extent oil. Some 30.6% of IEA Households used electricity to heat sanitary hot water in 2000, down fractionally from 1990. The per capita demand for sanitary hot water has strong cultural influences but also depends on the range of appliances using hot water. In North America and OECD Australasia, household appliances such as dishwashers and washing machines draw hot water from the central water heater whereas in Europe and Japan almost all such appliances needing hot water heat it directly in the appliance. One exception, which seems to be unique to Japan, are toilets which offer a hot water flush option. The large majority of hot water demand in all OECD countries is for all body washing in either showers or baths. The next major demand is for hot water through faucets that is used primarily for hand washing but also for dish- and less often clothes, vehicle- and household surface-washing. Sanitary heated water is also sometimes required for use in swimming pools, saunas, water beds and aquariums but these end-uses are far less common and almost always use independent heaters. Table 1.6 shows measured hot water demand by application in Queensland, Australia in 1993, which averaged about 115 litres per household or 40 litres per person.

If hot water use is standardised to an energetically equivalent amount delivered at 60°C, demand in European households has been found to be between 10 and 80 litres/day per person with an average of 36 litres. In the US, average demand has been estimated at 66 litres per person.

Table 1.6 **Average household hot water usage in Queensland, Australia in 1993**

End use	Dishwasher	Kitchen sink	Washing machine	Bath	Shower	Hand basin	All
Hot water consumption (litres/day)	2	22	7	15	60	10	115

Almost all electric water heating in the OECD is via resistance water heating which has a near 100% efficiency; however, higher efficiency levels can be attained by the use of heat pumps. The amount of energy needed to heat the water via electric resistance heating is a function of the quantity of hot water demand, the average temperature of the hot water, the inlet temperature of the cold water supply and the system storage and distribution losses. The vast majority of electrically heated hot water used in the OECD is delivered from storage water heaters. These mostly operate at mains pressure, but vented units, which are gravity fed from raised feed tanks, are still common in the UK, Ireland and OECD Australasia. Because vented hot water storage cylinders can be used with either electric or gas-fired heating elements, they are sometimes sold separately to the heating system, which is never the case for pressurised units. As with storage space heating, electric storage water heating has often been promoted by utilities through favourable off-peak tariffs as a means of improving generating plant load factors. In some countries, control of the water heating cycle has been given directly to the utility through a ripple control system although more commonly simple timers are used to activate off-peak water heating.

Aside from the efficiency of the heating system, the other key aspect determining storage water heater efficiency is the level of standing losses caused by the delay between the time the water is heated and when it is used. Standing losses are a function of the insulation performance of the tank, but are also determined by the surface to area ratio (therefore smaller tanks tend to have higher losses per unit volume), the degree of stratification, the time of heating and the dynamic interaction with the water draw-off. Although most households using storage water heaters in OECD Europe and Australia heat the water in the off-peak period, peak time storage water heating is common in North America. In regions of Europe where peak-time water heating is common, instantaneous or semi-instantaneous water heaters situated at each point of demand are generally used in place of centralised storage systems with their associated standing losses and distribution losses. A small proportion of hybrid solar-electric water heaters can be found in some OECD countries, most notably in Greece, Turkey and Australia.

The average capacity of storage water heaters varies considerably across the OECD. In OECD Australasia, 250 and 315 litre units are most common with 125 litre units accounting for ~12% of sales. In Europe, there is quite diverse differences between countries. In Germany, where small semi-instantaneous heaters are commonplace, about 73% of water heaters have a capacity of less than 15 litres. In France and the UK, most water heaters have a capacity of either 50-100 or 150-175 litres. In Italy, 100 litre units are the most common but units with capacities of less than 50 litres account for 44% of the stock. In the US, storage capacities range between 113 and 303 litres with ~197 litres the average.

Altogether it is estimated there were 99.4 million storage water heaters in use in OECD homes in 2000 of which the large majority were pressurised units.

Overall it is estimated that the average household with electric water heating in OECD Europe consumed 2,492 kWh/year for water heating in 2000 compared with 3,823 kWh/year in North America, 3,977 kWh/year in OECD Australasia and 1,372 kWh/year in Japan.

The electricity consumed in water heating standing losses averaged ~454 kWh/year per electric water-heater owning household in OECD Europe (20.5% of total water heater energy consumption) and 481 kWh/year in North America (12% of total water heater energy consumption).

Space cooling

Demand for residential space cooling is growing in OECD countries but is at markedly different levels in different regions. In 1990 air-conditioning consumed 132.2 TWh of electricity in IEA Households but this rose by 12.9% to reach 149.2 TWh in 2000. The share of IEA Households having air-conditioning was ~38% in 1998; however, the penetration of air-conditioning is very variable across the OECD. In the US, about 80% of new homes are designed with central air-conditioning and overall penetration rates had reached 37% of the residential building stock by 1993. Some 27% of US homes used room air-conditioning in 1993 but the share was falling as more homes converted to central air-conditioning.

Residential central air-conditioning is rare outside North America and in most other air-conditioned IEA homes cooling is provided for individual rooms using room air-conditioners.The majority of Japanese households had air-conditioning in 2000 with an average ownership of more than two room air-conditioners per household. Most of these were reversible units, i.e. they can also operate as heat pumps to provide space heating in the winter season, and these have dominated sales compared with cooling-only units since their introduction in 1982. Air-conditioner ownership was very low in

OECD Europe in 1990, at just 0.002 units per household, but it increased more than seven-fold to reach 0.018 units per household by 2000. Room air-conditioner ownership was 24% in Australia in 2000 and an additional 3.4% of households had central air-conditioning. In OECD Europe and OECD Australasia reversible units accounted for almost 50% of the market.

There are several principal types of room air-conditioner with the most common being single split units wherein the fan cooled condenser unit is positioned outside the building and the evaporator and air circulation fan are mounted inside the cooled space. The refrigerant is circulated between the two units via flexible piping. Single packaged room air-conditioners, which are also often known as window room air-conditioners, incorporate the fans, evaporator and condenser into a single packaged unit, which is designed to be mounted in a window or a wall. Mobile room air-conditioners, known as single duct air-conditioners, are also quite common especially in places with an occasional cooling requirement, and will typically have the evaporator and condenser incorporated into a single mobile packaged unit but will discharge the heated air from the condenser to the outside via removable flexible tubing which is typically hung out of the open window. The efficiency of this type of cooling is inherently lower than for other room air-conditioner types, not least because the need to open a window to extract the warm air from the condenser allows the ingress of warm air from outside the cooled space. In recent years, multi-split room air-conditioners have also been commercialised. These are like split packaged units except that they have multiple evaporator/fan units (typically four) linked to a single external condenser/fan unit and hence are designed to provide cooling for several independent spaces. In North America almost all room air-conditioners are of the single packaged type (windows or wall units). Elsewhere in the OECD the split packaged type dominates although single packaged, multi-split and mobile room air-conditioners all have significant market shares.

Home laundry and dishwashing

Most IEA Households have a washing machine and a growing number have clothes dryers and dishwashers. Home laundry and dishwashing appliances accounted for 9.7% of electricity consumption in IEA Households in 1990 (some 191.4 TWh) and 9.1% in 2000 (208.8 TWh). Over this period, ownership of washing machines grew from 70.1% to 74.3% of which some 82% were purely electric and the remainder used water heated by other fuels. Ownership of electric clothes dryers in the OECD grew from 28.5% of households in 1990 to 36.1% in 1998, while ownership of dishwashers grew from 29.0% to 36.2%. Ownership of washing machines is similar across all OECD regions, although some countries within OECD Europe have less private ownership due to a higher than average share of communal washing facilities, but clothes dryer ownership is much higher in North America and Northern Europe than it is in the rest of the OECD. Similarly, over half of North American households own a dishwasher, compared with ~34% in Europe, 27% in OECD Australasia and ~13% in Japan. Dishwasher and clothes dryer ownership levels are rising quite steadily whereas washing machine ownership is near to saturation.

Despite a slight increase in ownership OECD washing machine electricity consumption fell from 96.3 TWh in 1990 to 87.6 TWh in 2000. The annual average energy consumed by a washing machine varies considerably across the OECD because of the use of regionally specific washing machine technologies. OECD countries can be divided into those where clothes are washed using a mixture of heated water, detergent action and mechanical action (Europe and North America) and those where clothes are cleaned just by detergent and mechanical action (Japan and Australasia). Clothes washing in unheated water is possible if stronger detergents are used and if the mechanical action is more rigorous although this can have consequences concerning the wear and tear of the washing process on the clothing and regarding the release of waste-water pollutants. The energy used to produce the detergent is also an important factor in the overall life-cycle energy requirement of the washing process. If a washing machine heats up water internally this invariably dominates its total energy consumption for which the main determinants become the final heated water temperature and the amount of water to be heated. All washing machines use electricity to drive the motor and to operate the control system. Despite the common application of heated water for clothes washing in Europe and North America there still remain some important differences. Most North American washing machines draw hot water from the central water tank whereas most machines in OECD Europe, with the exception of some in the UK and Ireland, heat the water directly in the appliance. Until recently almost all North American appliances have used vertical axis drums, which are inherently less water and energy-efficient than the horizontal axis drums traditionally used in Europe. Furthermore, the capacity of most North America washing machines is appreciably greater than in Europe and the rest of the OECD, although in itself this does not necessarily imply higher overall energy consumption because wash frequency and clothes-loading patterns also have to be considered. Depending on cultural and climatic factors the spin-drying efficiency of a washing machine can have an important bearing on the total energy consumption of the washing and drying cycle. Spin drying is a far more efficient means of moisture removal than heating in a clothes dryer and therefore higher spinning moisture removal levels may result in slightly higher washing machine energy consumption but will reduce total washing and drying energy consumption when assisted drying is being used.

The interaction of all these factors complicates the interpretation of average clothes washing energy consumption levels per household across the OECD. The average North American household using electrically heated water is estimated to have consumed 955 kWh/year for clothes washing in 2000, compared with 221 kWh/year in OECD Europe, 96 kWh/year in OECD Australasia and a slightly smaller figure in Japan.

Clothes dryer energy consumption in the OECD was 58.1 TWh in 1990 and 77.1 TWh in 2000, which represents a growth in the share of total residential electricity consumption of 2.9% to 3.3% over the same period. Average clothes dryer electricity consumption per clothes dryer owning household shows surprisingly high variation across the OECD with North American households using 833 kWh/year in 2000, OECD-European households 353 kWh/year and OECD Australasian households 158 kWh/year. The most widespread clothes dryer technology is essentially the same across the OECD although there are some regional differences in average clothes dryer capacity and the prevalence of sophisticated sensing and end-of-cycle technology. Some of the apparent difference in regional average energy consumption may be due to uncertainty in the estimations, which in the case of Europe have been as high as 480 kWh/year for example, but they may also indicate strong cultural and climatic divergences, which influence the degree of clothes dryer use.

Dishwasher energy consumption in the 22 IEA countries was 37.0 TWh in 1990 and 44.1 TWh in 2000, which represents 1.9% in the share of total residential electricity consumption. Average dishwasher electricity consumption per dishwasher owning household shows surprisingly high variation across the OECD with North American households using 850 kWh/year in 2000, Japanese households ~295 kWh/year, OECD-

European households 295 kWh/year and OECD Australasian households 281 kWh/year. North American dishwashers tend to be larger than elsewhere in the OECD but the reported differences in household average dishwasher consumption suggest that they are also used more frequently than elsewhere. There is a dearth of high quality data on the energy used by washing dishes by hand and on the proportion and quantity of dishes washed by hand or in a dishwasher from which to compare the average per household energy consumption for the dishwashing process as a whole. Despite this, modern dishwashers are generally more efficient than before and increasingly use sophisticated sensors to determine the quantity and dirtiness of the dishes to be washed which enables the amount of energy needed for water heating to be minimised. Some dishwasher manufacturers have argued that cleaning dishes in a dishwasher generally uses less energy than washing them by hand in the kitchen sink.

Cooking

The energy used to cook food is strongly culturally dependent and shows high variability within OECD regions, especially Europe, as well as between regions. In North-America, OECD Europe and OECD Australasia, the most important cooking appliances, are ovens, hobs (ranges) and microwave ovens. Range or cook-top extractor hoods can also use significant amounts of electricity, while in Japan rice cookers are an important cooking end-use. The majority of cooking energy is used to heat food with much less being used for defrosting frozen food, food preparation and control of cooking appliances. In consequence, cooking is not an electricity specific activity and a significant share of primary cooking energy is attributable to natural gas or LPG. The use of fuels other than electricity for cooking varies among OECD countries.

Some 65% of IEA Households owned an electric oven and/or hob in 1990 and 69% in 1998. The energy consumption of electric ovens and hobs in the OECD, excluding microwave ovens, is estimated to have been 64.0 TWh in 1990 and 79.6 TWh in 2000; however, there is a high degree of uncertainty about these values. The frequency and length of cooking appliance use and the choice of cooking-cycles are relatively poorly researched and are very dependent on cultural factors, as well as evolutions in lifestyle and household composition. Modern households increasingly possess a broad range of specialised ancillary cooking appliances aside from the main cooking appliances, which increases the complexity of attempts to gather more detailed data by individually metering the various cooking loads. Furthermore, the cooking requirement is very dependent on the choice of meal (e.g. at one extreme food to be eaten raw requires no cooking while at the other food which involves extensive baking requires lengthy cooking), the state of the food to be cooked (i.e. depending on whether one is cooking fresh, frozen, partially pre-prepared or ready-made meals) and the frequency at which home prepared meals are consumed.

Appliances designed to prepare hot drinks can also make a significant contribution to household electricity demand and their use again depends upon cultural and lifestyle factors. In some OECD countries it is common practice to heat hot water for drinks in the microwave or on the stove top (hot plate) while in others specialised electric or gas kettles are used. In some countries coffee makers are the main drinks related end-use.

Consumer electronics, standby and miscellaneous end-uses

Consumer electronics include: televisions and associated equipment (satellite receivers, integrated receiver decoders (IRDs) or set top boxes and video cassette recorders (VCRs)); audio equipment such as various hi-fi, radio and recording equipment; home computers and home office equipment such as faxes, printers, scanners, data recording and storage devices. The share of residential electricity used by consumer electronics has grown appreciably over recent years, which reflects the growing number and diversity of such appliances in the home. Among these appliances, televisions are the most widespread and have the highest overall energy use. There were an average of 1.71 televisions per IEA Household in 1990 and 1.91 in 2000. Average ownership was over one per household in all OECD countries with OECD Europe having the lowest television ownership at 1.48 per household and OECD North America the highest at 2.44 per household. Across the IEA, televisions are estimated to have consumed 66.2 TWh/year in 1990 and 82.1 TWh/year in 2000.

Modern televisions are designed to operate with any combination of: video cassette recorders (VCRs), integrated receiver decoders (IRDs, sometimes called set-top boxes, which receive and decode digitally broadcast television signals for use with a television), satellite receivers (designed to receive analogue sound and picture signals broadcast by satellite), DVD video players (that reproduce digital video and audio signals recorded on a disc), antennae amplifiers (that amplify broadcast signals received by cable or an antenna), and dish positioners (an appliance to position a dish to receive signals broadcast by satellite). There are also some televisions that are an integrated combination of some of the above, i.e. TV/VCR combinations or TV/IRD combinations. Although the efficiency of cathode ray tubes improved substantially in the early 1970s, which led to a sharp decline in television on-mode power consumption up to about 1976, average television on-mode power levels have risen since the mid 1980s as new features have come onto the market. These include larger televisions, changes in aspect ratios, e.g. wide-screen models, higher frequency scan rates, digital TV, and stereo or wrap-around sound. More recently flat screen televisions have begun to enter the market using either plasma or LCD display technology.

The annual energy consumption of most other consumer electronics is higher in the long periods spent in idle or standby mode than it is in the comparatively brief on-mode periods. This is true for VCRs, set top boxes, most audio and hi-fi equipment and most office equipment. Collectively the standby and idle-mode electricity consumption across the IEA of consumer electronics (excluding televisions) and of miscellaneous end-uses (excluding all end-uses referred to above) is estimated to have been 61.1 TWh in 1990 and 120 TWh in 2000. If standby power consumption in all residential end-uses is aggregated these figures are likely to be significantly higher. Nonetheless, these consumption levels alone amounted to 5.2% of IEA residential electricity demand in 2000. Two competing effects are determining total standby energy consumption levels: on the one hand the ownership of appliances with a standby function is continuing to grow while on the other the average standby power level for many appliance types is falling. The ownership of appliances using standby is in a constant state of flux. New consumer electronics and other miscellaneous appliances periodically arrive on the market and can rapidly attain very high penetration rates, such as VCRs which began to be popularised in 1977 and have since reached high ownership levels in all OECD countries, and more recently set top boxes. The issue of standby is discussed in detail in Chapter 5.

The ownership of miscellaneous appliances is also growing rapidly in OECD countries. Table 1.7 summarises the variety of miscellaneous end-uses found in US households and gives estimates of the evolution of the stock from 1980 to 1995 and of their annual average unit energy consumption (UEC). The various end-uses are grouped into those where the primary energy consumption mode is for: motors, lighting, heating and electronics. Some of these end-uses have very high unit energy consumption levels, such as swimming pool pumps, spas and water bed heaters, and as a result can make quite significant contributions to total residential electricity consumption despite relatively low ownership levels. Water bed heaters, for example, used 42% of the electricity of televisions in the US in 1995 despite having ownership levels of just 15% of households compared with 233% for televisions.

Collectively, consumer electronics and miscellaneous end-uses, including standby loads and television energy consumption, accounted for 408.5 TWh of electricity consumption across the OECD in 1990 and 592.9 TWh in 2000. This represented a 4.5% annual growth in the share of total residential electricity consumption from 20.5% in 1990 to 25.5% in 2000. As with other end-uses, however, there are large differences among the regions. The average household in OECD Europe consumed 1,230 kWh/year for miscellaneous end-uses and consumer electronics in 2000 compared with 2,159 kWh/year in OECD Australasia, 1,817 kWh/year in Japan and 2,615 kWh/year in North America.

Table 1.7 **Stock, unit energy consumption and national energy consumption of miscellaneous electrical end uses in the US**

End use	Stock (million of units)				Unit energy Consumption	National consumption (TWh)			
	1980	1985	1990	1995	(kWh/year)	1980	1985	1990	1995
Motors									
Furnace fans	33	36	42	43	500	16.6	18.2	21.0	21.4
Ceiling fans	8	36	97	140	50	0.4	1.8	4.9	7.0
Pool pumps	1	2	5	4	1500	1.9	3.0	7.6	6.4
Well pumps	13	13	14	12	400	5.0	5.4	5.7	4.8
Dehumidifiers	8	8	8	11	400	3.1	3.2	3.4	4.4
Aquariums	4	5	5	8	548	2.4	2.6	2.8	4.2
Evaporative coolers	2	3	4	3	1183	4.9	3.1	4.4	3.2
Vacuum cleaners	80	86	92	96	31	2.5	2.7	2.9	3.0
Air-cleaners, mounted	1	2	3	5	500	0.6	1.1	1.7	2.5
Humidifiers	5	9	12	13	100	0.5	0.9	1.2	1.4
Air-cleaners, unmounted	0	0	11	22	55	0.0	0.0	0.6	1.2
Hand-held rechargeable vacuums	0	14	34	21	43	0.0	0.6	1.5	0.9
Electric lawn mowers	6	6	6	6	100	0.6	0.6	0.6	0.6
Blenders	50	62	71	80	7.3	0.4	0.5	0.5	0.6
Exhaust fans	29	32	37	36	15	0.4	0.5	0.6	0.5
Garbage disposers	31	30	38	41	10	0.3	0.3	0.4	0.4
Sump/sewage pumps	8	9	9	10	40	0.3	0.3	0.4	0.4
Whole-house fans	8	9	9	4	80	0.6	0.7	0.8	0.3
Electric toothbrushes	3	3	6	12	26	0.1	0.1	0.2	0.3
Window fans	4	9	10	15	20	0.1	0.2	0.2	0.3
Floor fans	22	39	35	36	8.1	0.2	0.3	0.3	0.3
Bottled water dispensers	1	1	1	1	300	0.2	0.3	0.3	0.3
Desk fans	6	19	28	32	8.1	0.1	0.2	0.2	0.3
Stand fans	0	0	4	28	8.1	0.0	0.0	0.0	0.2
Can openers	50	57	63	66	3.3	0.2	0.2	0.2	0.2
Hand mixers	20	41	64	89	1.5	0.0	0.1	0.1	0.1
Hand-held electric vacuums	0	2	8	20	3.9	0.0	0.0	0.0	0.1
Compactors	2	2	2	1	50	0.1	0.1	0.1	0.1
Food slicers	0	29	46	42	0.9	0.0	0.0	0.0	0.0

(continued)

End use	Stock (million of units)				Unit energy Consumption	National consumption (TWh)			
	1980	1985	1990	1995	(kWh/year)	1980	1985	1990	1995
Stand mixers	7	12	17	22	1.3	0.0	0.0	0.0	0.0
Electric knives	30	33	36	38	0.7	0.0	0.0	0.0	0.0
Central vacuums	0	0	0	1	24	0.0	0.0	0.0	0.0
Men's shavers	28	31	38	38	0.5	0.0	0.0	0.0	0.0
Hand-held massagers	4	7	10	12	0.3	0.0	0.0	0.0	0.0
Women's shavers	10	8	9	10	0.2	0.0	0.0	0.0	0.0
Juicers	0	0	2	4	0.4	0.0	0.0	0.0	0.0
Foot massagers	0	0	0	0	6.8	0.0	0.0	0.0	0.0
Subtotal, motors						***39.4***	***46.8***	***62.5***	***65.5***
Lighting									
Torchiere lamps	0	0	1	30	394	0.0		0.3	11.9
Grow lights	0	0	0	0	800	0.3	0.3	0.4	0.4
Subtotal, lighting						***0.3***	***0.3***	***0.7***	***12.3***
Heating									
Waterbed heaters	7	10	14	15	900	6.5	9.4	12.6	13.2
Automatic drip coffee-makers	40	53	68	81	116	4.7	6.1	8.0	9.4
Crankcase heaters	24	26	28	29	200	48	5.2	5.6	5.8
Irons	80	86	84	86	53	4.2	4.6	4.4	4.5
Spas/hot tubs	2	2	2	2	2300	3.7	4.0	4.3	4.5
Electric blankets	44	44	37	29	120	5.3	5.3	4.4	3.5
Toasters	81	87	79	85	39	3.1	3.3	3.1	3.3
Hair dryers	40	68	81	85	35	1.4	2.4	2.9	3.0
Toaster ovens	16	28	36	40	50	0.8	1.4	1.8	2.0
Percolator coffee-makers	14	25	23	17	65	0.9	1.7	1.5	1.1
Slow cookers	34	62	68	59	16	0.5	1.0	1.1	0.9
Waffle irons / sandwich grills	24	26	28	33	25	0.6	0.6	0.7	0.8
Hot plates	20	21	22	24	30	0.6	0.6	0.7	0.7
Auto engine heaters	2	2	2	2	250	0.4	0.4	0.5	0.5
Deep fryers	8	21	19	15	20	0.2	0.4	0.4	0.3
Heat tapes	2	3	3	3	100	0.2	0.3	0.3	0.3
Hair setters	21	19	22	27	10	0.2	0.2	0.2	0.3
Heating pads	20	42	61	68	3.4	0.1	0.1	0.2	0.2

(continued)

End use	Stock (million of units)				Unit Energy Consumption	National consumption (TWh)			
	1980	1985	1990	1995	(kWh/year)	1980	1985	1990	1995
Automatic griddles	22	23	25	26	5.5	0.1	0.1	0.1	0.1
Espresso makers	0	0	2	7	19	0.0	0.0	0.0	0.1
Electric grills	2	1	1	1	180	0.3	0.3	0.2	0.1
Air corn poppers	13	22	29	20	6.1	0.1	0.1	0.2	0.1
Electric kettles	0	0	1	1	75	0.0	0.0	0.1	0.1
Instant hot water heaters	0	0	0	0	160	0.1	0.1	0.1	0.1
Curling irons	28	28	39	54	1.0	0.0	0.0	0.0	0.1
Hot-oil corn poppers	7	13	16	11	2.5	0.0	0.0	0.0	0.0
Subtotal, heating						***39.0***	***47.7***	***53.4***	***55.1***
Electronics									
Cable boxes	16	32	50	58	175	2.8	5.6	8.8	10.2
Video cassette recorders	2	29	89	133	57	0.1	1.6	5.1	7.6
Compact audio systems	42	47	46	53	81	3.4	3.8	3.8	4.3
Rack audio systems	31	39	50	55	55	1.7	2.1	2.8	3.0
Doorbells	57	61	65	68	44	2.5	2.7	2.9	3.0
Computers	4	9	13	21	130	0.5	1.1	1.7	2.8
Clocks	81	87	93	97	26	2.1	2.3	2.5	2.6
Answering machines	2	10	45	66	35	0.1	0.3	1.6	2.3
Home radios, small/clocks	156	149	133	105	18	2.8	2.7	2.4	1.9
Cordless telephones	0	15	32	61	26	0.0	0.4	0.8	1.6
Video games	0	3	36	64	24	0.0	0.1	0.8	1.5
Boom boxes	15	56	78	73	19	0.3	1.1	1.5	1.4
Laser printers	0	0	2	5	249	0.0	0.0	0.4	1.4
Garage door openers	23	24	26	27	44	1.0	1.1	1.2	1.2
Security systems	0	6	13	19	43	0.0	0.3	0.6	0.9
Inkjet faxes	0	0	1	3	216	0.0	0.1	0.2	0.6
Printers	3	7	9	12	45	0.1	0.3	0.4	0.5
Satellite dishes	0	1	2	5	96	0.0	0.1	0.2	0.5
Home medical equip.	0	0	0	0	400	0.2	0.2	0.2	0.2
Copiers	0	0	1	2	25	0.0	0.0	0.0	0.0
Subtotal, electronics						***17.6***	***25.8***	***37.7***	***47.5***
TOTAL						***96***	***121***	***154***	***180***

Source: Sanchez 1998

POLICIES USED IN IEA COUNTRIES

KEY MESSAGES

- *Policies and measures to promote energy-efficient domestic appliances exist in each OECD country.*
- *However, they differ in nature, ambition and scope across individual countries and markets as well as across end-uses.*
- *Information labels, minimum energy efficiency standards and voluntary agreements are the most popular measures and are typically implemented at national and regional levels.*
- *Financial incentives and promotion campaigns are mostly implemented at sub-national - state/provincial and local - levels.*

This chapter comprises a critical review of current appliance programmes enforced in IEA Member countries. Analysis of some policy details appears as important as the presentation of the general policy context.

The current levels of residential electricity consumption in the OECD are occurring against a background of over a decade of energy efficiency initiatives. OECD countries use a variety of policies to improve the energy efficiency of home appliances and office equipment and, increasingly, home entertainment electronics and lighting equipment (Table 2.1). The most widely deployed policy measures are: information and awareness raising programmes; energy labelling; mandatory minimum energy performance standards (MEPS); and voluntary efficiency agreements (VAs). Other instruments, such as procurement programmes and financial incentives, are used less frequently and for limited duration. Labels, MEPS and VAs are typically implemented at national and regional levels, while financial incentives are mostly implemented by sub-national – state/provincial and local – authorities and by utilities and third-party consumer organisations.

Nearly all IEA countries, and many non-Member countries, use labels for refrigerators and other major home appliances. Many countries have also adopted minimum energy performance standards (MEPS) for refrigerators. For other home appliances, MEPS are used most in Canada, the United

States and Korea. Other countries use such regulatory standards, or similarly-defined targets, on a more sporadic basis. Japan has fleet average targets for refrigerators and room air-conditioners. Australia and New Zealand have now introduced MEPS on some equipment such as refrigerators, freezers and air-conditioners. Switzerland has used voluntary targets for refrigerators, washing machines, clothes dryers, dishwashers and electric ovens. The European Union has voluntary targets for washing machines, dishwashers, water heaters, televisions, videocassette recorders, audio equipment, digital receiver decoders and external power supplies.

For office equipment and home electronics, endorsement labels are the most commonly employed policy instrument. Energy Star (EPA 2002) and the Group for Energy Efficient Appliances (GEEA) (GEEA 2002) labels are used for personal computers, monitors, printers, copiers and fax machines. With the exception of Japan's standards for televisions, videocassette recorders, photocopiers, computers and magnetic hard-disk drives, MEPS are rarely used for such equipment. Voluntary targets, also called negotiated agreements, are the more common measures used to improve these types of electronic equipment. Switzerland uses voluntary targets for all major types of office equipment.

The deployment of these policies in the four OECD regions is discussed in the next sections. A great number of appliance efficiency policies have been adopted. Although some have been quite ambitious, overall these measures have been too weak to lower the energy consumption and carbon emissions of appliances in absolute terms. They have been successful in reducing energy and carbon growth rates, but have not been able to offset increased numbers and levels of use of appliances. To effect actual decreases in energy consumption and carbon emissions levels, appliance efficiency policies would need to be considerably more stringent than at present.

AUSTRALASIA

Since 1992 the Commonwealth (national) government has taken the lead in developing Australia's appliance efficiency policies, with the states and territories playing a key role in legislating efficiency requirements. The National Appliance and Equipment Energy Efficiency Committee

Table 2.1 **Use of labels, standards and targets programmes for major home appliances** (as of January 2002)

	Comparison Label												Endorsement Label												Standards											
	Australia	Canada	Czech Republic	European Union	Hungary	Japan	Korea	New Zealand	Norway	Switzerland	Turkey	United States	Australia	Canada	Czech Republic	European Union	Hungary	Japan	Korea	New Zealand	Norway	Switzerland	Turkey	United States	Australia	Canada	Czech Republic	European Union	Hungary	Japan	Korea	New Zealand	Norway	Switzerland	Turkey	United States
Refrigerators	M	M		M	M	M	M	V	M	V		M	V			V					V			V	M	M		M	M	T	M			?		M
Freezers	M	M		M	M	M		V	M	V		M	V			V					V				M	M		M	M					?		M
Dishwashers	M	M		M	M			V	M	V		M	V	V		V					V			V		M		V						?		M
Washing Machines	M	M		M	M		M	V	M	V		M	V			V					V			V		M		V			M			?		M
Clothes Dryers	M	M		M	M			V	M	V			V											V		M								?		M
Washing machines/Dryers	M	M		M	M			V	M	V														V		M										M
Ranges/Ovens		M																						V		M								?	?	M
Microwave Ovens																			V																	
Air-conditioners - Room	M	M				M	M	V				M	V											V		M				T	M					M
Air-conditioners - Central	V	V					M	V				M		V										V	M	M										M
Air-conditioners - Single Packaged	V	V					M	V				M												V	M	M										M
Air-conditioners - Split System	M	V					M	V				M	V												M	M										M
Heat Pumps	M	V					M	V				M	V								V			V		M										M
Space Heaters	V	V					M					M	V													M										M
Dehumidifiers																										M										
Furnaces		V										M														M								?		M
Water Heaters	V							V				M	V	V											M	M		V								M
Lamps				M	M	M	M		M	V		M		V		V	V		V					V		M				T	M					M
Ballasts							M					M		V										V		M		M		T	M					M
Copiers													V	V		V		V	V	V	V	V		V						T	M			V		
Fax Machines													V	V		V		V	V	V	V	V		V							M			?		
Computers													V	V		V		V	V	V	V	V		V						T	M			V		
Monitors													V	V		V		V	V	V		V		V							M			?		
Printers													V	V		V		V	V	V	V	V		V							M			?		
Scanners													V			V		V		V		V		V							M					
Multi-function Devices													V	V		V		V		V		V		V												
Hard-disk Drives																														T						
Televisions						M										V			V		V	V		V				V		T	M			?		
VCRs and DVDs																V			V		V	V		V				V		T	M			?		
Radios																V						V		V				V			M					

M = Mandatory; V = Voluntary; T = Target
Source: Harrington and Damnics, 2002.

(NAEEEC), made up of Commonwealth and states and territories officials, has harmonised existing state programmes and organised efforts to develop new programmes. However, because of the constitutional situation, the NAEEEC is still technically a co-ordination body. It writes model legislation that the states and territories then mirror. New Zealand adopted the Australian mandatory energy labelling scheme in April 2002. Its MEPS programme, which entered into force in July 2002, is partially harmonised with the Australian MEPS programme (EER 2002).

Table 2.2 **Summary of appliance policy instruments in Australia and New Zealand**

	Comparison Label	Endorsement Label (Galaxy Award)	Standards
Refrigerators	M	V	M
Freezers	M	V	M
Clothes Dryers	M	V	
Washing Machines	M	V	
Washing Machines/Dryers	M		
Dishwashers	M	V	
Air-conditioners			
- Room	M	V	
- Central	V		M
- Single Packaged	V		M
- Split System	M	V	M
Heat Pumps	M	V	
Space Heaters	V	V	
Water Heaters	V	V	
Copiers		V	
Fax Machines		V	
Computers		V	
Monitors		V	
Printers		V	
Scanners		V	
Multi-function Devices		V	

M = Mandatory; V = Voluntary
Source: Harrington and Damnics, 2002

Labels

Australia's comparison label is a category-type label. It awards appliances 1 to 6 stars (6 for the lowest energy use) based on their energy consumption. The primary focus is on ranking product models against a predetermined, open-ended efficiency scale (based on service per kWh). Secondly, the label indicates energy use (kWh per year) and performance, such as noise and cooling characteristics for refrigerators. The design and star rating algorithms of the label were recently upgraded to ensure their currency, usefulness to consumers and technical rigour. The Australian Greenhouse Office administers the labelling programme for electrical products; the Australian Gas Association administers the programme for gas water heaters, space heaters and central heaters.

Australia has also two endorsement labelling programmes. Galaxy Awards are given to appliances that have the highest star rating in their mandatory labelling category. Energy Star labels are applied to office equipment.

The categorical energy label used in Australia has been shown to have had a significant impact on the efficiency of products on the Australian market; furthermore the benefits of a vigorously applied check testing programme are also apparent from inspection of the data (Waide 2001). It is estimated that had the states not introduced the labels in 1986, the annual energy consumption of all new appliances of the labelled types sold in 1992 would have been about 11% higher than it was, and total household electricity consumption would have been about 1.6% higher (Wilkenfeld 1993). The sales-weighted electricity consumption of refrigerators and freezers was estimated to be 12% below what it would have been without labelling, for dishwashers 16% below, for clothes dryers 1% below and for air-conditioners 6% below (Wilkenfeld 1997). The labels were estimated to be realising about a third of their theoretical potential – the energy savings that would have occurred had consumers been perfectly informed and perfectly rational, and chosen the most cost-effective model in the size and configuration they bought – for refrigerators (35%), dishwashers (36%) and air-conditioners (39%), and somewhat less for clothes dryers (13%) (Wilkenfeld 1997, IEA 2000).

MEPS

In 1995, Australian energy ministers agreed to implement MEPS for household refrigerators and domestic electric storage water heaters which came into force in 1999 (Holt 1999). The levels set for these first MEPS were not very ambitious. In 1999, Australia adopted a policy to match the world's "best regulatory practice" standards for a wide range of domestic and commercial equipment. Under this programme, Australia reviews the appliance standards of its major trading partners, and then sets its own standards to the level of the most stringent ones found. The first of these new MEPS will apply to refrigerators and freezers from 2004. They are based on the US standards implemented in 2001. New MEPS for room air-conditioners, central-air-conditioners, electric water heaters, clothes dryers and front-loading washing machines are due to come into force from 2005 to 2007 (AGO 2001, GWA 2001). The appliance label was estimated to save 5 Mt of CO2 between 1986 and 2000. In 2000, the MEPS programme was projected to abate more than 81 Mt CO2 between 2000 and 2015 (GWA 2001).

Assessment

Australia's labelling programme is very up to date. The labels have recently been upgraded to ensure their technical rigour and usefulness to consumers with respect to current appliance markets. They are supported by a vigorously applied check testing programme. There is good co-ordination between the labelling and MEPS programmes. A revision of MEPS levels triggers an immediate revision of energy labels to ensure that the latter remain relevant.

Australia's new MEPS programme is very transparent and ambitious. The targeted levels of appliance efficiency are clearly set out. The presumption is that stringent targets are necessary, and the onus is on manufacturers to explain why a less ambitious regulation may be adequate. The programme is further strengthened by having a set schedule for writing new specifications and updating old ones.

The programme was developed fairly quickly, in part because the analytical component of the process focused more on other countries' MEPS than on the technical and economic situation in the domestic appliance market.

The policy, however, is subject to economic cost-benefit analyses where government agencies proposing MEPS must show that the proposed level is in the community's best interest. By matching (not exceeding) world best regulatory practice, no market is foreclosed to Australian based suppliers and Australia can rely on the engineering-economic analysis conducted in Europe or North America to demonstrate that the proposed technical improvement is feasible.

However, the lack of formal engineering-economic analysis means that the full economic implications of adopting a given MEPS level are not fully known. In addition, the programme is very dependent on international policy-making activity. Lack of such activity could render Australia's programme moribund, and overly aggressive international activity could theoretically bind Australia to an excessively stringent MEPS.

EUROPE

The Single European Market created in 1992 seeks to eliminate inter-community trade barriers within the European Union. This has meant that regulatory policies concerning tradable goods – including appliance labels, MEPS and VAs – are developed at EU-wide harmonised levels[5]. Other appliance measures, such as information, procurement and financial incentive programmes, are carried out at the Member State and local levels.

In recent years, other OECD European countries have adopted appliance efficiency policies that are largely consistent with those of the European Union. The Czech Republic, Hungary and Poland have largely harmonised their regulatory requirements with those of the European Union as part of the process of acceding to the Union (AE 4/1999). Norway has implemented labelling programmes that follow the European Union directives on clothes dryers, washing machines, dishwashers, lamps, and refrigerators and freezers (EEU 1999). Switzerland, after using its own system of target values and endorsement labels to improve appliance and equipment efficiency in the 1990s, launched a new programme in

5. Prior to 1992, there were some instances of individual EU Member States undertaking labels, MEPS and VAs to improve appliance efficiency. The German government negotiated a VA to raise the efficiency of new appliances with the main German based household appliance manufacturers association ZVEI in 1983. In France mandatory energy labelling for some appliances was introduced in the 1980s and MEPS had been imposed for refrigerators as early as the 1960s although these were not revised and eventually became obsolete (Waide 1995, 1997).

January 2001 that encompasses the EU comparison label and MEPS for household appliances, the GEEA label for consumer electronics and office equipment and the Energy Star label for office equipment. Turkey implemented labels and MEPS for residential appliances and equipment in March 2002, and is considering a number of other measures. The mandatory label is entirely inspired by the European Union appliance labelling scheme.

Details of the energy labels, MEPS and VAs in place in the EU are given in Table 2.3.

Table 2.3 **Summary of European Union appliance policy instruments** (current and under negotiation*)

Sector	Sub-sectors covered	Instrument	Directive	Minimum efficiency level/ maximum power demand	In force**/ target date
Multiple		Framework legislation for energy labels	92/75		1.1.1994
Cold appliances		1st label	94/2		1.1.1995
		2nd label*	-		2003-4?
		1st minimum standard	96/57	Label class C except for chest freezers where it is E	3.9.1999
		2nd minimum standard or industry agreement*	-	Recommendation is for a new threshold set at the current class A	2003-5
Wet appliances	Washing machines	1st label	95/12		1.10.1996
		2nd label*	-		2002-3
		Industry agreement	CD/ 24.1.2000	Label class D (with minor exceptions) Label class C	1.1.1998 1.1.2000
		Industry agreement*	-	5% reduction from 1,04 kWh per wash-load (1996 baseline)	2001
	Clothes dryers	Label	95/13		1.10.1996
	Washer-dryers	Label	96/60		1.1.1998
	Dishwashers	1st label	97/17		1.8.1999
		2nd label*	-		2004
		Industry agreement	-	≥ 10 place settings: D; < 10 place settings: E ≥ 10 place settings: C; < 10 place settings: D	1.1.2001 1.1.2005

(continued)

Sector	Sub-sectors covered	Instrument	Directive	Minimum efficiency level/ maximum power demand	In force**/ target date
Consumer electronics	TV and VCRs	Industry agreement	98/C12/02	Standby: max cons. 10 W; fleet average 6 W	1.1.2000
				Standby: fleet average 3 W	1.1.2009
	TVs	Label*	-		n.a.
	Audio	Industry agreement	-	Standby: 5 W	1.1.2001
				Standby: 3 W	1.1.2004
				Standby: 1 W	1.1.2007
	Digital receiver decoders	Industry agreement	-	Standby: 9 W for stand-alone, 10 W for integrated digital receiver decoder	1.1.2003
				Standby: new targets to be defined in 2003	2005
	External power supplies	Industry agreement	-	No-load: = 0,3 W and < 75 W: 1 W	1.1.2001
				No-load: = 0,3 W and < 75 W: 0,5 W	1.1.2003
				No-load: 0.3-0.75 depending on power output	1.1.2005
Lighting	Lamps	Label	98/11		1.1.2001
	Fluorescent ballasts	Minimum standard	2000/55	C	21.5.2002
				B2	21.11.2005
				A3 or B1 depending on the market situation	21.11.2008
Cooking	Ovens	Label	2002/40	Electricity only	30.6.2003
				Gas - no test procedure	
Water heating	Boilers	Minimum standard	92/42	Eliminated the least efficient boilers on the market. Label being considered	1.1.1998
	Electric storage heaters	Label*	-	Most details resolved but still under discussion	2004?
		Industry agreement		Phase out supply of equipment with a first level of standing losses	31.12.2000
				Attain fleet average equipment sales with standing losses at the second level or better	1.1.2002
Air-conditioners		Label	2002/31		30.6.2003
		Industry agreement *		The major manufacturer association intend to impose their own MEPS to phase out the least efficient models	2002-3
Office Equipment		Energy Star Label *	Agreement of 28.9.1999 and COM 2000		

* Under negotiation or development; provisional details given where available but these may change.
** In force indicates the date on which the provisions should be in force in the Member States, e.g. the date from which energy labels should be on the appliances in the shops.
Source: LCF 2000, updated Lane 2001, Waide 2001 and EC 2002a, 2000b

Labels

In 1992 a European framework energy labelling Directive was passed which authorised the Commission, in consultation with a regulatory committee composed of representatives of the 15 EU Member States, to issue mandatory comparative energy labels for household appliances (EC 1992)[6]. The labelling specifications are spelled out in individual implementing directives for each product type. Label promotion and information activities to increase the public's awareness and understanding of the labels lies with the public authorities (at the national and local levels), some utilities and retailers. For its part, the European Commission is conducting pilot projects on increasing consumer awareness and training retail staff.

The EU comparison labels are category-type labels. The primary focus is on ranking the product models against a predetermined, open-ended efficiency scale (based on energy consumption [kWh] per year). Secondly, the labels indicate energy use (kWh/year) and performance, such as noise and cooling characteristics for refrigerators.

Various endorsement labels are used in Europe. The Group for Energy Efficient Appliances (GEEA) label is used to designate office equipment and home electronics having low power consumption in standby mode. The EU has recently become a formal partner of the International Energy Star programme wherein specific internationally traded goods, most notably those concerned with information technology, are eligible to use the Energy Star voluntary endorsement logo if they meet specified efficiency requirements.

There are also ecolabelling schemes. The EU scheme issues a voluntary endorsement ecolabel to products that satisfy a stringent set of ecological criteria (ECO 2002). Ecolabelling criteria have been established for a variety of household appliances and lamps and for which the energy efficiency is usually the most important ecological requirement. It is applied directly to the EU energy comparison label for these products. There are various endorsement labels used in individual countries in Europe, including the Austrian Eco Label, the British Energy Efficiency Recommended Logo, the Dutch Milieukeur Label, the German Blue Angel eco-label (Umweltzeichen), the Nordic Swan Ecolabel and the Spanish Aenor-Metio Ambiente Label (Harrington 2001).

6. Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances.

MEPS and VAs

Specific directives imposing MEPS for boilers and for refrigerators and freezers were passed in 1992 and 1996 respectively (EC 1992b, EC 1996). Unlike for labels, there is currently no framework regulation for MEPS in the EU and thus each additional MEPS requirement has to be introduced as a separate piece of primary legislation.

There are currently EU-level minimum efficiency standards for three residential product classes – hot-water boilers, refrigerators and freezers – and a fourth on lighting ballasts. The standards for domestic gas- and oil-fired hot-water boilers took effect at the beginning of 1998; those for refrigerators and freezers took effect in September 1999. The standards for refrigerators and freezers are closely linked to the labels, with the maximum allowable energy for most models set to about the level dividing the C and D label categories, thus excluding the majority of D, E, F and G models from sale.

Because of the arduous and time-consuming process of developing MEPS legislation for individual products, the Commission has often sought instead to negotiate voluntary agreements with industry. These implore the majority of manufacturers supplying the given product to the EU market to either cease manufacture of less efficient equipment or raise the fleet average efficiency of their product lines or both. Thus far, negotiated agreements on seven products have been concluded.

Each new energy label, MEPS regulation and voluntary agreement is determined after conducting a thorough study to investigate the energy savings potentials for a particular end-use and the policy measures best able to bring this about. These studies are paid for by the European Commission and are usually conducted by a working group typically comprised of independent experts, national energy agencies, academic institutions and industry representatives.

The first task of these studies is to determine product sub-categories and to identify an energy efficiency measure, which naturally varies for each primary equipment type. The market and stock characteristics are then analysed including the efficiency distribution of all products on the current market. This information is then supplemented by a techno-economic energy engineering analysis whose purpose is to determine the technical potentials available to improve the efficiency of existing equipment and the costs of doing so. This type of analysis is not constrained by the technical characteristics of equipment currently on the market and may consider technical options which have not yet been commercially applied providing they are readily available and understood. A number of policy measure scenarios are then considered and projections are made regarding the energy and CO2 savings and costs of each scenario compared with a business as usual scenario. The impact of these policies on the equipment market and on manufacturers is further considered in order to gather all the information needed to make an informed policy decision. The study group then makes a set of policy recommendations which have often involved a mixture of energy labelling and MEPS.

Procurement

There have been several appliance efficiency procurement initiatives in Europe. The Energy+ programme was carried out at the European level; the others were run at national and local levels.

Swedish National Energy Authority Technology Procurement Programme

Sweden's technology procurement programme, administered by the Swedish National Energy Authority (STEM)[7], gathers potential purchasers of some particular equipment (item, process or system) and puts them together with energy experts in order to draft energy efficiency and other performance specifications for an equipment development competition. The objective is that the life-long annual running costs of the equipment must be lower than those of existing alternative equipment already on the market. Manufacturers are then asked to compete for the opportunity of developing a prototype for the equipment concerned. From their side, the potential purchasers undertake to buy an agreed minimum number of the winning products. STEM subsidises the purchasers with a certain proportion of the purchasing cost of the new products, in order to cover the risks always associated with the application of new technology, under the condition that the product

7. This programme was previously run by the National Board for Industrial and Technical Development (NUTEK).

installations can be used for demonstration purposes. STEM also assists in marketing the new product.

STEM has initiated about 30 technology procurement projects, including those on combination refrigerators/freezers, heat pumps and windows for the residential sector. The competition for efficient combination refrigerators/freezers was announced in April 1990 and concluded in October 1991. The programme performance requirements called for a maximum energy use of 1 kWh/litre a year which was about 50% below the average value of models on the market at that time. The winner was guaranteed a first order for at least 500 units. At the same time, purchasers were encouraged by a subsidy of SKr 1,000 for each unit from the first batch. Five companies took part in the competition. The winning proposal of the technology procurement was submitted by Electrolux AB, a Swedish company. Its prototype "TR 1066" was a 287 litre unit that used 0,79 kWh/litre a year, being 33% more efficient than the most efficient model already on the market, 44% more efficient than the most popular model, and 60% more efficient than the average model in use in homes in Sweden. The group's original order was for approximately 600 units. Since the programme's inception, some 3,350 Electrolux TR 1066s have been purchased. Furthermore, the market share for efficient refrigerator/freezers has increased from less than 1% to 5% in a matter of a few years, showing the leverage that incentives to a single manufacturer can cause.

Danish Energy Savings Trust "A" Club

One example of using bulk purchasing to obtain lower prices on energy-efficient appliances is the Danish Energy Savings Trust (DEST) "A" Club procurement competition in 1999-2000. DEST pooled the purchasing power of housing companies, municipalities and regional councils (having a building stock of some 100,000 apartments) to obtain reduced prices on A-rated refrigerators. The contract with the competition winner was sweetened by offering rebates for appliances sold early in the programme. The programme did not attempt to commercialise new technology, but rather to reduce prices on existing products[8].

8. *Appliance Efficiency Newsletter, v.3, i.3, 1999 and v.3, i.2, 1999.*

EU Energy+ programme

The Energy+ programme is an initiative of the European Commission and various national energy and environment agencies to promote the development and use of highly energy-efficient refrigerator-freezers, those using less than three-quarters of the energy of equivalent class A models. The European refrigerator market has evolved considerably since the 1995 introduction of the refrigerator label, with many models now qualifying for the most efficient (class A) category. Energy+ seeks to help differentiate the most efficient models in advance of the implementation of new refrigerator labelling criteria (expected in 2004).

The programme centres on the promotion of two lists of companies and organisations. The first list contains the retailers and institutional buyers who have declared their intention to promote and/or purchase Energy+ appliances. The second shows the manufacturers who submit products that meet the Energy+ energy efficiency specifications. Random tests are carried out to verify performance claims.

The programme also staged a competition to determine the best product in each of two refrigerator categories. The winners were granted the European Energy+ Award, and promoted as the leading products of their type on the market. The appliances that won in 2000 use only 33 and 35% of the energy used by an average European cold appliance of comparable size and type.

Financial Incentives

During the past two decades, there were many programmes in EU countries that offered financial incentives to *consumers* for purchasing energy-efficient appliances and retiring older appliances. These programmes, offered as part of demand-side management (DSM) initiatives, were more often implemented by utilities and local and regional authorities than by national governments. They were typically of limited duration. The most common financial incentive is the rebate, which acts as a sort of financial endorsement of a products' energy-efficiency attributes (and by association, general quality).

The programmes have been too numerous to catalogue here, but some examples include:

- During 1988-90, a Spanish utility offered residential customers rebates to install high-efficiency air-conditioners, and the utility promoted the programme through newspaper, radio and television advertising, as well as through brochures, direct mail, shows and exhibits. The programme was intended to increase air-conditioner ownership and led to increased energy use (ECEEE 1995, Edward Vine, paper 39).

- In 1989, the Austrian utility SAFE (Salzburger AG für Energiewirtschaft) offered a programme for electric household appliances that consisted of a rebate for investments and a bounty (reward) for conserved energy (kWh). The rebate was subject to the condition that the old unit was retired. The bounty was an additional amount of half the electricity price for each kWh saved, up to a maximum of 5% of the initial electricity bill, for three years following the programme (ECEEE 1995, Edward Vine, paper 39).
- In 1990 and 1991, the Danish power distribution companies EFFO and EASV carried out a campaign to get old and energy-inefficient freezers replaced by new low-energy models. Customers were offered subsidies of ECU 2.7 for each year of life of the old freezer beyond ten years. As the freezers owned by the households participating in the programme were rather old – average age about 21.5 years, the subsidy was ECU 57, or almost 15% of the price of a new freezer. To qualify for the subsidy, the replacement had to be a low-energy freezer (ECEEE 93, Anders Larsen v2, paper 63).
- In a pilot programme during 1992-95, the German electric utility RWE Energie AG offered a DM 100 cash rebate to any of their customers who bought an energy-efficient refrigerator, freezer, dishwasher or washing machine (ECEEE 1995, Stefan Thomas, paper 12).
- Beginning in 1999, the Netherlands Ministry of Finance's National Energy Rebate Programme has offered subsidies for A-class refrigerators, dishwashers and washing machines, dryers and washers. The goal is to triple the market share of A-class appliances compared with 1997 levels (Appliance Efficiency Newsletter, v.3, i.4, 1999).
- In 1999, the Danish Electricity Savings Trust (DEST) ran an eleven-week-long rebate scheme to stimulate the demand for class A appliances in Denmark. Rebates were given on class A refrigerators (DKr 500) and clothes dryers (DKr 1,000). To participate in the campaign, retailers had to agree to keep prices of the class A appliances low and to provide explanatory materials to customers. The campaign

was promoted through television and radio advertisements (Appliance Efficiency Newsletter, v.4, i.2, 2000).

- In the STEM Technology procurement programme (described above), purchasers received subsidies to cover the risks associated with adopting new technologies and the costs of showing the installed products for demonstration purposes.

Assessment

The comparison label is the most comprehensive part of the EU appliance policy system. The labels are up to date (or under revision) and are very relevant to the current range of appliance models in the market. The design of the label has proven effective in communicating the relative efficiency performance of different appliances to consumers, retailers and manufacturers. In particular, the use of a categorical efficiency scale sets clear efficiency targets for manufacturers and facilitates product efficiency comparisons by consumers. Information on the non-energy performance of appliances is also shown so that any reduction in energy consumption attained through poorer service is clearly visible. This increases manufacturer engagement with the scheme. The label has been supported by a variety of related additional measures at the local level, such as advertising and information campaigns, retailer training and rebates.

The EU's residential appliance MEPS programme is, in comparison, less developed, covering only three product classes – hot-water boilers, refrigerators and freezers. There is a close and transparent relationship between the labels and MEPS programmes. The refrigerator and freezer MEPS are defined so as to prevent the sale of all category D and poorer efficiency models for the most common appliance types. The administrative and political difficulties of developing MEPS has led the European Commission to pursue efficiency improvements through negotiated agreements with appliance manufacturers. Thus far, negotiated agreements have been concluded on seven products. The agreements have been less ambitious than would be expected with MEPS. The target efficiency levels are significantly lower than recommended in independent studies, the compliance provisions are less stringent than MEPS, and the coverage of manufacturers is less than complete.

The EU appliance programmes have been developed upon strong analytical foundations. Thorough market and engineering-economic analyses of each appliance programme have been conducted by a working group comprised of independent experts, national energy agencies, academic institutions and industry representatives. Such analyses could conceivably underpin a programme based on Least Life-Cycle Cost principles.

The EU appliance programmes, especially the MEPS element, have taken a long time to develop, implement and upgrade. This is principally for two reasons. First, there is no framework regulation for MEPS, so each additional appliance MEPS requires new legislation. Second, there are no authoritative programme schedules, procedural timelines and target efficiency levels to guide the writing of new labels, MEPS and VAs specifications, which invites considerable delay. The lack of clear procedural rules has had other consequences as well. It has inhibited full stakeholder participation in the most sensitive parts of the programme development process. Industry is fully represented in the final discussions of technical specifications, but advocates for more stringent efficiency requirements such as energy efficiency and environmental advocacy organisations are excluded.

JAPAN

Japan has a tradition of promoting energy efficiency extending back to the oil crises of the 1970s and first introduced MEPS for refrigerators and room air-conditioners in 1979 under the Energy Conservation Law (AE 3/1999). These were satisfied in 1983 and were not upgraded until the early to mid 1990s when revised MEPS requirements were imposed.

The centrepiece of Japan's appliance and equipment efficiency programme is now the ambitious Top-Runner standards scheme, implemented to make progress towards the Kyoto climate change targets. Under the scheme, only the most efficient appliances on the market in the late 1990s will still be allowed to be sold from 2003 to 2007 depending on the appliance type[9]. It is a modified fleet average standards scheme, wherein today's best models set the levels for tomorrow's standards. The programme aims to improve appliances and equipment by 15 to 83% (of 1997 levels) by 2003 to 2007.

9. The Top-Runner programme is also being used to improve the fuel efficiency of passenger cars and trucks.

Table 2.4 **Summary of appliance policy instruments in Japan**

	Comparison Label	Endorsement Label	Standards
Refrigerators	M		M
Freezers	M		
Air-conditioners			
- Room	M		M
Lamps	M		M
Ballasts			M
Copiers		V	M
Fax Machines		V	
Computers		V	M
Monitors		V	
Printers		V	
Scanners		V	
Multi-function Devices		V	
Hard-disk Drives			M
Televisions	M		M
VCRs & DVDs			M

M = Mandatory; V = Voluntary
Source: Harrington and Damnics, 2002.

Labels

In Japan, manufacturers and importers of energy-consuming equipment are obliged to indicate the energy efficiency of their products. In addition, a voluntary labelling scheme was introduced in the summer of 2000 for household appliances. These new labels indicate, with a symbolic mark, the product models' percentage fulfilment of the Top-Runner efficiency standards. The Ministry of Economy, Trade and Industry, by agreement with the US Environmental Protection Agency, also uses the Energy Star endorsement label for office equipment. The products concerned are personal computers, displays, printers, facsimile and copying machines, scanners and multi-function devices. The Japanese and US programmes maintain identical product specifications, and manufacturers who join one country's programme enjoy privileges in the other country's programme.

Targets

The 1998 revisions to the Energy Conservation Law established the Top-Runner standards programme. Top-Runner requires that the weighted-average energy efficiency of each manufacturer's and importer's future shipments in each predefined product category be at least as high as the most energy-efficient model on the current market. It is a modified fleet average standards scheme with two important distinctions. First, the averages apply to predefined categories of products. Second, today's best model sets tomorrow's standards.

The products included in the Top-Runner programme are: passenger cars and trucks, air-conditioners, refrigerators, fluorescent lights, televisions, video cassette recorders (VCRs), photocopiers, computers and magnetic hard-disk drives. The targets are set according to categories of types, configurations and capacities of the products. For example, there are 32 different target levels pertaining to air-conditioners, differentiated by two principal types (heat pump, cooling-only), five configurations (e.g. direct blow/window, direct blow/wall mounted and duct type) and five cooling capacities (ranging from 2.5 to 28 kW). Equipment with highly specialised uses, unconfirmed measurement and efficiency evaluation methods or low market penetration rates are not subject to the standards. The specific improvement rates of energy efficiency and the years they are to be met are shown in Table 2.5.

Table 2.5 **Expected energy savings from the Top Runner programme**

Product	**Expected energy savings by the fiscal target year**	**Units**	**Fiscal target year**
Air-conditioners			
Heat pump type	63.0%	COP	2004 (cooling year)
Cooling-only type	14.0%	EER	2007 (cooling year)
Fluorescent lights	13.1%	lm/W	2005
Television	16.4%	kWh/year	2003
VCR (standby power use)	58.7%	W	2003
Photocopiers	31.0%	Wh/h	2006
Refrigerators, refrigerator-freezers, freezers	22.5%	kWh/year	2004
Computers	56.0%	W/MTOPS	2005
Magnetic hard disk drives	72.0%	W/Gb	2005

Source: AE 3/1999.
Coefficient of Performance (COP) = cooling or heating capacity divided by power input.
Energy Efficiency Ratio (EER) = cooling output divided by power input.
Mega operations per second (MTOPS).

Assessment

Japan's Top Runner programme was implemented quite rapidly as part of an effort to meet CO_2 emission reduction requirements at a reasonable cost. The methodological approach, which is quite different from MEPS setting practices elsewhere, has several notable strengths. First and foremost, its targeted efficiency levels are ambitious for most products, making significant energy savings and CO_2 emission reductions likely. For example, the energy consumption of new refrigerator-freezers is set to decline from an average value of over 1,900 kWh/year in 1995 to just 535 kWh/year in 2004. Very ambitious improvements in efficiency are also pending for many other equipment types. Furthermore, the targeted efficiency levels are clear, firmly set and analytically simple (requiring only a statistical appraisal of the efficiency of products on the current market). The clear and immutable principle underlying the targets, together with the low administrative burden and analytical requirements, makes Top Runner quick to develop and implement.

There are, however, some important cost and innovation ramifications to the Top Runner method of setting targets according to particular market circumstances and not formal engineering-economic analysis. First, as in the case of Australian MEPS, the lack of engineering-economic analysis means that the full economic implications of adopting a given target level are not fully known. Second, the top of the domestic market (at the time the targets are determined) may or may not be consistent with a least-cost approach to energy use, CO_2 emission reductions or other policy goals. It is possible for the targets to be too lax or too stringent from a least-cost perspective. For example, there may be some very simple cost-effective design modifications that are overlooked. Or some products in other markets (perhaps even manufactured in Japan) that represent more cost-effective solutions to the given policy goals. Lastly, there are possibilities for gaming the scheme – with manufacturers either colluding (whether tacitly or overtly) to halt efficiency improvements or attempting to create targets attainable only with proprietary technologies.

SOUTH KOREA[10]

Korea has implemented many appliance efficiency measures including energy labelling, MEPS and industrial voluntary efficiency targets. In 1992, under the Rational Energy Utilisation Act of 1980, the Ministry of Commerce, Industry and Energy (MOCIE) was authorised to set MEPS levels on the basis of analyses carried out by agencies such as the Korean Institute of Energy Research (KIER).

10. Korea's efficiency policies are presented, even though it does not figure in the quantitative analysis of this report.

Table 2.6 **Summary of appliance policy instruments in South Korea**

	Comparison Label	Endorsement Label	Standards
Refrigerators	M		M
Freezers			
Washing Machines	M		M
Microwave Ovens		V	
Air-conditioners:			
- Room	M		M
- Central	M		
- Single Packaged	M		
- Split System	M		
Heat Pumps	M		
Space Heaters	M		
Lamps	M	V	M
Ballasts	M		M
Copiers		V	M
Fax Machines		V	M
Computers		V	M
Monitors		V	M
Printers		V	M
Scanners			M
Televisions		V	M
VCRs & DVDs		V	M
Radios			M

M = Mandatory; V = Voluntary
Source: Harrington and Damnics, 2002.

Korea's labels, standards and targets are very closely linked to each other. Each product in the programme receives two energy efficiency set points. The less stringent value defines the MEPS level – no product less efficient than this may be sold after the date the levels take effect – and corresponds to the bottom of the label rating 5 range. The more stringent value is the "target" and corresponds to the requirements for label class 1 rating. When the MEPS levels are made more stringent, the energy label ratings are automatically revised and the target levels are made more stringent – often the old target value becomes the new MEPS level. The aim of the MEPS is to eliminate the most inefficient models from the market while the targets are to encourage manufacturers to continually increase the efficiency of products. MEPS are updated regularly in Korea – typically on a three to five year cycle. (Harrington 2001, EES 1999).

Apart from the mandatory energy labelling and MEPS programmes, there is a voluntary "Energy Boy" endorsement label for office equipment, televisions and VCRs that meet the US EPA Energy Star power management requirements.

Table 2.7 **Energy efficiency regulations and programmes in South Korea**

Product Description	Comparative energy label	Endorsement label	MEPS
Refrigerators and/ or Refrigerator-Freezers	M		M (1996, 1999)*
Room Air-Conditioners (unitary- and split-type)	M		M (1996, 1999)*
Incandescent Lamps	M		M(1992)
Fluorescent Lamps	M		M (1999)
Fluorescent Lamp Ballasts	M		M (1999, 2002)
Washing Machines	M (2000)		M (2001)
Television, VCR		V **	
Computers and/or screens		V **	
Printers		V **	
Fax Machines		V **	
Photocopiers		V **	

M = Mandatory; V = Voluntary
Sources: EES 1999 from Lee 1999 (see references for Chapter 3).
* Year current MEPS levels took effect and year of planned revisions indicated.
** Energy Boy programme

NORTH AMERICA – CANADA

Canada makes extensive use of labels and MEPS to improve appliance efficiency. Appliance energy labelling has been in place at the federal level since 1978 (EES 1999) through the EnerGuide label. The Energy Efficiency Act (EEA) passed by the federal parliament in 1992 led to MEPS being introduced for 22 different equipment types in 1995; these are generally set at efficiency levels that are harmonised with US regulations for those equipment types where MEPS have also been developed in the US (NRCan 1999)[11]. In addition to having MEPS for all the household equipment covered in the US regulations, Canada also has them for ground- or water-source heat pumps, integrated washer-dryers, electric ranges, automatic icemakers and dehumidifiers.

11. Labels and MEPS are developed at the federal (national) level and, because of jurisdictional issues, apply only to products imported into Canada and/or shipped between provinces, and not to products manufactured and sold within a single province. However, given matching provincial regulations in manufacturing provinces and the nature of the appliance and equipment markets, the measures apply to the vast majority of the applicable products sold in Canada.

Those residential appliances covered by these regulations account for nearly 75% of residential energy use (NRCan 2001, The State of Energy Efficiency in Canada, Office of Energy Efficiency Report 2001; http://oeenrcan.gc.ca/neud/dpa/data_e/publications. cfm).

Labels

Canada's EnerGuide comparison label is a range-type label. The primary focus is on the numerical indication of the model's energy use or efficiency. Secondly, the labels show the product's ranking on an energy-use scale of all similar models available in Canada.

Environment Canada administers the Environmental Choice Program, which includes an ecolabel, that provides recognition to products certified to improve energy efficiency, reduce hazardous by-products, use recycled materials, be recyclable or provide some other benefit. Certification and labelling criteria have been developed for central air-conditioners, dishwashers, lamps and ballasts, office equipment and water heaters.

In July 2001, Canada became a partner of the Energy Star programme, and follows Energy Star labelling requirements for home appliances, office equipment, consumer electronics, exit signs, water coolers, dehumidifiers, and heating, ventilation and air-conditioning (HVAC) equipment.

MEPS

Most of Canada's energy efficiency standards are set at levels consistent with those in the United States, though the approaches of the two countries to setting the stringency levels are somewhat different. Canada bases its minimum energy performance requirements on actual products that are widely available in the market. The range of product efficiencies in the market establishes the boundaries within which efficiency options are analysed and decided upon. This contrasts with the more stringent US approach, where regulations are based on what is technologically possible and economically justifiable.

Theoretically, this would imply that Canadian standards would tend to be less stringent than those in the United States. However, the Canadian regulatory process and markets are greatly influenced by the American situation. The more stringent American regulations are felt in the Canadian market because of cross-border trade and the multinational appliance and equipment manufacturers operating on both sides of the border (IEA 2000).

Table 2.8 **Summary of appliance policy instruments in Canada**

	Comparison Label	Endorsement Label	Standards
Refrigerators	M		M
Freezers	M		M
Clothes Dryers	M		M
Washing Machines	M		M
Washer/Dryers	M		M
Dishwashers	M	V	M
Ranges/Ovens	M		M
Air-conditioners:			
- Room	M		M
- Central	V	V	M
- Single Packaged	V		M
- Split System	V		M
Dehumidifiers			M
Heat Pumps	V		M
Furnaces	V		M
Space Heaters	V		M
Water Heaters		V	M
Lamps		V	M
Ballasts		V	M
Copiers		V	
Fax Machines		V	
Computers		V	
Monitors		V	
Printers		V	
Multi-function Devices		V	

M = Mandatory; V = Voluntary; T = Target
Source: Harrington and Damnics, 2002

Financial Incentives

The programmes have been numerous. Two examples are:

During 1990-91, British Columbia Hydro implemented a pilot buy-back programme, which offered a C$50 bounty for customers who would allow the utility to come and take their “second” refrigerators away. The programme complemented the utility’s efforts to influence consumers' buying behaviour in favour of efficient new refrigerators (The Results Center Profile #10). The pilot programme operated for two years, picking-up more than 16,000 refrigerators and saving an estimated 119 GWh over the calculated remaining life of the second refrigerators. For a total cost of $2.8 million (1990 $) the programme has also resulted in peak capacity savings of 1.36 MW.

More recently, a BC Hydro project provided incentives to retail staff for sales of Energy Star qualified refrigerators and washing machines. Over 7,500 units were marketed for the BC Hydro service area. Based on the success of the project, it was used as a model for the Yukon.

Assessment

Canada's appliance labelling and MEPS programmes are extensive and mature. They are similar in form and stringency, but not always in analytical underpinnings, to their US counterparts. This is due partly to the tight integration of the Canadian and US appliance markets, and partly to the ongoing consultations among agency staffs in the two countries. Canada's programmes are supported by a coherent and well articulated compliance and enforcement policy.

The Canadian and US appliance labels are both based on a very old design (dating to the late 1970s). They indicate an appliance model's energy use or efficiency numerically, and show graphically how it compares with the most-efficient and least-efficient models on the market. The format of the Canadian label has been fairly stable. It was last revised in 1995. The label requires consumers to compare products based on numerical figures, rather than easier-to-remember categories. It also gives manufacturers no specific efficiency targets to aim for. However in 2001, Canada introduced the Energy Star endorsement label to easily identify the most energy-efficient models available for a type of product.

Canadian appliance MEPS are among the most stringent and most comprehensive in the world. The high level of stringency derives, not from extensive engineering-economic analysis on the part of Canada, but from stringent US MEPS felt through the integrated Canadian and US appliances markets. As long as the US maintains its highly analytical approach to MEPS and the integrated appliance markets endure, Canada can continue to develop stringent MEPS via relatively simpler market analysis techniques.

NORTH AMERICA - UNITED STATES

The United States makes extensive use of comparison labels, endorsement labels and standards to improve the energy efficiency of residential appliances and office equipment.

Labels

Mandatory comparative energy labelling of major household appliances has been in force since 1978 through the National Energy Policy and Conservation Act (NEPCA 1978, CFR 1999) and is administered by the Federal Trade Commission. The energy label, known as the Energy-Guide, has to be displayed at the point of sale by all appliances of the designated product type and indicates the efficiency of each appliance compared to the maximum and minimum efficiency levels found on the market at that time.

The Energy-Guide labels are range-type comparison labels, with the primary focus on the numerical indication of the product models' energy use or efficiency. Secondly, the labels show the products' ranking on an energy-use scale of all similar models available in the United States. They also show the estimated annual energy cost, based on the national average energy price.

In addition, the United States has a voluntary endorsement labelling scheme, known as the Energy Star, under which the more efficient appliances on the market are eligible to apply for and display the Energy Star label on their products (EPA 2002). The Energy Star programme combines an endorsement label with information and promotion campaigns and alternative financing activities to improve energy efficiency (EPA 1998). The programme, begun in 1992, is a voluntary partnership of the Department of Energy (DOE), the Environmental Protection Agency (EPA), product manufacturers, distributors, utilities, energy-efficiency advocates, consumers and other organisations. For the label, EPA and DOE work with manufacturers and other interested parties to establish energy-efficiency specifications for existing, proven technologies. Product models that exceed these specifications can be identified with the Energy Star label. For products subject to minimum efficiency standards, the models qualify for the Energy Star label if they exceed the standards by a certain amount, varying from product to product. Typically, the top quartile of models within a product class qualify for Energy Star. Other products, such as office equipment, qualify for the label if they have special features which enable them to use less energy than similar products.

An ecolabel, the Green Seal of Approval, is also used to designate air-conditioners, clothes dryers, washing machines, dishwashers, heat pumps, lamps, ranges and ovens, refrigerators and freezers meeting certain energy and environmental criteria.

Table 2.9 **Summary of appliance policy instruments in the US**

	Comparison Label	**Endorsement Label**	**Standards**
Refrigerators	M	V	M
Freezers	M		M
Clothes Dryers		V	M
Washing Machines	M	V	M
Washer/Dryers		V	M
Dishwashers	M	V	M
Ranges/Ovens		V	
Air-conditioners:			
- Room	M	V	M
- Central	M	V	M
- Single Packaged	M	V	M
- Split System	M		M
Heat Pumps	M	V	M
Furnaces	M		M
Space Heaters	M		M
Water Heaters	M		M
Lamps	M	V	M
Ballasts	M	V	M
Copiers		V	
Fax Machines		V	
Computers		V	
Monitors		V	
Printers		V	
Scanners		V	
Multi-function Devices		V	
Televisions		V	
VCRs & DVDs		V	
Radios		V	

M = Mandatory; V = Voluntary; T = Target
Source: Harrington and Damnics, 2002,

MEPS

The US federal government introduced a national programme of mandatory minimum energy performance standards for household appliances through the National Appliance Energy Conservation Act of 1987 (NAECA 1987, AHAM 1993), in partial response to the prospect of some states implementing their own energy efficiency standards. The first national standards – for refrigerators, freezers, room air-conditioners and water heaters – took effect in January 1990. NAECA, as it is known, was amended in 1988 to include regulations for fluorescent lamp ballasts and in 1992 minimum efficiency requirements were introduced for a variety of lamps, induction motors, most types of commercial heating and air-conditioning equipment and plumbing fixtures through the Energy Policy Act (EPAct) (EPAct 1992). Apart from a temporary moratorium during 1995-96, the standards have been, and continue to be, updated and strengthened regularly (Table 2.10).

NAECA and EPAct authorise the US Department of Energy (DOE) to issue MEPS for household and commercial energy using equipment which "shall be designed to achieve the maximum improvement in energy efficiency which the Secretary (of the DOE) determines is technologically feasible and economically justified". The US procedure for developing standards begins with a rigorous investigation of incremental investments and energy savings, including identification of the least life-cycle cost configuration. The US also considers impacts on manufacturers and consumers. These results are disseminated in a "Technical Source Document" for comment and discussion. The standards must have a payback time of three years for an average consumer. Standards are also applied to water-using residential devices, most notably shower heads. The water standards have been found to save considerable energy in water heating.

Table 2.10 Minimum energy performance standards for residential electrical equipment in the US

	Minimum energy performance standards								
	First round of MEPS			Second round of MEPS			Third round of MEPS		
Equipment type	**Year of final rule**	**Year implemented**	**Efficiency gain**	**Year of final rule**	**Year implemented**	**Efficiency gain**	**Year of final rule**	**Year implemented**	**Efficiency gain**
Refrigerators and freezers	1987	1990	9%	1990	1993	30%	1997	2001	31%
Washing machines	1987	1988	2.5%	1991	1994	35%	2001	2004-7	45%
Clothes dryers	1987	1988	0.5%	1991	1994	15%			
Dishwashers	1987	1988	0%	1991	1994	45%			
Room air-conditioners	1987	1990	30%	1997	2000	10%			
Water heaters	1987	1990	4.7%	2001	2004	3.7%			
Ranges and Ovens	1987	1990	0%						
Pool heaters	1987	1990	n.a.						
Direct heating equipment	1987	1990	n.a.						
Mobile home furnaces	1987	1990	n.a.						
Central air-conditioners	1987	1992	14%	2002	2006	13%			
Furnaces	1987	1992	6.5%	Due 2004					
Ballasts	1987	1990	n.a.	2000	2005	20%			
Showerheads and Faucets		1994	n.a.						

Source: Buskirk, 2000; LBNL, 2002; IEA estimates.
n.a. = Not Available

Procurement

US Super Efficient Refrigerator Program

The Super Efficient Refrigerator Program (SERP), Inc. was a non-profit corporation formed in 1991. Its mission was to advance the technology and deployment date of chlorofluorocarbon (CFC)-free efficient refrigerators/freezers that would surpass 1993 MEPS and advance technology in anticipation of the new 1998 MEPS. Twenty-four US utilities committed $30 million for a winner takes-all competition. The winning manufacturer would not only have to create the most efficient CFC-free refrigerator, but would also have to be capable of manufacturing, distributing and tracking its sales. The prize, the Golden Carrot award, was a contract under which incentives would be paid as units were sold in the participating utilities' service territories. At a minimum, the candidate refrigerators were required to be between 25 and 50% more efficient than required to meet 1993 standards. In order for the winner manufacturer to receive incentive payments, the SERP models' wholesale prices could not be higher than standard CFC models with similar features. The Whirlpool Corporation won the competition based on energy savings and its ability to produce, market and deliver the refrigerators in a timely manner[12].

The SERP induced a manufacturer, Whirlpool, to manufacture a line of highly efficient refrigerators that exceeded minimum US government energy efficiency standards by 30% to 41%. The new refrigerators helped demonstrate the feasibility of producing refrigerators that greatly exceeded the existing government energy efficiency standards (a key goal of the programme); however, the refrigerators were eventually withdrawn from the market due to lower-than-expected sales. The cause for the lower-than-expected sales appears to have been insufficient and problematic marketing (Ledbetter et al. 1999).

US Consortium for Energy Efficiency

The apparent success of SERP prompted its founders to create the Consortium for Energy Efficiency (CEE) to apply the model to other end-uses. CEE is a non-profit, public benefit corporation whose members include electric, gas and water utilities, research and development organisations, state energy offices and regional energy programmes. Major

12. The Results Center, Profile #106.

support is provided by the US Environmental Protection Agency (EPA) and the Department of Energy (DOE). The consortium aims to expand national markets for super-efficient technologies using market transformation strategies (CEE Web site).

CEE's initiatives have used several market transformation approaches, including:

- Common specifications. By setting uniform efficiency targets that are technically and economically feasible, but not yet widely available, CEE attempts to induce the production of super-efficient products by demonstrating that there will be a significant market.
- Bulk purchases. Bulk purchases are used to demonstrate a technology, to establish an initial market for a super-efficient product and to induce a shift in the market-place to more efficient products.
- Government procurement. CEE works with the Energy Efficiency Procurement Collaborative, an organisation dedicated to the achievement of market transformation through harnessing the purchasing power of state and local government as well as providing the benefits of lower operating costs and environmental benefits from higher energy efficiency to taxpayers.
- Manufacturer incentives/Golden Carrot. This approach is used when utilities elect to pool their financial resources in order to provide a large enough incentive to induce a new super-efficient technology to market with manufacturers competing for the pooled incentive.

Utility participants choose to implement these initiatives in a number of ways, including incentives, consumer/supplier education, promotion and financing.

CEE's efforts in the residential sector include a variety of specification development, qualifying product identification, promotional and educational activities aimed at:

- Washing machines.
- Super-efficient refrigerators, room air-conditioners, washing machines and dishwashers.
- Compact fluorescent lamps (CFLs) and fixtures.

- Central air-conditioners and heat pumps.
- Gas furnaces.

Demonstration projects

The federal government has supported a wide range of R&D that has led to improvement in appliance and equipment efficiency, e.g. more efficient compressors, insulating materials, heat pump water heaters, ground source heat pumps, improved furnace burners, building design, etc.

By and large, state government(s) have not participated directly in the research and development (R&D) leading to more efficient appliances. There are examples, however, of governments participating in demonstration projects to document the actual (as opposed to estimated) energy savings of efficient appliances. For example:

In 1999 and 2000, Lafayette and Wilsonville, Oregon participated as "test communities" in the Save Water and Energy Education Program (SWEEP), a government-utility-appliance manufacturer programme to demonstrate how high-efficiency appliances and water and energy awareness and education activities can save money for citizens and communities[13]. SWEEP was designed to maximise water and energy savings in these communities and to serve as a model for other communities seeking an integrated approach to resource efficiency.

Fifty test homes, 25 in each community, received new efficient washing machines, clothes dryers and dishwashers and toilets; and new showerheads and aerators (as needed). Data were collected on the water and energy use of each appliance in the homes during a two-month baseline period (before SWEEP was implemented) and a two-month retrofit period (after the new equipment was installed).

Such high-profile demonstration projects are useful to highlight the benefits of efficient appliances to various parties. First, they show consumers the level of energy cost savings that they might realistically

13. The SWEEP participants were: the towns, the US Department of Energy, Electrolux Home Products (donor of washing machine/dryer pairs and dishwashers), Caroma US, Inc. (donor of high-performance dual-flush toilets), the Pacific Northwest National Laboratory (PNNL), Portland General Electric (the serving electric utility and donor of faucet aerators and low-flow showerheads), Energy Technology Laboratories (also a donor of showerheads), the Oregon Office of Energy, CTSI Corporation (a water resource management company), the Northwest Energy Efficiency Alliance, the League of Oregon Cities, and the Mid-Willamette Valley Council of Governments.

expect from efficient appliances. This makes the benefits part of a purchase decision a little less “invisible”. Second, demonstration projects can be useful in showing utilities and local and regional governments how implementing programmes to encourage the use of efficient appliances might be useful in addressing their concerns; for example, in the SWEEP programme, municipalities with constrained water supplies.

Financial incentives

In the 1980s and 1990s, many US utilities offered financial incentives to *consumers* for purchasing energy-efficient appliances and retiring older appliances. The most common financial incentive was the rebate, which acts as a sort of financial endorsement of a product’s energy-efficiency attributes (and by association, general quality). The programmes were numerous, including:

- The Sacramento Municipal Utility District (SMUD) offered an incentive of $100 to customers who traded in an older refrigerator in conjunction with the purchase of a new model. The district collected over 30,000 refrigerators through the programme (Home Energy Magazine Online January/February 1993).
- In 1987, the Wisconsin electric utility implemented the United States’ first large-scale residential appliance turn-in programme. The goal was to get under-utilised but operable second refrigerators, freezers and room air-conditioners out of service and properly dismantled. The utility provided the appliance removal service and gave participating customers their choice of a $25 cheque or 50 savings bonds for a room air-conditioner, and a $50 cheque or 100 savings bonds for a refrigerator or freezer (The Results Center Profile #24). From 1987 through 1991, over 240,000 residential appliances were picked up and properly dismantled through APTI. More than $10 million in incentives has been paid out since the inception of the APTI programme. Refrigerators account for around 60% of the appliances turned in, while room air-conditioners account for 30%, and freezers account for 10%. All of the collected appliances are recycled. Metal components are recycled and the refrigerants, which contain chlorofluorocarbons (CFCs), are drained and stored for re-use. Over 30 tons of CFCs have been recovered from old appliances. All appliance capacitors are

removed at a processing facility and sent to an EPA-approved facility to be destroyed. Through 1991, the APTI has resulted in demand savings of 20,8 MW and energy savings of 62.9 GWh. In 1991, the programme produced demand savings of 5,2 MW and 8.2 GWh of energy savings. In addition, over 452 tons of sulphur dioxide emissions, which are a primary cause of acid rain, were avoided.

During 1997-98, the Northwest Energy Efficiency Alliance (NEEA), a group of water and energy utilities, local governments and energy-efficiency market transformation bodies in the north-western United States used financial incentives to promoted energy- and water-efficient washing machines. NEEA's Washwise programme used consumer rebates, salesperson incentives, and a marketing and information campaign to raise the market profile of resource-efficient, horizontal-axis washing machines (traditionally a small segment of the US market). It increased the market penetration of these washing machines from around 2% in May 1997 to 17% in 2000. The financial incentives have been discontinued on the regional basis, but several utilities continue to offer rebates locally. NEEA's washing machine marketing and promotional activities are now carried out within the national Energy Star programme (AE 4/2000).

There have also been proposals, but no implementation, to offer financial incentives through the national tax code. The 1999 US Climate Change Technology Initiative called for tax credits (a reduction in federal income taxes) of 10 to 20% on certain air-conditioners, heat pumps and water heaters. Tax credits to manufacturers for producing energy-efficient products have also been proposed. The revisions to the US standards for washing machines, published in January 2001, were based on an agreement between manufacturers and energy conservation advocates. The agreement called for support of a tax credit to be given to manufacturers for producing washing machines meeting or exceeding the standards before their implementation dates. The agreement also included support for Congressional enactment tax credits on refrigerators and freezers[14]. There is a $30 million cap per tier per company, with any one manufacturer prohibited from collecting more than $60 million in total[15]. Such a proposal has been included in pending energy legislation.

14. Everett Shorey and Tom Eckman, Appliances and Global Climate Change: Increasing Consumer Participation in Reducing Greenhouse Gases, prepared for the Pew Center on Global Climate Change, October 2000.

15. CEE – Residential Clothes Washer Initiative Update; http://www.ceeformt.org/resrc/updates/01-05rwsh/01-05rwsh.html.

Assessment

The United States' appliance labelling and MEPS are extensive and mature. Numerous appliances are subject to comparison labelling and MEPS requirements and are eligible for Energy Star endorsement labels.

The MEPS programme is particularly strong in its procedural and analytical aspects. The delays that have hampered programmes elsewhere have been reduced in the United States, because there are authoritative programme schedules, procedural timelines and target efficiency levels to guide the drafting of MEPS specifications. There is a multi-year schedule for programme expansion and updates. Technical specifications are drafted within a clear and open process that follows set timelines. The primary regulatory objective (achieving the maximum improvement in energy efficiency that is determined to be technologically feasible and economically justified) is fixed in legislation and is not the subject of dispute.

Analysis is given an explicit and central role in determining the strength of MEPS. This, along with the immutability of the primary regulatory objective, means that discussions remain focused on the quality of the analysis rather than regulatory objectives. The analytical dimension is strongly focused on engineering-economic analysis, which means that MEPS are frequently set at levels far more stringent than the efficiency of the most efficient appliance currently found on the market. Finally, the independent or advocacy roles of each of the stakeholders are properly acknowledged and given a formal status.

The appliance comparison labels, like those in Canada, are based on a very old design (dating back to the late 1970s). They indicate numerically an appliance model's energy use or efficiency, and show graphically how it compares with the most-efficient and least-efficient models on the market. Annual revisions are conducted to keep the high and low efficiency endpoints current. They require consumers to compare products based on numerical figures, rather than easier-to-remember categories. They also give manufacturers no specific efficiency targets at which to aim.

National MEPS in the United States were first established in the early 1990s, and have been regularly expanded and updated (i.e. strengthened) since then. They are now among the most stringent and most comprehensive in the world. Evidence of their high stringency is seen in

Australia's choice of the US 2001 refrigerators and freezers MEPS as the basis for its "world's best practice" MEPS. The US MEPS are based on a rigorous engineering-economic approach to identifying Least Life-Cycle Cost appliance configurations (including designs and technologies not yet on the market). Unlike in Canada, the programme does not have a strong, government-sponsored compliance and enforcement policy, although there is no indication of substantial non-compliance, but there is strong anecdotal evidence of a high degree of compliance. While the MEPS cover most of the major appliances, there still exists a significant portion of the residential electricity use -for instance "miscellaneous" uses that may amount to as much as 20%- that is not yet covered by any energy efficiency regulation.

THE IMPACT OF CURRENT AND FUTURE POLICIES

KEY MESSAGES

- *Existing appliance energy efficiency policies are already delivering reliable and cost-effective reductions of energy consumption and greenhouse gas emissions in OECD countries.*
- *Substantial energy efficiency improvements exist to reduce further energy consumption and greenhouse gas emissions from residential appliances and equipment cost-effectively.*
- *Most importantly, these savings can be achieved at negative cost to society.*
- *Cost-effective appliance policy can therefore make a major contribution to meeting existing and future greenhouse gas emission targets.*

This chapter presents the findings of the policy scenario to assess the electricity, CO_2 and cost savings potentially achievable in the next decades from cost-effective appliance energy efficiency programmes. To assess the impact of current policies, two detailed residential electricity consumption end-use scenarios have been produced for each of the IEA Member country regions: the No Policies and Current Policies scenarios. The sole difference between them is that the former has a slower rate of efficiency improvement, based on the best estimate of the efficiency progressions by end-use which would have occurred had none of the current policies been implemented from 1990 onwards. Satisfaction with the apparent success of the policies already introduced is tempered when compared with the scale of the remaining untapped cost-effective efficiency savings and the consideration that in all OECD regions total residential electricity consumption is still set to rise. The scale of untapped future savings is evaluated. The costs of CO_2 abatement are discussed in detail. The main results are compared with existing ones available in literature.

IMPACTS OF CURRENT PROGRAMMES

A number of studies on country or regional levels have examined the benefits and costs of implementing labels and standards. Most of the studies have focused on expected (ex-ante) energy savings, CO_2 reductions and costs. A few have examined the actual (ex-post) results of the programmes.

Australia

It is estimated that had Australia not introduced the labels in 1986, the annual energy consumption of all new appliances of the labelled types sold in 1992 would have been about 11% higher than it was, and total household electricity consumption would have been about 1.6% higher (Wilkenfeld 1993). This represented a saving of about 630 GWh and about 0.65 Mt CO_2 in 1992.

Another study examined the labelling programme by comparing the present pattern of appliance purchases with what the pattern would be if all buyers had used the energy label plus the sales price to select the model with the lowest life cycle cost. That is, if all buyers were perfectly informed and economically "rational". The conclusions were that for refrigerators purchased in 1992, the energy savings were about 35% of what they would have been if all buyers had chosen the most cost-effective model in the size and configuration they bought. The labels were achieving a third of the theoretical potential. The figures were similar for dishwashers (36%) and air-conditioners (39%), and substantially less for clothes dryers (13%) (Wilkenfeld 1997).

Canada

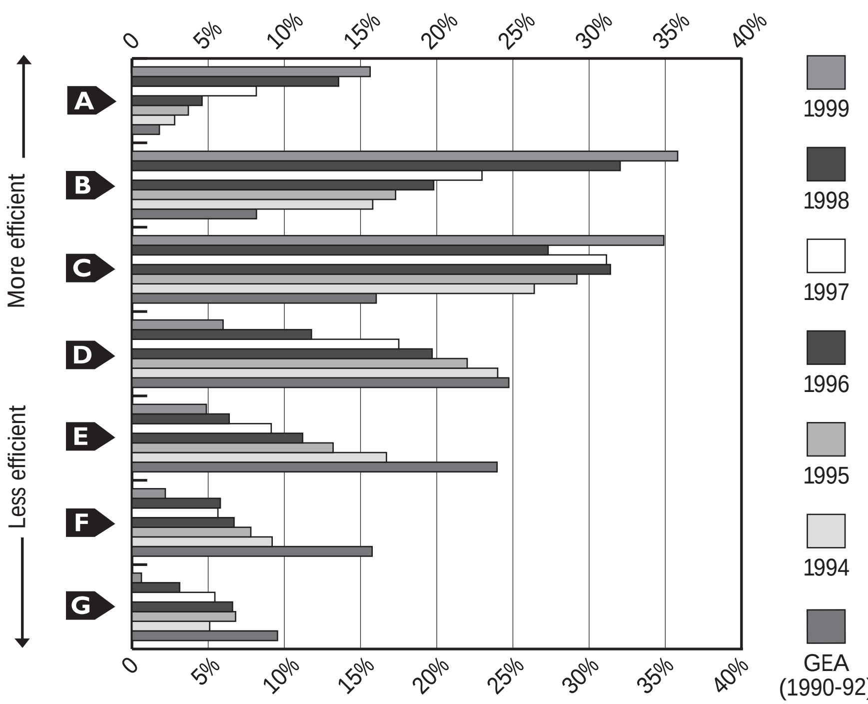
Natural Resources Canada has found that appliance standards have significantly affected the energy efficiency of new appliance models. The agency cites declines in energy use of between 18% and 45% for refrigerators, freezers, dishwashers, washing machines and dryers (NRCan, 2001). Labels and standards helped shift refrigerator sales towards more efficient models. Between 1990 and 1997, the sales-weighted average consumption of new refrigerators decreased by 37.6%, from 61.7 kWh per cubic foot in 1990 to 38.6 kWh per cubic foot in 1997. The energy efficiency of top-mount refrigerators has improved by 32% since 1990, despite a 7% increase in the size of these appliances. The market share of refrigerators requiring 49 kWh per cubic foot or less rose from 5.3% in 1990 to 99.6% in 1999.

In 2001-02, NRCan completed an ex-post evaluation of the impacts of its EnerGuide for equipment labelling programme. The results of the evaluation showed that the labelling programme help reduce electricity consumption by 91 GWh/year in 2000 alone. If the programme's impact is calculated for the period from 1990 to 2000, the cumulative savings are approximately 530 GWh/year of electricity.

European Union

Evaluations of the EU comparison labelling programme have shown a marked progression towards the more efficient categories (towards class A) appliances. The sales-weighted annual average energy-efficiency

Figure 3.1 **Share of EU cold appliance market by labelling class from 1990-92 to 1999**



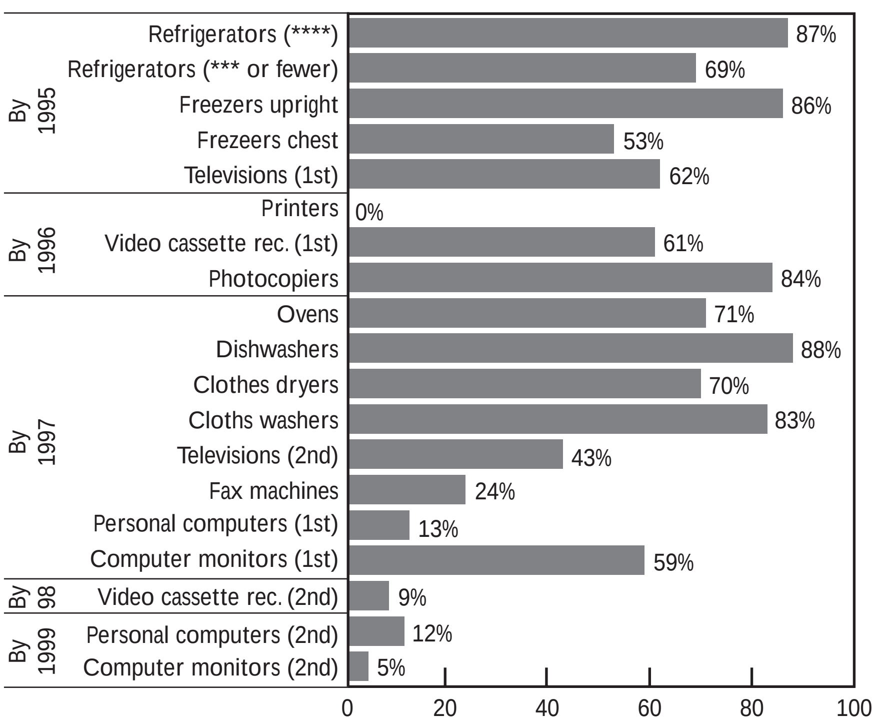
Source: (Waide 2001)

index of refrigerators and freezers fell 22.4% from 1990/92 (102.2%) to 1999 (79.3%) in eleven of the most populous EU countries (Waide 2001). The average market efficiency had been static or had even shown a slight deterioration in the years immediately preceding the introduction of labelling and MEPS.

Switzerland

The results of the target value programme are shown in Figure 3.2. Though none of the product categories achieved their targets by the end of 1997, substantial progress was made for some product categories.

Figure 3.2 **Results of Swiss target value programme, as of the end of 1997**



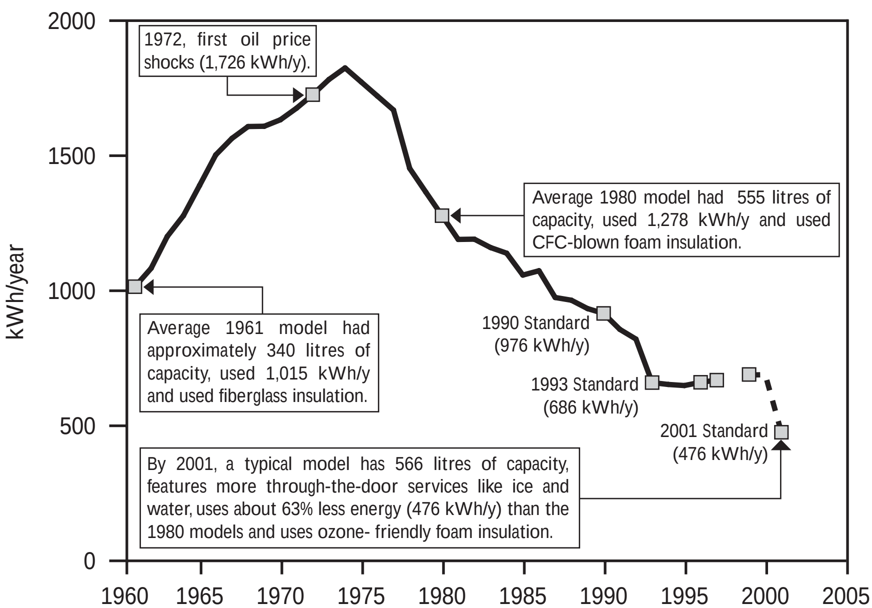
(1st) = First target value; (2nd) = Second target value

Source: Swiss Federal Office of Energy, Press Release (25 August 1999) and SwissEnergy: The Follow-Up Programme to Energy 2000, January 2001.

United States

Market surveys in the United States have shown evidence of the effects of minimum energy performance standards. Figure 3.3 shows the trends in sales-weighted average energy use of refrigerators in the US. It shows that refrigerators were steadily getting bigger and more energy consuming up until the first oil shock and California's introduction of standards in 1976 (becoming effective in 1978). With the subsequent California and federal standards, average refrigerator energy use has declined to less than a third of the 1974 level.

Figure 3.3 **Average energy consumption for new refrigerators in the United States**



One retrospective study examined the price, amenity and equity effects of the 1990 and 1993 US refrigerator standards on consumers (Greening 1996). More precisely, it evaluated the effects on real refrigerator prices, refrigerator volumes and features, and low income households. The analysis of national refrigerator sales data showed that, following the introduction of the standards: (i) real prices did not increase, and in some case decreased, and (ii) refrigerator features, such as size and amenities, were not diminished. Average real prices for units meeting the 1990 standards remained unchanged from earlier models, and units meeting 1993 standards were 14% less expensive than previous models. Food and freezer volumes were relatively stable until the 1993 standard, and decreased afterwards. Normalised to food and freezer volumes, the net reduction in real refrigerator prices declined 8% during 1987 to 1993. Though the time series data were limited, the analysis found that the standards did not appear to have disrupted the historical decline in refrigerator prices. The authors postulated that, while it is possible that the standards may have dampened the historical trend in price reduction for particular product classes, if it occurred, it was probably the result of increased amenities rather than the cost of energy efficiency features. The authors caution that their results do not imply that manufacturers did not incur costs in meeting the standards, but that the costs were not passed on to consumers in the form of higher prices. As for equity issues, the analysis of refrigerator ownership data in California showed that lower income households were just as likely to have high efficiency units as higher income levels (IEA 2000.)

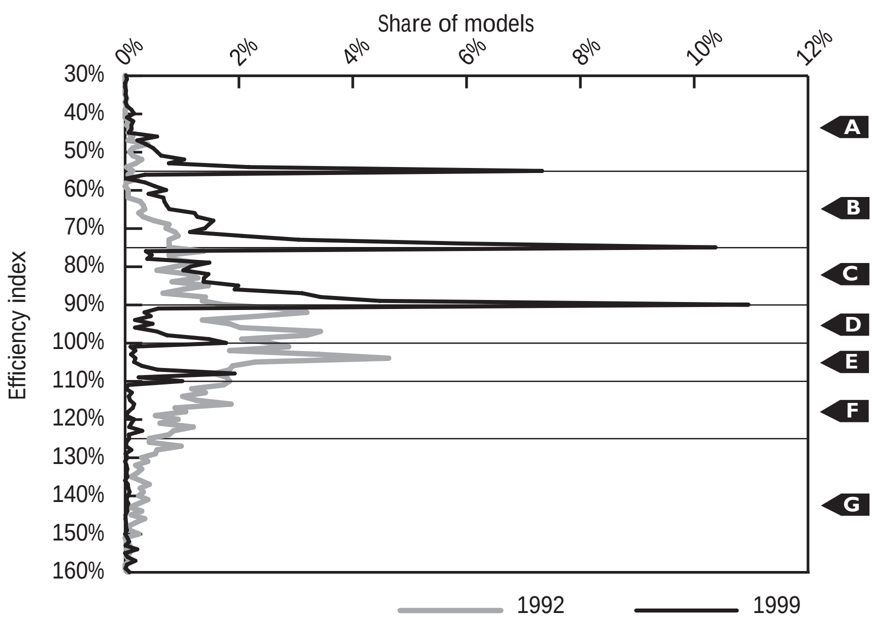
POLICY SCENARIOS: NO POLICIES AND CURRENT POLICIES

Estimating consequences of current policies

It is important for policy-makers to know how much energy has been conserved through the current programmes and how much energy could be conserved were the ambition of those programmes to be increased. The evaluation of savings attributable to current policy measures is not a perfect science as it depends upon a number of assumptions. The only data which can be gathered with a high degree of confidence are information on how much energy is being used by each end-use and even here there has not always been sufficient research conducted to provide unequivocal estimates for all end-uses and regions.

The estimation of how much energy would have been used had current policy measures not been implemented is necessarily less precise, although there is plenty of evidence to demonstrate the magnitude of the impacts of specific appliance efficiency policy measures. The change in efficiency of refrigerators offered for sale in the EU refrigerator market before and after the introduction of mandatory energy labelling provides a good example of this. Figure 3.4 indicates the distribution of refrigerator energy efficiency (expressed in terms of the energy efficiency index, EEI) as a function of the number of models offered for sale in 1992 (before energy labelling) and in 1999 (after several years of energy labelling and with new MEPS about to come into effect). The pre-labelling and MEPS distribution is completely random with a very wide spread in efficiency (more than 450%) between the least and most efficient appliances on the market. In contrast, the 1999 distribution is about 25% more efficient on average and is strongly influenced by the structure of the energy label. In fact, almost every single model that had been retired since the introduction of energy labelling had been replaced by a model that was designed to just satisfy a specific energy label class efficiency threshold. The top two energy label classes, A and B, were attained by a high proportion of the refrigerator models on the 1999 market and are considerably more efficient than the minimum energy performance requirements which are set at efficiency levels near the energy label C-class threshold for most refrigerator types.

Figure 3.4 **The distribution of refrigerator energy efficiency in the EU before and after energy labelling**



Source: Waide 2002.

The impact of the MEPS, which entered into effect in September 1999, is also apparent as refrigerators in the lower energy label efficiency classes had almost been eliminated despite including models that were available for sale prior to the MEPS taking effect.

Generally, an evaluation of a policy's impacts will assume that previous efficiency trends would have continued unchanged had no policy measures been introduced and that all other aspects of a product's sale and use would be the same as did occur with the policy in place (e.g. that the equipment retirement rates, sales volumes, capacities, features and characteristics of use would have been the same as those that did occur). Applying these assumptions for each residential electricity end-use in the dynamic equipment energy stock model described in Chapter 1, has enabled estimates of the savings attributable to the policies enacted in OECD countries from 1990 onwards to be established. However, useful retrospective policy analysis may also be helpful to project the impacts forward in time to estimate where future residential electricity consumption is heading and to calculate the continuing impacts of current policies. This is especially true for the evaluation of appliance efficiency measures which only apply to the efficiency of new equipment sales because, depending on the appliance type, it takes between six and twenty years for half of the existing stock to be replaced.

Assumptions and data sources for the current policies and no policies scenarios

To assess the impact of current policies, two detailed residential electricity consumption end-use scenarios have been produced for each of the OECD Member country regions: the *No Policies* and *Current* Policies scenarios. The sole difference between the No Policies and Current Policies scenarios is that the former has a slower rate of efficiency improvement, based on the best estimate of the efficiency progressions by end-use which would have occurred had none of the current policies been implemented from 1990 onwards.

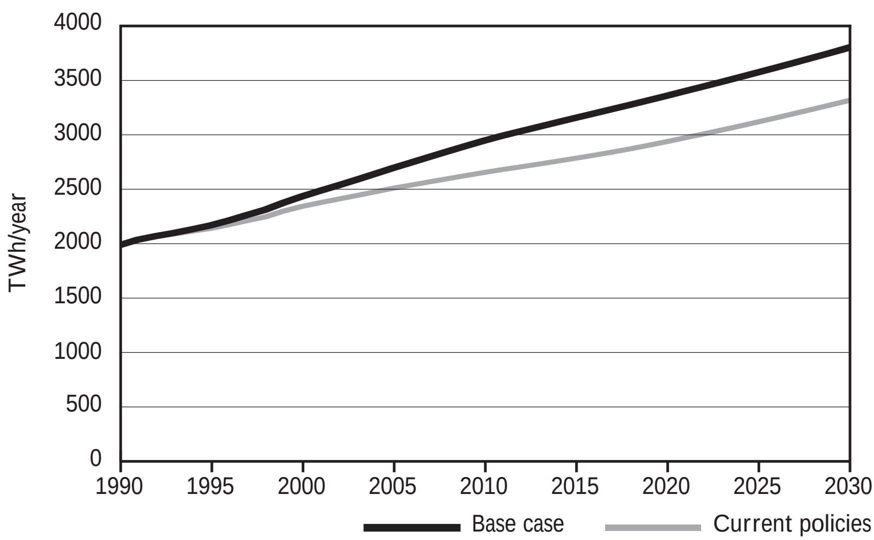
Some results from the Current Policies scenario were presented in Chapter 1 as this coincides with the energy consumption by end-use that has actually been experienced between 1990 and the current time. The same end-use stock model used to organise the historical energy data up to the year 2000 is primed with the historical energy and efficiency data for each electricity end-use.These are then projected into the future based upon reasonable assumptions regarding future demand for individual energy services (which is driven by underlying trends in the key drivers of household numbers, equipment ownership levels, and comfort and usage levels, all of which are assumed to progress smoothly from the historical levels) and by consideration of probable future changes in equipment efficiency levels. The latter are directly influenced by current energy efficiency policies whenever these exist. It is often possible to make informed estimates of the impact of policies which have already been enacted especially when these result in step changes in the efficiency of products available on the market (the US MEPS and EU energy labelling programmes are good examples of these) and when sufficient market data have been gathered to enable the magnitude of the step change to be recorded.The Current Policies scenario assumes that existing programmes are maintained into the future but that their ambition is not altered in any way. The efficiency levels of end-use equipment used in the No Policies scenario are drawn from published sources whenever these exist (i.e. either they are drawn from the results of post-implementation evaluations, or they are derived from published estimates of the impact of programmes made in the process of developing the policy) or from estimates made from the analysis of equipment efficiency time series before and after the introduction of a policy. In some cases the available data are comparatively rich (for many end-uses in Australia, North America and some European countries) but in others less data are available.

Projected impacts of current policies

With the policies currently in place, residential electricity consumption is projected to grow from 2,341 TWh in 2000 to 2,654 TWh in 2010 and 2,936 TWh in 2020 making a total increase of 25.4% over the period to 2020. With a continuation of current policies, it is forecast that 14.5% of total residential electricity used in OECD countries in 2010 will be attributable to space heating, 6.5% to space cooling, 13.3% to water heating, 13.5% to lighting, 10.3% to cold appliances, 4.6% to television in the on-mode, 7.5% to standby power, 2.6% to washing machines, 3.3% to clothes dryers, 1.7% to dishwashers, and 21.5% to cooking and other uses (Figure ES.2, page 13). Appliance standby energy consumption is the fastest growing end-use reflecting a strong anticipated increase in ownership of appliances with standby functionality from 8.1 appliances per household in 1990 to 21.2 per household by 2020. The share of electricity used to provide standby functionality is projected to undergo a strong increase from 3.1% of total residential demand in 1990 to 10% in 2020. This occurs despite some significant policy stimulated reductions in standby power consumption levels for individual end-uses over the simulation period.

According to the IEA projections, the policies enacted since 1990 reduced OECD residential electricity consumption by 3.8% in 2000 and will go on to reduce it by 9.9% in 2010 and 12.5% in 2020 compared to what would have happened had they not been introduced. In cumulative terms they saved 1.6% of residential electricity consumption by 2000 and are forecast to save 4.6% by 2010 and 7.4% by 2020.

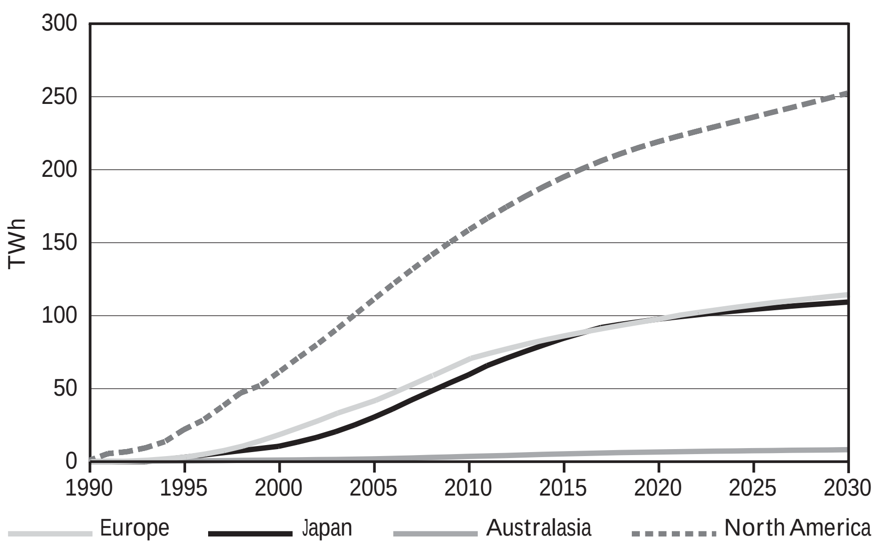
Figure 3.5 **Residential electricity consumption by end-use in the 22 IEA Member Countries for the Current Policies and No Policies Scenarios**



Electricity savings by region

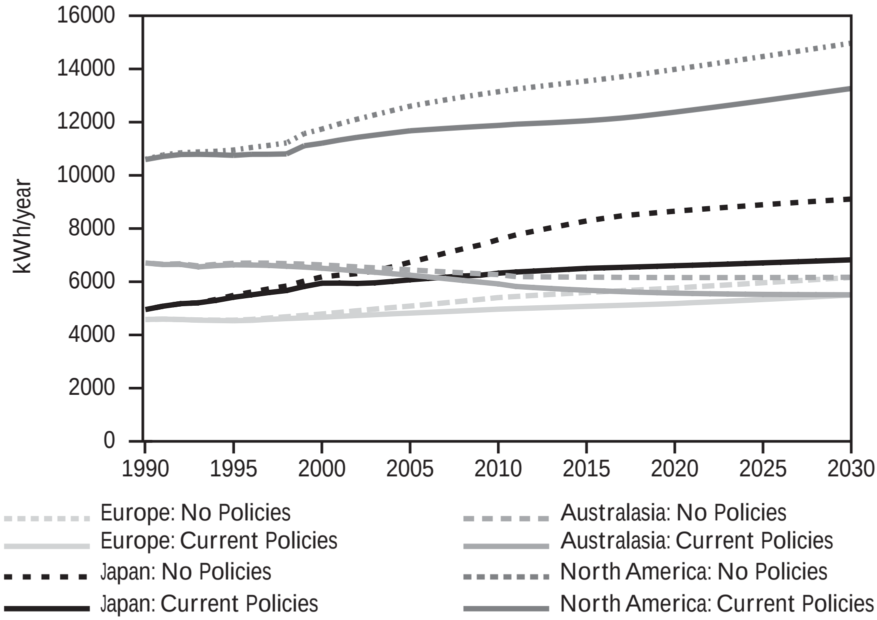
The largest total savings have occurred in OECD North America where some 61.2 TWh of residential electricity was saved in 2000 and 158.5 TWh is projected to be saved by 2010 assuming a continuation of current policies (Figures 3.6 and 3.7). These savings occur despite OECD North America having by far the highest per capita residential electricity consumption across the OECD regions. In percentage terms, these values correspond to savings of 4.5% in 2000 and 9.6% in 2010. The policies enacted in OECD Europe since 1990 (primarily those in the EU) are estimated to produce electricity savings of 18.9 TWh in 2000 and 70.8 TWh by 2010. In percentage terms, this corresponds to savings of 2.5% in 2000 and 8.1% in 2010, whose slightly lower values reflect the slower start and less comprehensive enactment of appliance efficiency policies made in the EU compared with North America in the decade to 2000. In Japan, the pace of policy initiation was slower in the 1990s but accelerated from early 2000 onwards. Savings of 10.5 TWh are estimated for 2000 rising to 59.4 TWh in 2010. In percentage terms, these savings are the most impressive across the OECD with values of 3.8% in 2000 and 16.6% in 2010; however, due to some important data limitations there is greater uncertainty in these projections compared with those for the other regions. Despite Australia's effective early labelling programme, the failure to introduce ambitious MEPS until 2004 and the late adoption of energy labelling and MEPS in New Zealand (April 2002) means that the increase in savings occurs comparatively late in the simulation period with savings of 1.9% (1.1 TWh) being attained in 2000 and projected savings of 5.6% (3.6 TWh) in 2010.

Figure 3.6 **Residential electricity savings for the Current Policies scenario***



*Compared with the No Policies scenario by region.

Figure 3.7 **Residential electricity consumption per household for the Current Policies and No Policies scenarios by region**



Cost-benefits of current policies

The costs of implementing the current set of appliance efficiency policy measures have only been partially analysed in OECD Member countries but are generally far lower than the value of the benefits. The costs associated with energy labelling, MEPS and VAs include the administrative cost of designing and implementing the policy measures; the cost to manufacture more efficient equipment as passed down the supply chain to the final consumer; and any promotional and training costs carried by other interested parties such as manufacturers, retailers and installers. The benefits include the reduced operating costs and the lower environmental impacts of the equipment, such as lower indirect CO_2 emissions, associated with the net increase in equipment efficiency.

Estimating costs and benefits

In the EU and US, estimates of the projected increase in appliance purchase price as a function of efficiency are routinely made for products which are to be subject to regulatory energy efficiency policy measures.

These data have been assembled from product studies conducted as a component of the policy design process and its derivation is discussed in the next section. In fact, the estimates of increased average product costs as a function of average efficiency improvements derived in this manner have generally been found to be inflated compared with the actual increases in product costs which have occurred whenever retrospective market analyses have been conducted (Greening 1996, ADEME 1998, 2000b, 2001), which suggests that more elegant ways have been found to raise product efficiency than is typically projected at the time the efficiency policy is being designed. Nonetheless, as policy design studies provide the only commonly available source of data for incremental product costs as a function of efficiency, they are used to provide the estimates of incremental product prices applied in this analysis. The administrative costs of policies such as MEPS and energy labelling are normally very small by comparison with the other costs and hence are not directly included in this analysis (LBNL 2002).

The benefits of higher average efficiency levels are simpler to derive. The reduction in operating costs is calculated by multiplying the annual reduction in energy consumption due to the policy measure by the average electricity applying to the equipment type in the region concerned. The avoided CO_2 is calculated by multiplying the annual reduction in energy consumption due to the policy measure by the average CO_2 emission factor applying to the equipment type in the region concerned.

Tables 3.1 and 3.2 show the estimated reduction in energy bills and estimated increase in equipment purchase costs from 1990 to 2030 attributable to the residential electrical appliance energy efficiency policies that were already in place in OECD North America and OECD Europe circa 2002. The net cost savings shown in both tables are the difference in the two costs. Also indicated are the annual and cumulative reductions in indirect carbon dioxide emissions attributable to the policies enacted in both regions. These estimates show that cumulatively 792 Mt of CO_2 emissions are expected to be avoided in OECD North America from 1990 to 2010 as a result of current residential appliance efficiency policies and that far from being incurred at a positive net cost to consumers and society, these policies are anticipated to save North American consumers some $62 billion in net costs over the same period. In OECD Europe, it is estimated that some 211 Mt of CO_2 emissions will be avoided from 1990 to 2010 as a result of current residential appliance efficiency policies and that these will be achieved at a net saving to European consumers of some €51 billion over the same period. The CO_2 savings in OECD Europe are more than three times lower in absolute terms compared with OECD North America but are only one-third lower in cumulative terms when expressed as a percentage of indirect emissions from residential electrical energy consumption in 1990.

Table 3.1 **Estimated carbon dioxide emission reductions for currently adopted OECD North American residential appliance efficiency policies**

Year	Energy cost saving (billion $)		Equipment purchase cost increase (billion $)		Net cost saving (billion $)		Carbon dioxide reduction		
	Annual savings	Cumulative savings from 1990	Annual increase	Cumulative increase from 1990	Annual savings	Cumulative savings from 1990	Annual ($Mt\text{-}CO_2$)	Share of residential total in 1990 (%)	Cumulative ($Mt\text{-}CO_2$)
1995	1.4	3.5	1.3	4.6	0.1	-1.1	11.0	2%	28.7
2000	4.5	19.2	2.4	14.0	2.1	5.2	33.0	4%	150.4
2005	8.5	53.4	3.2	28.4	5.3	25.0	61.7	7%	399.6
2010	12.2	107.3	3.6	45.5	8.6	61.8	89.0	9%	792.2
2015	15.0	177.2	4.0	64.7	11.0	112.6	109.3	11%	1,300.9
2020	16.9	258.4	4.4	86.0	12.5	172.4	122.7	11%	1,890.3
2025	18.1	346.8	5.0	109.8	13.2	237.0	131.8	11%	2,531.6
2030	19.4	441.1	5.5	136.4	13.8	304.7	140.7	11%	3,217.0

Source: IEA Appliance Stock Model (electrical end-uses only).

Energy-efficiency policy measures, and especially those aimed at the residential sector, stand apart from other CO_2 abatement policy measures, such as fuel-switching, because they are still in the domain where they can be achieved at a large net financial benefit to society even without the value of pollution externality costs being taken into account. The cost savings indicated in Tables 3.1 and 3.2 give an insight into the imperfect nature of the residential equipment market as far as energy performance is concerned. Such large net cost savings are attainable through enacting equipment efficiency policy measures because, in their absence, a variety of barriers exist that prevent the true economic value of energy efficiency investments being apparent to, or obtainable by, residential equipment buyers at the time of purchase. The estimates in Table 3.1 suggests that each tonne of CO_2 saved to 2010 by current policies in OECD North America was attained at a net cost saving of \$78, i.e. the net cost of CO_2 abatement is -\$78/tonne-CO_2. For OECD Europe, the equivalent value is -€241/tonne-CO_2. The difference in the cost for CO_2 abatement between the two largest OECD regions reflects the higher electricity costs and currently lower efficiency standards in Europe.

Table 3.2 **Estimated carbon dioxide emission reductions for currently adopted OECD European residential appliance efficiency policies**

Year	Energy cost saving (billion €)		Equipment purchase cost increase (billion €)		Net cost saving (billion €)		Carbon dioxide reduction		
	Annual savings	Cumulative savings from 1990	Annual increase	Cumulative increase from 1990	Annual savings	Cumulative savings from 1990	Annual ($Mt-CO_2$)	Share of residential total in 1990 (%)	Cumulative ($Mt-CO_2$)
1995	0.4	0.8	0.0	0.0	0.4	0.8	1.4	0%	2.9
2000	2.4	8.2	0.8	2.4	1.7	5.8	7.6	3%	26.0
2005	5.4	29.4	1.5	7.9	4.0	21.5	16.9	5%	92.1
2010	9.1	67.5	2.0	16.8	7.1	50.7	28.4	8%	210.7
2015	11.1	119.2	2.5	28.6	8.5	90.6	34.7	10%	372.5
2020	12.5	179.1	2.7	41.8	9.8	137.3	39.3	10%	560.3
2025	13.7	245.4	3.0	56.3	10.6	189.1	43.2	11%	769.1
2030	14.5	316.4	3.4	72.6	11.1	243.8	46.0	11%	993.6

Source: IEA Appliance Stock Model (electrical end-uses only).

ASSESSING THE COST-EFFECTIVENESS OF NATIONAL SPENDING ON APPLIANCE PROGRAMMES

There has been an ongoing debate in the economics and policy analysis communities over whether carbon emissions can be reduced at zero or negative net costs. On the one side, a school of thought argues that carbon emission reductions must always cost something, as the economy is currently at a more or less optimal equilibrium, and that any deviations must introduce inefficiency and hence societal costs. On the other side, a different school of thought argues that there are many cost-effective technologies and policies to reduce energy use and hence carbon emissions. If the appliance energy efficiency programmes save money for society and reduce pollution at the same time, they result in carbon emission reductions at negative net cost. If the appliance programmes impose costs on society that exceed the benefits, the cost of reducing carbon emissions using this policy mechanism is greater than zero, lending credence to the first school of thought.

Appliance energy efficiency programmes are cost-effective because they are intrinsically designed that way. Applying the principle of life-cycle cost in the policy decision process, is a guarantee that the possible extra cost for a more efficient product will be compensated by the energy savings during its life span. However, there exists a cost to initiate, administer, manage and monitor appliance programmes. Resources, both human and financial, must be allocated to tap the potential savings.

What are the resources currently placed by IEA governments on appliance energy efficiency programmes? What is the impact on the energy demand of individual national programmes? Is there a link between the resources allocated to and the impact of appliance energy efficiency programme?

Many appliance programmes have been developed in the last decade. However, few evaluations are available and have been performed on appliance energy efficiency programmes.

In 1998, Koomey et al. published an interesting evaluation of the US appliance energy efficiency standards which assess the cost and benefit of this programme to the US economy.

Net national economic impact on the US economy

The total present value of bill savings from the standards (1990 to 2010) is about $46 billion, and the present value of annualised costs is about $13 billion, for a total net present value savings of $33 billion. Savings will continue to accrue after 2010, but they are accounted for in this analysis. The overall benefit/cost ratio is about 3.5, and this ratio varies little when considering the savings and costs by fuel type. Benefit/cost ratios for specific end-uses range from just below 1.0 for the least cost-effective standard (natural gas dryers) to more than 100 for the most cost-effective standard (natural gas room heating).

Table 3.3 **Federal government expenditures to implement US appliance efficiency programmes**[1]

Fiscal year[2]	Programme Costs contractors/other million 1995 $	Department of Energy Salaries million 1995 $	Total million 1995 $	Total Present Values (PV) to 1995[3] million 1995 $
1978	8.6	1.2	9.7	30.8
1979	8.5	1.0	9.6	28.2
1980	9.2	0.9	10.2	28.1
1981	6.4	0.8	7.2	18.6
1982	2.8	0.8	3.6	8.8
1983	1.5	0.8	2.3	5.2
1984	2.5	0.7	3.2	6.8
1985	3.5	0.7	4.2	8.4
1986	2.6	0.7	3.3	6.1
1987	2.7	0.7	3.4	5.8
1988	2.3	0.6	3.0	4.8
1989	2.2	0.6	2.8	4.2
1990	2.0	0.9	3.0	4.1
1991	2.2	0.9	3.1	4.1
1992	2.7	0.9	3.6	4.4
1993	3.7	1.1	4.7	5.4
1994	8.3	1.0	9.4	10.0
1995	10.3	1.0	11.3	11.3
1996	5.2	1.4	6.5	6.1
Total			**104**	**201**

1. Expenditures are for all standards, not just residential standards.
2. US government fiscal years (FY) run from 1 October through 30 September.
Fiscal year 1996 began 1 October 1995.
3. Present value (PV) to 1995 calculated at 7% real discount rate.
Source: Koomey *et al*. 1998.
Unfortunately, no other evaluation as detailed as this US one has been found in the literature.

As shown in Table 3.3, total cumulative federal government expenditures to develop and implement all equipment standards are roughly $200 million (also present valued to 1995 using a 7% real discount rate). This figure is to be compared with the total cumulative net present value savings of $33 billion for the US economy. Every dollar of federal money spent on standards will therefore result in $165 of net savings for US consumers through 2010. This assessment of cost-effectiveness is believed to be a conservative one, because:

- The estimate of total present-value savings is a lower bound.
- In many cases the savings will continue past 2010.
- The costs are for both residential and commercial equipment standards while the benefits are for the residential standards alone (although this latter effect is not likely to lead to a large correction, since the bulk of federal funding has been allocated to residential standards).

A tentative estimation of IEA government spending on appliance programmes

Despite the difficulty to collect figures of national expenditures in appliance energy efficiency programmes, it has been possible through a small survey, individual contacts and budget analysis to extract some estimations of IEA government spending on appliance standards and labels programmes.

Not surprisingly, the appliance efficiency programme showing the largest impact, namely the US DOE appliance standards programme, is the one currently fuelled with sustainable resources, both human and financial. Appliance energy efficiency programmes can be designed to generate electricity and bill savings, and contribute to the reduction of the related greenhouse gas emissions at a negative cost to society, providing financial and human resources are allocated to develop, implement and monitor the policy.

Table 3.4 **Comparing national budgets for appliance energy efficiency in different IEA economies**

IEA Member countries	Description of Main programmes	Estimated Government Staff Man-year in 2000	Estimated Consultant StaffMan-year in 2000	Estimate of Government's Budget for Appliance Programme million 2000 $
European Union	Voluntary Agreement +MEPS + Labels	3	6	< $1
Australia	MEPS + Labels	3	6	
Canada	MEPS + Labels	5	4	
Japan	Top Runner	5	4	
Switzerland	Voluntary programme	2	4	
United States	MEPS + Labels	10	50	$ 7

THE POTENTIAL FOR INCREASED SAVINGS

Satisfaction with the apparent success of the policies already introduced is tempered when compared with the scale of the remaining untapped cost-effective efficiency savings and the consideration that in all OECD regions total residential electricity consumption is still set to rise. The scale of untapped future savings can be evaluated in a number of ways. The highest technically achievable savings which would have no impact on equipment functionality or lifestyles would be attained by substituting the existing equipment stock with the most efficient equipment currently available or that could be available. This would produce very large savings but is also likely to be expensive because of the cost of purchasing and installing ultra-efficient equipment. The same equipment could be phased into the stock by imposing MEPS set at the level of the most efficient equipment available as is done in Japan's Top Runner programme. Setting MEPS at these levels would result in a lower cost than that incurred by immediate substitution because the consumer would pay for the more efficient equipment at the same moment that they would normally be replacing their old equipment or buying first time equipment. In this case, the only additional cost is the difference in price of the more efficient equipment compared with the average efficiency equipment it replaces.

The cost and benefits for the consumer depend upon the purchase price and discounted operating costs, collectively known as the life-cycle cost, of the more efficient equipment compared to those of the less efficient equipment. From the consumer's perspective, the most cost-effective situation occurs when new equipment is replaced by equipment having an efficiency level corresponding to the lowest or least life-cycle cost (LLCC). The efficiency level associated with the LLCC is a fundamental benchmark that has been used in policy development in North America and the European Union. In both regions, for each equipment type that is under regulatory consideration, a technical study is conducted whose goal is, among others factors, to determine the efficiency level associated with the LLCC.

The technique used to evaluate this is known as techno-economic energy-engineering analysis. The results from such an analysis are shown in Table 3.5 and Figure 3.8 for a recent investigation of refrigerators in the European Union (ADEME 2000) which provides a good example of the process. The energy consumption implications of various higher efficiency design options were evaluated using a suite of dynamic refrigerator simulation software that was specifically developed for the purpose. The higher efficiency design options considered included: increased door insulation; increased cabinet insulation; increased evaporator surface area; increased condenser surface area; increased evaporator heat capacity; increased condenser heat capacity; more efficient compressors; decreased door leakage (better gaskets): higher-quality insulation (vacuum insulation panels, VIPs), gas-filled panels or alternative foaming agents); low-wattage fans to increase heat transfer at the evaporator and condenser; variable-speed compressors; variable-capacity compressors; rated-speed compressors; linear (free-piston) compressors; optimised electronic control; alternative refrigerants (i.e. refrigerant mixes); flow regulation valves; compressor-run capacitors; phase-change materials in the evaporator and/or condenser; and the use of an off-cycle migration valve to prevent pressure equalisation of the refrigerant. The energy savings from the most promising design options were estimated using a fully calibrated refrigerator energy simulation software tool.

Economic data on the manufacturing cost of each design option were assembled from numerous sources and were critiqued by industry to ensure a high level of agreement on the core values. Information on costs and mark-ups through the distribution chain was used to convert incremental manufacturing costs associated with higher efficiency design options into incremental final consumer prices. Each design option was then ranked in terms of cost-effectiveness and deployed in order of ascending payback period (the amount of time it would take the consumer to recoup the cost of their investment in the higher efficiency option). The results can be expressed in terms of a life-cycle cost curve as a function of the appliance's efficiency.

Figure 3.8 shows the normalised life-cycle cost (i.e. the life-cycle cost of an appliance at a given efficiency level divided by that of the same type of appliance with an efficiency index of 100%, which corresponds to the average efficiency of this type of appliance on the European market in 1992) as a function of the efficiency index for each of the main types of cold appliance sold in the EU.

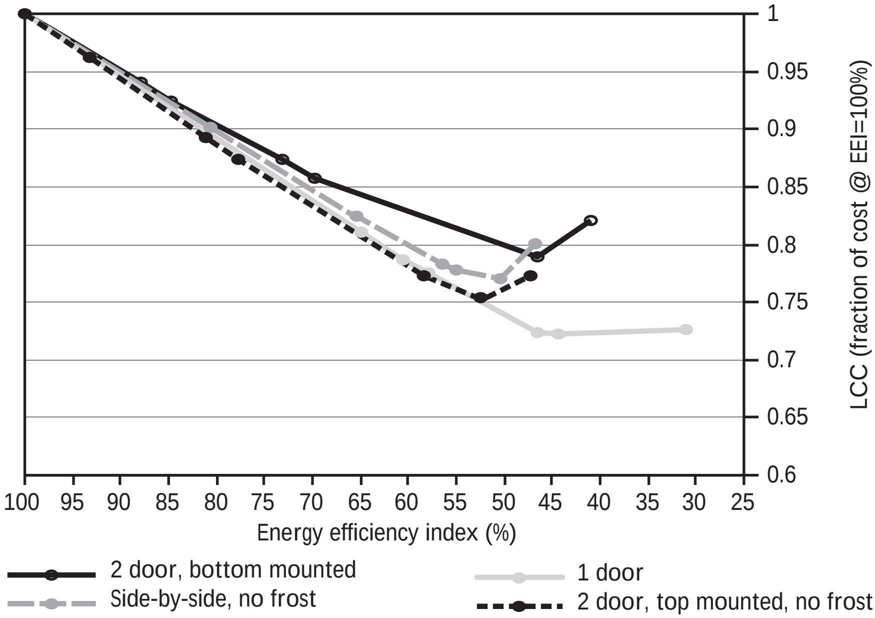
Table 3.5 **Energy-efficiency index (EEI), energy consumption and incremental purchase price for cold appliances with the least life-cycle cost (LLCC) for each cold appliance category**

Appliance type	Base-case model	Energy consumption			Purchase price		
		Base case (kWh/year)	Improved model at LLCC (kWh/year)	EEI for LLCC (%)	Base case (Euro)	Improved model at LLCC (Euro)	Increase in price (%)
Simple refrigerator	Bosch KTR 1430	252.7	112.1	40.3	303.4	350.0	15.4
Refrigerator chiller	Gram KS 400-04	256.6	165	51.1	914.6	960.4	5
0-star refrigerator	Zanussi ZI 1611	225	139.7	49.6	303.7	342.5	12.7
1-star refrigerator	Fagor FDS 1140	204.7	123.5	45.0	216	258.6	19.7
2-star refrigerator	Thomson TOP 15	212.4	131.1	41.9	281.7	326.2	15.8
3-star refrigerator	Whirlpool ARG 422	252.7	163.7	54.2	390.2	421.7	8
1-door 4-star refrigerator-freezer	Arthur Martin AR 7334	313.3	213.9	44.3	455.8	494.2	8.4
2-door BM refrigerator-freezer	Whirlpool ART 868 G	603.4	289	46.5	608.3	748.7	23
2-door BM (built-in) refrigerator-freezer		603.4	290	51.11	1,105.2	1,402.2	27
2-door TM (NF) refrigerator-freezer	Candy CF 400 FF	643	357.5	51.9	608.2	675.3	11
2-door TM (manual defrost) refrigerator-freezer	Brandt ADF 357	530.7	268	42.1	501.5	561.2	11.8
2-door SBS (NF) refrigerator-freezer	Maytag GS 2124 SEDW	823.9	514	50.4	1,065.9	1,167.8	9.55
Upright freezer	Bosch GSD 1343	371.6	209	55.0	379.6	433.4	14.2
Upright freezer (built-in)		371.6	203.6	56.2[1]	777.4	884.4	14
Chest freezer	Thomson S20	271.4	182.3	51.5	394.9	443.0	12.2

Abbreviations: BM = bottom-mounted; nf = no-frost; SBS = side-by-side; TM = top-mounted.

1. EEI for built-in models after taking into account a higher volume-loss penalty.

Figure 3.8 **Normalised life-cycle cost (LCC) as a function of energy-efficiency index (EEI) for European refrigerators as estimated via a techno-economic energy-engineering analysis**



Refrigerator types are identified by their category number under the EU energy labelling scheme. (1D = one door; 2D = two doors; TM = top-mounted frozen-food compartment; BM = bottom-mounted frozen-food compartment; SBS = side-by-side; nf = no-frost.)

The results show that:

- The estimated sales-weighted average EEI for all refrigerator types at the point of least life-cycle cost is 46.8%.
- The LLCC occurs for appliances that are rated energy label class A or better for all categories except the built-in upright freezer, which has an EEI of 56.2%.
- The most efficient cold appliances on the market in 1999 had EEIs of 31% for refrigerators, 29.6-34.6% for refrigerator-freezers and 39% for freezers, thus the estimated LLCC efficiency level is exceeded by the most efficient models on the market.

- Appliances designed to reach the LLCC efficiency level would be expected to cost an average of €23 more to manufacture and €66 Euro (15%) more to purchase (assuming that 100% of the incremental costs are passed on to the consumer and that a multiplicative factor of 2.9 exists between manufacturing cost and retail price) compared to those that just satisfy the 1999 MEPS; however, they would avoid electricity costs worth an average of €24.7 per year or €272 over a typical 15-year product life time. The average payback time for the consumer would be 2.7 years assuming a 5% real discount rate.
- The sales-weighted average energy consumption of refrigerators that just satisfy the 1999 MEPS level is ~422 kWh/year, of those at the class A threshold ~255 kWh/year and of those at the LLCC efficiency level ~216 kWh/year.
- Over its lifetime, a typical refrigerator at the 1999 MEPS level would give rise to 3,089 kg of indirect CO_2 emissions, at the class A threshold to 1,867 kg and at the LLCC efficiency level to 1,581 kg assuming EU average CO_2 emissions per kWh consumed.

It is clear that the LLCC is a moving target and that as technologies improve and production volumes of high-efficiency components increase, the EEI that gives the LLCC for the consumer will decline. An additional energy-engineering analysis was conducted to estimate the expected maximum conceivable medium- to long-term efficiency levels for the main types of cold appliance. It is estimated that the lowest technically achievable EEIs in the medium to long term are 16-18% for refrigerators, 19-23% for refrigerator-freezers and 22-26% for freezers.

Similar analyses have been conducted for most of the major electricity end-uses in the European Union and US and provide an invaluable insight into the relationship between efficiency and product cost in both economies. The efficiency associated with the LLCC can occur at a level which is greater than that provided by any of the products currently on the market (as has been the case for refrigerators in the US) or at a level which may be exceeded by the most efficient products on the market (as has been the case for refrigerators in the EU). Nonetheless, the LLCC is a vital policy benchmark because it defines the efficiency level at which the average consumer attains maximum economic benefit. All efficiency improvements up to the LLCC efficiency level are delivered at a net economic benefit to the consumer and society as a whole. Efficiency improvements beyond the LLCC may be in the overall economic interests of society (especially if the collective value of avoided environmental externality costs is taken into account) but are no longer optimised in narrow cost-benefit terms for the average appliance purchaser and user.

POLICY SCENARIO: LEAST LIFE-CYCLE COST EFFICIENCY LEVELS FROM 2005

As comparatively reliable data on the relationship between life-cycle cost and efficiency are available for the majority of residential electrical end-uses in the two largest economies in the OECD, a high efficiency scenario has been produced wherein it is generally assumed that all electrical equipment sold from 2005 onwards attains the LLCC efficiency level for each product type and in each economy.

For reasons of simplicity, the LLCC from 2005 scenario assumes that there is no competition for current electric end-uses from other fuels and hence does not consider the economic trade-offs of future heating applications (such as space and water-heating, cooking and clothes drying) being provided by alternative fuels such as gas, or solar energy; however, in reality, these options do exist. Nor does the scenario consider the potential primary energy, CO_2 and cost savings from using micro or district cogeneration or the impact of passive solar building measures aimed at improving the thermal and energetic efficiency of residential buildings - all of which can be attractive policy options.

Instead, the scenario is confined to the consideration of technical options which would raise the electrical efficiency of residential electricity end-uses in a cost-effective manner for the average consumer/end-user without influencing the manner in which the equipment is used and without adversely affecting the quality of service provided. In determining the efficiency level associated with the LLCC, there is no constraint imposed on the maximum length of the payback period for higher efficiency equipment, i.e. it is only necessary for the LLCC efficiency level to produce the lowest total cost of purchasing and operating the appliance discounted over its normal lifetime. This differs from the US

NAECA regulations where it is a questionable assumption that the simple payback period that is associated with any new minimum energy efficiency regulation must be three years or less for an average appliance consumer.

The details of the assumptions underpinning the scenario are explained below for the different types of equipment considered.

Major household appliances

For the major household appliances it is assumed that the efficiency of all new models sold from 2005 onwards will be equivalent to the LLCC level. For refrigerators, freezers, washing machines, dishwashers, room air-conditioners, central heating circulation pumps, central air-conditioners and ovens, the information on what efficiency level corresponds to the LLCC is drawn from the latest regional technical studies. In particular, data on the efficiency levels, UECs and product costs at the LLCC are drawn from the following studies in OECD Europe: ADEME 2000, Novem 2001, GEA 1995, EERAC 1999, Grundfos 2001, EECCAC 2002, TTS 2000 and from the following sources for OECD North America: TSD 1995, 2000a, 1993, 1997, 2002, 1998. The technology considered at the LLCC for all these products is well understood and is either already being deployed for some products or could be deployed quite readily without significant changes in the functionality of the products, i.e. for the most part the technical changes are quite invisible to the user. Information on the most probable incremental product costs associated with the LLCC efficiency levels and with intermediate efficiency levels is also drawn from these sources and has been used to construct simple average cost versus efficiency functions for each product and region. For the years between 2002 and 2005, it is assumed that the efficiency of new products moves linearly toward the LLCC level as the market begins to respond to the efficiency requirements which will apply from 2005 onwards.

OECD North America. In all cases it was further assumed that the efficiency level associated with the LLCC was a slowly moving target with an annual rate of improvement of between 0% and 1.5% per annum from 2005 onwards depending on the appliance type. A 0.5% improvement per year was assumed for refrigerators, freezers, washing machines, dishwashers; 0.1% per year for clothes dryers; no improvement was assumed for ovens and ranges (hobs). For central air conditioners it was assumed that the rate of improvement in the efficiency level associated with the LLCC would be 1.5% per annum from 2005-10 and 1% per annum from 2011 onwards. For room air-conditioners it was assumed that the rate of improvement in the efficiency level associated with the LLCC would be 1% per annum from 2005-10 and 0.7% per annum from 2011 onwards.

OECD Europe. In all cases it was further assumed that the efficiency level associated with the LLCC was a slowly moving target with an annual rate of improvement between 0% and 3.1% per annum from 2005 onwards depending on the appliance type. A 0% per annum improvement was assumed for refrigerators and freezers from 2005-2020 and 0.5% per annum thereafter; 0% per annum was assumed for washing machines; 3.1% per annum for dishwashers from 2005-2010 and 0.5% thereafter; 1% per annum for ovens and ranges (hobs); no improvement was assumed for clothes dryers after 2005 or for central heating circulation pumps after 2010. For room and central air-conditioners it was assumed that the rate of improvement in the efficiency level associated with the LLCC would be 1.5% per annum from 2005-10 and 1% per annum from 2011 onwards.

Electric clothes dryers are a special case. The most recent studies in the EU and US are relatively old, published in 1995 (GEA 1995) and 1993 (TSD 1993) respectively, and only gave limited consideration to the use of heat pumps; however, in the last few years three different electric clothes dryers using heat pumps have appeared on the European market. The efficiency of these appliances is twice that of a conventional clothes dryer which makes them a technology worthy of consideration in a high efficiency scenario; however, they are also fundamentally more expensive. With the current niche market and very small production volumes, it is difficult to estimate with any great certainty what future prices heat pump clothes dryers might attain were they to become the standard clothes dryer technology. Therefore estimates of the incremental costs for heat pump dryers are taken from the analysis conducted by five national laboratories for the US Department of Energy (CEF 2000) and are applied in other regions by assuming their incremental purchase cost is a fixed proportion of the price of a conventional clothes dryer in all the regions examined. On this basis, heat pump dryers would appear to be cost-effective for the majority of households in OECD countries and the LLCC scenario assumes that all new dryers sold after 2005 in OECD Europe and OECD North America will use heat pumps.

Resistance space heating and heat pumps

It is assumed that from 2006 to 2008 in North America and from 2006 to 2010 in OECD Europe a major retrofit of existing electric space heating systems will be initiated.

In North America, under the Least Life-Cycle Cost from 2005 scenario, some 37.5% of resistance space heating will be replaced by air-source heat pumps from 2006 to 2008. This is based on an assumption that it is economic and viable to make this retrofit in 20% of northern and 80% of southern North American households when there is already an air-source central air conditioning system in place. In this event, there are no incremental costs for the installation of an air distribution system and it is merely necessary to replace the furnace unit with an equivalent power heat pump unit. In North America it is conservatively assumed that retrofitting resistance space heating units with ground-source heat pumps is uneconomic and hence is not an option for households without air-source central air-conditioning systems. In practice, however, this may well not be the case. It is assumed that the most common air-source heat pump will have a seasonal average heating efficiency of 2.57 W/W in 2008.

In Europe it is assumed that 80% of electric resistance space heating will have been substituted by heat pump units by 2010. The higher figure in Europe occurs because it is assumed that ground-source heat pumps are the predominant technology and that they can economically be applied more widely, especially for the 50% of electrically heated homes which are multi-family dwellings. In OECD Europe air-based heat distribution systems are rare while the average size of heated space tends to be smaller and the building thermal mass and level of insulation higher compared with the average North American house. These circumstances tend to favour the installation of ground-source hydraulic heat pumps, which usually have higher seasonal average heating efficiencies of the order of 4 to 5 W/W but would normally have higher installation costs. In addition to bore drilling, pipe installation and the cost of the heat pump unit, there are also costs associated with installing a hydraulic heat delivery system (radiators) which are rare in electric resistance heated households. Even in Europe, however, there may also be some instances when air-to-air heat pumps are more appropriate. The stock average seasonally-averaged heating coefficient of performance of the new heat pumps is assumed to be 3.5 W/W in 2005 in OECD Europe.

In both economies it is further assumed that sustained policy efforts will stimulate the average efficiency of new heat pumps to increase at a rate of 0.5% per annum from 2005 onwards.

In calculating the economic costs and benefits of this measure, it has been assumed that the average cost of retrofitting a resistance electric furnace by an air-to-air heat pump will be $2,396 per household in OECD North America in the year 2005. In OECD Europe the average cost of installing a heat pump is close to € 5,000 per household, which is based upon predominantly ground-source heat pumps with hydraulic heat distribution systems being installed in multi-family housing.

The energy performance and cost assumptions used in the scenarios for both regions draw heavily on the following references: CEF 2000, Sciotech 1998, Mayer 2001, EHPA 2002.

Electric storage water heaters

In North American and European households that have non-electric space heating, installing a heat pump storage water heater rather than an electric resistance water heater will generally double the efficiency of the water heater and be cost-effective for the consumer provided the water heater is above a minimum storage capacity (Hiller 2002, Lutz 2002). Under the LLCC efficiency scenario it is assumed that all households that install an electric water heater above a minimum storage capacity from 2005 onwards and that do not have electric resistance space heating will install a heat pump water heater. This is because it is likely to be cost-ineffective to use heat pump water heaters in households that are heated via electric resistance space heating as the water-heater heat pump will generally draw a significant proportion of ambient heat from the heating system. It is further estimated that it may not be cost-effective to use heat pump water heaters in households that have air-to-air heat pump space heating and therefore the LLCC efficiency scenario assumes that heat pump water heaters are not installed in these households. The result of these assumptions is that in OECD Europe some 70% of new electric storage water heaters installed from 2005 onwards will be heat pump units in the LLCC efficiency scenario while in OECD North America some 36% of new units will be heat pump units. The lower figure in OECD North America is due to the higher coincidence of electric storage water heating with resistance or air-to-air heat pump electric space heating than in OCED-Europe.

In OECD Europe, the LLCC efficiency scenario further assumes that the average standing losses of all new conventional water heaters sold from 2005 onwards will be reduced by one-third compared with the average levels under the Current Policies scenario to take account of the outstanding cost-effective potential to improve insulation quality (EVA 1998). In OECD North America, the Current Policies scenario includes new MEPS, which take effect in 2004, that are already set at levels close to LLCC efficiency levels if heat pumps are not considered but are far from it if they are.

The cost to purchase heat pump water heaters is taken from analyses developed in the US (EF 2000, TSD 1993) and is assumed to average $726 in 2005 for a water heater with an efficiency factor of 1.79 (measured under the standard US test procedure). This compares with an assumed cost of $330 for a conventional electric resistance water heater which just satisfies the 2004 US MEPS requirements and has an efficiency factor of 0.918. The incremental cost and energy performance of conventional electric storage water heaters with improved insulation is drawn from EVA (1998) and TSD (2000b), Lekov (2000) for Europe and North America respectively.

Lighting

In the LLCC efficiency scenario, 80% of all incandescent lamps, which are used for one hour a day or more, will be substituted by compact fluorescent lamps between 2004 and 2007. The corollary of this is an assumption that some 20% of existing luminaires that would otherwise contain incandescent lamps used for an hour or more per day are not suitable for compact fluorescent lamps (CFLs). The net impact of this substitution is to lower the average UEC per lamp socket from 49.7 kWh/year to 24.3 kWh/year in North American households and from 26.2 kWh/year to 10.8 kWh/year in European households. In all regions it is assumed that a CFL costs an average of $6 while a standard incandescent lamp costs $0.8. It is further assumed that the average cost of implementing the programme is $4 per CFL. The average operational life of the CFLs is assumed to be 9,000 hours while incandescent lamps are assumed to last for an average of 750 hours.

The LLCC efficiency scenario further assumes that sales of high-voltage halogen torchieres will be phased-out by 2005 and their market share replaced by CFL torchieres.

Data for these assumptions draw on: DELight (1998), EURECO (2002), Ecodrome (1998), ADEME (2001), Kofod (1999), DECADE (1997), EDS (1997), CEF (2000), Page (1999), Calwell (1996), McGowan (1999).

Standby power loads

A high proportion of residential electric equipment now has a power demand associated with providing standby functionality. The average power demand of each standby load was estimated in the No Policies and Current Policies scenarios by drawing on a variety of published sources (EURECO 2002, Ecodrome 1998, Ciel 1997, Novem 1996, ADEME 1995, AE 2/1998, Stinglwagner 2001, Siderius 2001, Takahashi 2001, Nakagami 2001, Matsunaga 2001, Sasako 2001, Toeda 2001, Rosen 2000, Ross 2000, IEA 2001, Sanchez 1998, CEF 2000). It is assumed in the LLCC efficiency scenario that from 2005 onwards all standby loads in new residential electrical equipment will be no higher than 1 W, which corresponds to the goals of the IEA 1-W plan (IEA 2002). For most appliances, this requirement is likely to be quite feasible to attain and at a very low incremental cost; however, for some applications (most notably, cable and satellite TV decoders) this could be a difficult target. By contrast there are many residential standby applications where much lower targets could be attained at low cost and thus, when considered overall, an equipment average target of 1 W standby demand seems attainable.

Overall it is assumed that the incremental cost of equipment with an average standby power load of 1 Watt is ~$5 per appliance which is consistent with estimates given in other sources such as CEF (2000).

Consumer electronics, miscellaneous uses and other electric cooking

In the LLCC scenario it is assumed that all consumer electronics, other than electric cooking and miscellaneous electrical equipment, sold from 2005 onwards has an efficiency at the LLCC level.

These end-uses can be divided into those that use power to provide services associated with electronics, heating (including cooking), lighting and motive power. Despite the growing contribution of miscellaneous equipment to residential electricity consumption, there has been less work undertaken to determine the potential for cost-effective energy savings for the miscellaneous end-uses compared with other end-uses, especially in Europe. In consequence, this study draws heavily on estimated cost-effective savings potentials derived from US studies and in particular the Scenarios for a Clean Energy Future (CEF) study (2000) and Sanchez (1998). The CEF made estimates of the potential for cost-effective energy savings and of the incremental equipment costs involved for a wide variety of miscellaneous equipment which are transposed into the current study for the LLCC scenario. A simplified equipment stock model was used for each miscellaneous end-use to project the change in stock energy consumption as a result of new equipment entering the stock at LLCC efficiency levels from 2005 onwards.

In aggregate terms, the CEF study estimated that cost-effective efficiency improvements of the order of 25% are available for miscellaneous residential electronics applications, 53% for miscellaneous residential motors applications, and 15% for miscellaneous residential heating applications in the US. In fact, the CEF savings potentials include savings due to a reduction of standby power levels but this is treated as a separate end-use in the presentation of the results from the current scenarios. For the majority of consumer electronics and home office equipment, lowering standby power levels is the major means of achieving cost-effective energy savings; however, for home PCs there are additional potential savings through the application of more sophisticated power management systems, higher efficiency monitors and even, theoretically, by promoting the development of more ergonomic software.

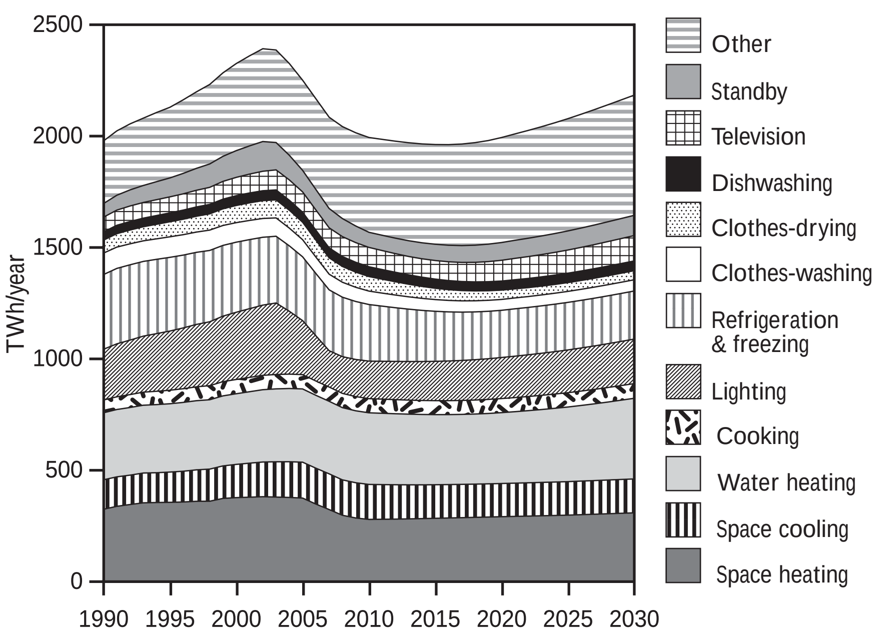
Whenever there were no suitable local data available, the CEF energy savings potentials were assumed to be applicable to each type of new miscellaneous equipment entering the stock in the other OECD regions. An exception was for televisions operating in the on-mode where the most comprehensive investigation of cost-effective energy savings potentials has occurred in Europe (Novem 1998) and this was taken as the reference internationally.

Energy and CO_2 savings

Under the LLCC from 2005 scenario, residential electricity consumption is projected to rise from 2,341 TWh in 2000 to a peak of 2,408 TWh in 2002 before declining quite sharply to 2,012 TWh in 2010 and 2,013 TWh in 2020 making a total decrease of 14% over the period. Under the LLCC from 2005 scenario, it is forecast that 13.9% of total residential electricity used in OECD countries in 2010 will be attributable to space heating, 7.8% to space cooling, 16.0% to water heating, 8.4% to lighting, 12.6% to cold appliances, 4.3% to TV in the on-mode, 3.4% to standby power, 3% to washing machines, 3.2% to clothes dryers, 2.2% to dishwashers, 3.2% to cooking and 22% to other uses (Figure 3.9).

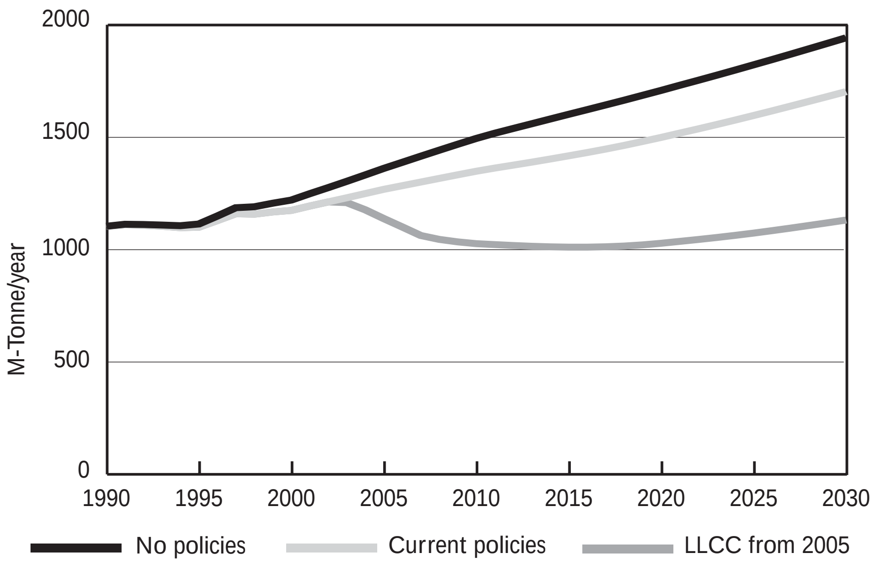
According to the IEA projections, the least life-cycle cost from 2005 scenario would reduce residential electricity consumption by 24.2% in 2010 and 31.4% in 2020 compared to what would have happened under the current policy measures (Figure ES 3, page 14). In cumulative terms, it is forecast to save 13.2% of total residential electricity consumption from 2002 to 2010, 21.8% from 2002 to 2020 and 26% by 2030. These savings are about 2.3 times larger again than what is projected to be achieved with Current Policies compared to the No Policies scenario over the same period.

Figure 3.9 **Projected OECD residential electricity consumption by end-use under the Least Life-Cycle Cost efficiency levels in 2005 scenario**



The savings in CO_2 emissions are proportional to the savings in energy consumption and are projected to rise from 322 million tonnes of CO_2 in 2010 (some 29% of 1990 levels) to 572 million tonnes of CO_2 in 2030. Perhaps as importantly from a policy-makers perspective, the total CO_2 emissions in 2010 are slightly below 1990 levels (Figure 3.10).

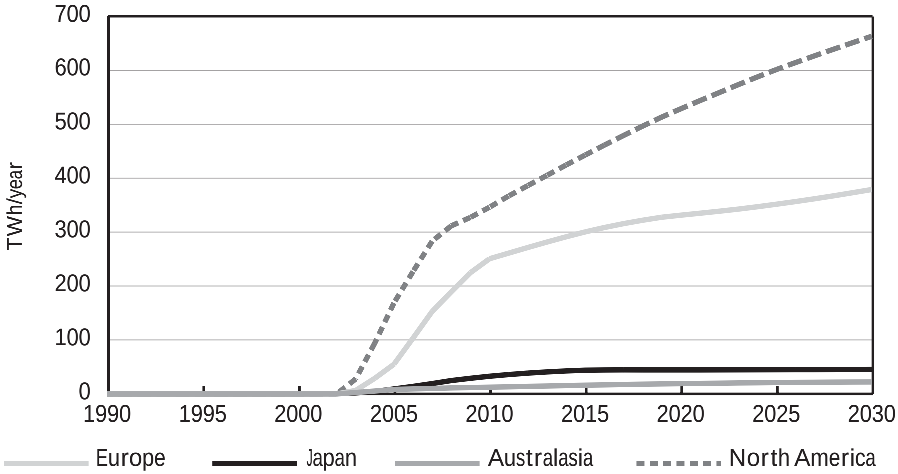
Figure 3.10 **Residential electricity-related indirect CO_2 emissions in the OECD for the No Policies, Current Policies and Least Life-Cycle Cost efficiency levels in 2005 scenarios**



Electricity savings by region

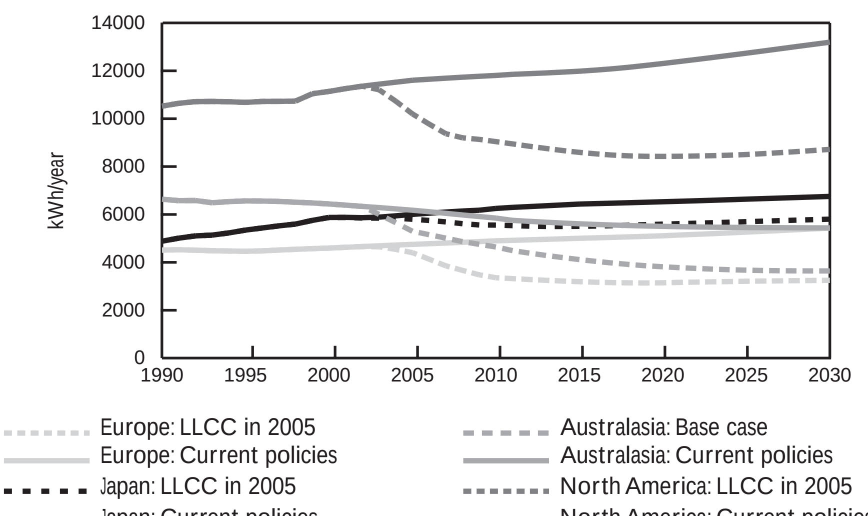
The largest cost-effective savings potential is in OECD North America where some 346 TWh of residential electricity is projected to be saved by 2010 and 528 TWh by 2020 under the LLCC from 2005 scenario (Figures 3.11, 3.12). In percentage terms, these values correspond to savings of 23.3% in 2010 and 31.4% in 2020. Enactment of the LLCC from 2005 measures in OECD Europe is estimated to produce electricity savings of 250 TWh in 2010 and 331 TWh by 2020. In percentage terms, this corresponds to savings of 31% in 2010 and 37.9% in 2020. In Japan, savings of 32.8 TWh are estimated for 2010 rising to 44.5 TWh in 2020. In percentage terms, these savings are 11% in 2010 and 14.2% in 2020;

Figure 3.11 **Residential electricity savings for the Least Life-Cycle Cost efficiency levels from 2005 scenario***



* Compared with the Current Policies scenario by region.

Figure 3.12 **Residential electricity consumption per household for the Least Life-Cycle Cost efficiency levels from 2005 scenario and the Current Policies scenario by region**

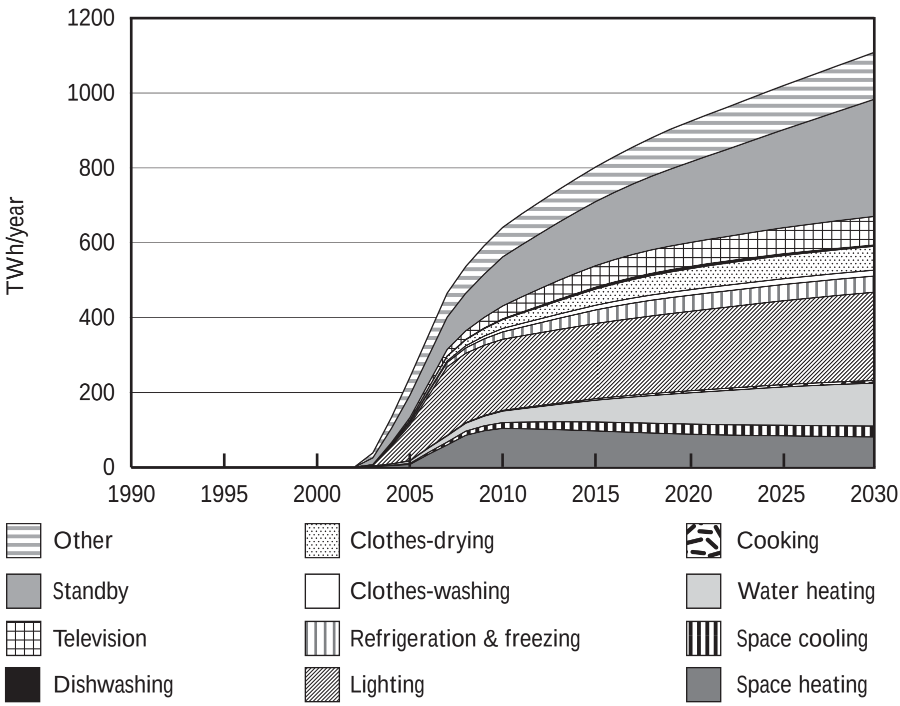


however, due to some large data limitations there is much greater uncertainty in these projections compared with those for the other regions. In Australasia, savings of 20.4% (12.5 TWh) in 2010 and 30.3% (19.1 TWh) in 2020 are projected, but again a lack of cost versus efficiency data for this region means these values are crude estimates.

Electricity savings by end-use

The evolution of energy savings compared with the Current Policies scenario is indicated in Figure 3.13.

Figure 3.13 **Projected IEA residential electricity savings by end-use for the Least Life-Cycle Cost efficiency levels from 2005 scenario compared with the Current Policies scenario**



Not surprisingly, the larger savings occur for those end-uses which are currently unregulated, namely: standby power, lighting, cooking and other (miscellaneous) end-uses. There are also large savings for partially regulated end-uses where a dramatic change in current practice is envisaged, namely space heating, water heating and clothes drying. Over the longer-term, the largest savings for any one activity will be obtained from efficiency improvements in standby power which will account for 131 TWh of savings in 2010, 214 TWh in 2020 and 313 TWh in 2030. Savings in lighting give the largest savings in 2010 of 190 TWh and produce savings of 212 TWh in 2020 and 236 TWh in 2030. The retrofit of a significant proportion of electric resistance space heating with heat pumps will produce savings of 104 TWh in 2010, 89 TWh in 2020 and 81 TWh in 2030. While those for water heating will rise from 31 TWh in 2010 to 115 TWh in 2030. Savings for the traditionally regulated, depending on the economy, end-uses of refrigerator, freezers, dish-washers, washing machines, clothes dryers and space cooling will rise from 70 TWh in 2010 to 155 TWh in 2030.

Cost-benefits of the LLCC from 2005 scenario

Applying the same estimates of the projected increase in appliance purchase price as a function of efficiency that were considered for the cost-benefit analysis of the current policies given in Tables 3.1 and 3.2, it is also possible to estimate the cost-benefits of enacting least life-cycle cost policy measures from 2005 onwards. Tables 3.5 and 3.6 show the estimated reduction in energy bills and estimated increase in equipment purchase costs from 1990 to 2030 attributable to the residential electrical appliance energy efficiency policies that were already in place in OECD North America and OECD Europe circa 2002 and imagining these were complemented by a new round of policy measures that would render average equipment efficiency at least life-cycle cost levels from 2005 onwards. The net cost savings shown in both tables are the difference in the two costs.

Also indicated are the annual and cumulative reductions in indirect carbon dioxide emissions attributable to the least life-cycle cost policies enacted in both regions. These estimates show that an additional cumulative total of 1,024 Mt of indirect CO_2 emissions is expected to be avoided in OECD North America from 1990 to 2010 as a result of the LLCC residential appliance efficiency policies compared with the Current Policies scenario. Furthermore, these policies would be anticipated to save North American consumers some $33.9 billion in net costs beyond the savings identified in the Current Policies scenario over the same period.

In OECD Europe, it is estimated that some 394.9 Mt of additional CO_2 emissions would be avoided from 1990 to 2010 as a result of LLCC residential appliance efficiency policies compared with the Current Policies scenario but that these would be achieved at a net additional cost to European consumers of some €15 billion over the same period.

In OECD North America, the additional LLCC policies result in the cumulative CO_2 savings from 1990 to 2010 being increased by 2.3 times above those expected with the current policies case and the cumulative net cost savings being increased by 1.5 times compared with the current policies case. In OECD Europe the additional LLCC policies result in the cumulative CO_2 savings from 1990 to 2010 being increased by 2.9 times above those expected with the current policies case and the cumulative net cost savings being decreased by 30% compared with the current policies case.

Table 3.6 **Estimated carbon dioxide emission reductions when the currently adopted OECD North American residential appliance policies are complemented by LLCC efficiency measures from 2005 onwards***

Year	Energy cost saving (billion $)		Equipment purchase cost increase (billion $)		Net cost saving (billion $)		Carbon dioxide reduction		
	Annual savings	Cumulative savings from 1990	Annual increase	Cumulative increase from 1990	Annual savings	Cumulative savings from 1990	Annual ($Mt\text{-}CO_2$)	Share of residential total in 1990 (%)	Cumulative ($Mt\text{-}CO_2$)
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
2005	13.7	23.6	15.0	29.0	-1.3	-5.5	97.0	12	167.2
2010	28.0	144.3	14.5	110.4	13.5	33.9	200.1	23	1,023.8
2015	35.8	308.2	15.7	185.9	20.2	122.4	256.2	28	2,195.5
2020	42.8	508.8	18.1	271.1	24.7	237.8	305.8	32	3,629.4
2025	48.7	740.6	20.9	370.1	27.8	370.5	347.9	33	5,286.5
2030	53.7	999.2	21.6	477.7	32.1	521.6	383.9	34	7,135.4

* Compared with the Current Policies scenario.
Source: IEA Appliance Stock Model (electrical end-uses only)

The estimates in Table 3.6 suggest that each tonne of CO_2 saved to 2010 under the LLCC scenario OECD North America would be attained at a net cost saving of \$33.1, i.e. the net cost of CO_2 abatement is \$33.1/tonne-CO_2. For OECD Europe the equivalent value is + €38.1/tonne-CO_2. However, if the period of interest is extended to 2020 the net cost of CO_2 abatement is -\$65.5/tonne-CO_2 in OECD North-America and -€168.9/tonne-CO_2 for OECD Europe. The initial positive abatement cost in Europe is mainly caused by the much higher levels of retrofitting with heat pump electric space heating between 2005 and 2010 which is assumed in Europe compared with North America, but this initial investment also contributes to the higher cost-effectiveness of the savings seen by 2020 in Europe. Also the difference in the cost for CO_2 abatement between the two largest OECD regions reflects the higher electricity costs and currently lower efficiency standards in Europe.

Table 3.7 **Estimated carbon dioxide emission reductions when the currently adopted OECD European residential appliance policies are complemented by LLCC efficiency measures from 2005 onwards**

Year	Energy cost saving (billion Euro)		Equipment purchase cost increase (billion Euro)		Net cost saving (billion Euro)		Carbon dioxide reduction		
	Annual savings	Cumulative savings from 1990	Annual increase	Cumulative increase from 1990	Annual savings	Cumulative savings from 1990	Annual (Mt-CO_2)	Share of residential total in 1990 (%)	Cumulative (Mt-CO_2)
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
2005	7.1	11.7	26.6	39.6	-19.5	-27.9	21.7	7	35.9
2010	32.4	130.7	10.0	145.8	22.4	-15.0	97.6	32	394.9
2015	38.8	312.3	10.6	197.5	28.2	114.8	117.7	38	944.6
2020	42.8	519.4	11.8	253.5	30.9	265.9	130.3	42	1,574.8
2025	45.4	740.9	13.1	316.5	32.3	424.4	138.6	45	2,250.0
2030	48.9	978.2	14.0	384.5	35.0	593.7	149.5	49	2,974.7

Source: IEA Appliance Stock Model (electrical end-uses only)

A reality check: are energy-efficient appliances more expensive?

When selecting the least life-cycle cost level to set a minimum energy efficiency requirement for a given range of appliances, the policy-makers accept the idea that the appliance will indeed be priced a little higher when the end-consumer purchases it. As the energy savings will compensate, sometimes largely, the extra incremental cost for purchasing a more energy-efficient model, it is reasonable to believe that the policy gets closer to an optimal market economy. But, in practice, are the models, which are becoming more energy-efficient under the policy, more expensive on the market place?

The predicted cost-effective efficiency gains in residential appliances do not need to come at the expense of functionality, desirable features or significantly higher purchase costs.

For example, in the US, market data are regularly published on the average retail price of products sold in a given year (LBNL 2002). This is the case for domestic refrigerators, freezers, room air-conditioners, washing machines, clothes dryers and dishwashers. All these families of appliances are covered with US Department of Energy energy efficiency standards. Even when adjusted for inflation, the industry data show considerable decline in the average retail price between 1985 and the late 1990s. Such a trend is verified for all the above products. For refrigerators, the study shows that standards did not appear to have changed the historical rate of decline in refrigerator prices; that there was no decrease in refrigerator or freezer volume (a proxy for service quality, since refrigeration performance is in any case assured through standards). Also, there is no simple relationship between efficiency and cost – sometimes greater efficiency costs more, for example when heat pumps are used to replace electric resistance heating, but sometimes it costs less through better design, system-wide savings, material or other savings. In addition, the “efficiency” investment may in fact be triggered for other reasons – typically higher productivity or product/service quality and/or lower costs – with efficiency gains being realised almost as a side-benefit.

In the UK, Schiellerup (2001) investigated the effectiveness of the minimum energy efficiency standards on cold appliances on the British market. Data availability on developments in the cold appliance market in Britain is very good compared to most other EU markets and has permitted an unbroken quarterly analysis since 1995. Significant reduction in energy consumption have been measured as a result of the minimum energy efficiency standards enforced in September 1999 in a context of falling retail prices.

In Australia, redesigning a dishwasher has not made it more expensive

In the late 1990s, Australian dishwasher manufacturer Dishlex was looking for a new image in the marketplace. Their products were being outclassed in the marketplace on energy and water efficiency, noise and consumer appeal. By working with a local university team, RMIT's Centre for Design, a new product range with the maximum six star energy rating under Australia's energy label and AAA water-efficiency rating was developed.

The Centre for Design applied an innovative process called *EcoRedesign* to the dishwasher. A multidisciplinary team was established to work with the company's development team. Life-cycle analysis indicated that operational energy and water use were the dominant impacts of a dishwasher.

By revising pipe diameters and lengths, minimising sump volumes and pump volumes, the quantity of water per fill was reduced to less than 4.5 litres, achieving less than 18 litres per standard wash programme. A computer model was developed to simulate the operation of the dishwasher on a minute-by-minute basis. This facilitated rapid evaluation of the effects of changes such as heating element wattage, insulation, mass of components and materials, and so on. This model avoided many months of prototype construction and testing, and facilitated optimisation of performance. Other members of the design team identified and designed-out sources of noise, improved filter performance and developed the cabinet design.

Overall the new dishwasher is manufactured and marketed at a cost similar to the much less efficient model it replaced. The new product range has proved to be an outstanding market success, with a major consumer association declaring one model its "best buy".

Source: Alan Pears, Senior Research Associate, Centre for Design, RMIT University, Melbourne.

POLICIES WHICH CAN BRING ABOUT COST-OPTIMISED EFFICIENCY GAINS

In theory, there are a raft of policy measure which could bring about the same outcome as projected in the Least Life-Cycle Cost efficiency levels from 2005 scenario (Figure 3.14). These include: MEPS, VAs, fleet average or CAFE standard mandatory requirements or VAs, procurement programmes such as Energy+ or SERP, fiscal incentives such as reduced VAT for efficient equipment, energy labelling (either mandatory comparative labelling such as the EU's labelling scheme, or voluntary endorsement energy labelling such as the Energy Star or both), building codes, utility or government sponsored rebate schemes, government sponsored retrofit programmes, training, awareness building campaigns, etc.

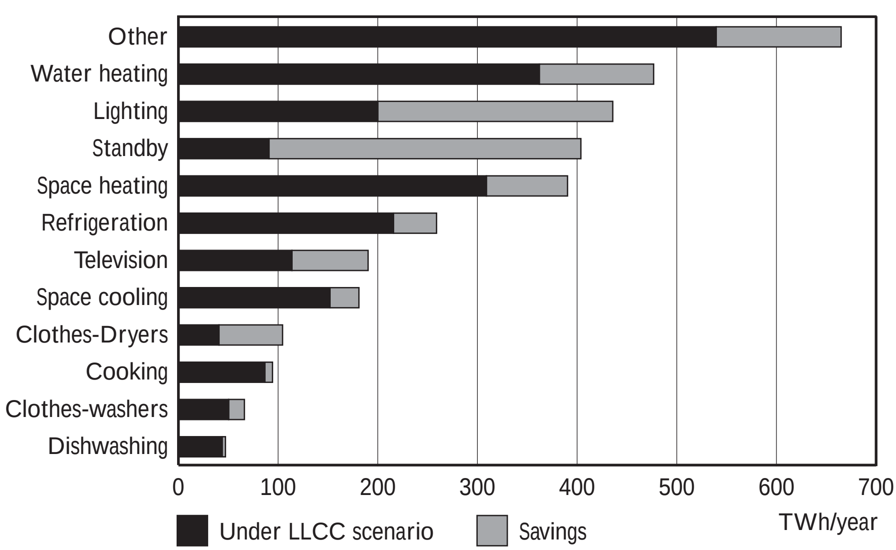
The most certain and most proven outcome is offered by MEPs. If these were set at the least life-cycle cost efficiency level, then all new products sold after the enforcement date would be at the least life-cycle cost efficiency level or better. This would bring about the forecast savings or better for all the household appliances including refrigerators, freezers, dishwashers, washing machines, clothes dryers, TVs, cooking appliances, space cooling appliances and other uses. In theory, the same result (i.e. that the average efficiency of products sold after a certain date is at the least life-cycle cost efficiency level or better) could be obtained through negotiated voluntary agreements with industry. However, in this case there is less certainty of outcome for the following reasons: it is difficult to negotiate an agreement with the entire industrial sector as there are often significant elements of industry that lie outside the main trade association; it is very difficult to negotiate voluntary agreements of the required stringency; voluntary agreements are legally non-binding; monitoring and enforcement of the terms of voluntary agreements is inherently more difficult than for MEPS, especially if the VA involves a fleet-average efficiency target.

In practice, a fleet-average new product efficiency at the least life-cycle cost level could be obtained by setting MEPS at a level just below the LLCC efficiency level and by introducing complementary policies to encourage some products to attain higher than the legal minimum efficiency level. These could include labelling, procurement, fiscal measures, rebates, information and awareness campaigns, etc. For some key end-uses, however, conventional MEPS are not likely to provide the same outcome as projected in the Least Life-Cycle Cost efficiency levels from 2005 scenario. This is the case for water heating, lighting and space heating. For water heating, the Least Life-Cycle Cost efficiency levels from 2005 scenario assumes that heat pump water heaters are used in all new cases where it is technically and economically justified from 2005 onwards. In practice, it is not economically justified to use a heat pump water heater when the primary source of space heating is electric resistance heating and the heat pump draws energy from the ambient space round the water heater, which is the most common type of heat pump water heater. If gas is the primary space heating fuel, then it is economically justified to use a heat pump water heater. Under these circumstances, there should be a requirement in the building codes for all new electric water heaters in homes with non-electric space heating to have an efficiency level consistent with a heat pump water heater. This would achieve results similar to those in the Least Life-Cycle Cost efficiency levels from 2005 scenario.

In the case of electric space heating, the Least Life-Cycle Cost efficiency levels from 2005 scenario assumes that a high proportion of electric resistance space heating is replaced by electric heat pump systems, which could be either air-source or ground-source systems, from 2005 to 2010. The replacement is undertaken through a major retrofit programme. To be fully effective, such a programme would need to be legally enshrined, probably via a revision to the building codes, in a manner that would specify the circumstances in which an electric resistance heating system should be replaced by electric heat pump heating or an alternative non-electric heating system. The same regulations could establish a time-frame for compliance and could set out the mechanism by which the existing heating system would be replaced. It is possible to imagine an environment where the retrofitting cost is advanced by the state at no or low interest but the home owner or occupier is required to pay off annual instalments set at a level commensurate with the calculated value of the energy savings. Many possible variations around this concept that could produce the same outcome are conceivable.

Lighting is perhaps the most difficult end-use to attain the savings projected in the Least Life-Cycle Cost efficiency levels from 2005 scenario because of the assumption that all incandescent lamps which are used on average for an hour a day or more and which have fittings that are compatible with the use of compact fluorescent lamps (CFLs) are substituted by CFLs between 2004 and 2007. At one extreme, a similar result could be obtained by prohibiting the sale of lamps with an efficiency of less than that of a typical CFL; however, in this case many residents would be obliged to change their lamp fittings, the average pay back period of the measure would be much longer (as it applies equally to lamps which typically operate for less than an hour a day and to those which are operated for longer) and there would be some aesthetic consequences which might be unpopular. As this may be a step too far for many regulators, it is unlikely that MEPS would be countenanced that would prohibit whole classes of products from sale. Some of the same effects could be attained by a vigorous and well organised awareness campaign linked to a state-sponsored retrofit programme. It is possible to conceive different levels of intervention and support which could be more or less costly but more or less certain in their outcomes. In one scenario, an energy-auditor could visit a property and manually substitute CFLs for incandescent lamps in the most promising spaces with agreement from the home owner. The cost of this could be born through a small domestic energy consumption tax levied on the domestic energy bill.

Figure 3.14 **Projected IEA electricity savings by end-use for the Least Life-Cycle Cost efficiency scenario compared with the Current Policies scenario in 2030**



Such a measure might be combined with a general energy audit and could be just one of a portfolio of energy efficiency actions that would be included with the audit thereby increasing the impact and cost-effectiveness of the action. There are many other potential policy measures that could bring about some of the same results.

A different but complementary result to the IEA World Energy Outlook's alternative scenario

In September 2002, the IEA released the new edition of its *World Energy Outlook* (WEO) which provides projections of global trends in energy supply and demand, trade and investment and carbon dioxide emission (WEO 2002). A chapter is dedicated to the analysis of an alternative policy scenario compared to the reference policy scenario. This alternative policy scenario analyses the impact on the energy markets, fuel consumption and energy-related CO_2 emissions of policies and measures that OECD countries are currently considering to reduce their greenhouse gas emissions. The stock model portions of both the present *Cool Appliances* and WEO analyses are grounded on the same primary references concerning detailed end-use energy demand in the OECD residential sector. The references listed at the end of each chapter of the present publication include all the sources used for the WEO alternate scenario. In *Cool Appliances*, the energy demand in the residential sector for the OECD Asia Pacific region is taken directly from the WEO data source. However, the WEO alternative scenario is not strictly comparable with the analysis presented here. The level of energy savings is more modest in the *World Energy Outlook* than in the present analysis, as this later explores the impact of bringing each individual electricity end-use in the OECD residential electricity to its least life-cycle cost level.

Comparison with other scenarios

The current publication offers a unique IEA-wide picture of electricity reduction in the residential sector. However, the findings disaggregated to the level of a country or of a group of countries (like the European Union) can be compared with existing policy scenarios. As most of the data used in the present analysis come from existing published source of information, it is not surprising that our scenarios are in close agreement with key references such as: *Scenarios for a Clean Energy Future* (CEF 2000), *Realized and Prospective Impacts of U.S. Energy Efficiency Standards for Residential Appliances* (LBNL 2002), *European Climate Change Programme* (ECCP 2002).

LESSONS LEARNED AND APPLIANCE POLICIES DESIGN

KEY MESSAGES OF CHAPTER

- *There is significant variation in the coverage, stringency, design and implementation of appliance policy.*
- *A comprehensive basket of policies supported by an active and effective institutional framework, with voluntary and partnership measures building upon a solid foundation of minimum energy performance standards and labelling, is likely to be the most effective approach.*
- *Different policies may be required for different end-uses and markets, therefore policy must always be designed on the basis of real market information.*

This chapter draws the lessons learned from both existing policies and projected savings obtained with the model developed in the previous section. It presents an attempt to design an optimal appliance policy.

THE 3 Es AND THEIR TECHNOLOGY AND MARKET COROLLARIES

Energy efficiency[16] has long been a central pillar of many governments' energy strategies, because it advances each of the principal "3E" policy goals: energy security, economic development and environmental protection. Energy-efficient appliances in particular help:

16. Energy conservation, a similar but distinct concept connoting some degree of austerity however mild, was used to help counter the oil disruptions of the 1970s, but is in general disfavour at present. Energy conservation *refers to energy savings associated with reduced energy service, such as less comfortable room temperatures, smaller refrigerators or dimmer lights.* Energy efficiency *refers to energy savings associated with improved technologies that allow energy savings with no reduction in energy service.*

- Reduce the need for new power plants and transmission lines – saving capital expenses, avoiding siting problems and improving system reliability *(energy security)*.
- Save consumers money through reduced utility bills *(economic development)*.
- Combat climate change and other environmental effects of energy production and use *(environmental protection)*.

While the 3Es provide the overall political impetus for appliance policies, the day-to-day design and application of such policies is usually guided by more concrete technology and market aims. Among the more common are:

- Technology Corollaries
- Increased share of energy-efficient appliances in use, more purchases of energy-efficient appliances, and more rapid retirement of less-efficient appliances.
- Increased appliance maintenance to combat degradation of actual operating efficiency levels.
- Wider prevalence of behaviour patterns that support energy-efficient operation of appliances.
- More rational design of appliance systems, such as reduced over-sizing of heating, air-conditioning and ventilation equipment.
- Market Corollaries
- Increased presence of energy-efficient appliances on market.
- Reduced marginal costs (differences) between standard and energy-efficient appliances.
- Greater informational and promotional support for the purchase of energy-efficient appliances.
- Increased incentives for institutional buyers to purchase energy-efficient appliances.

These "intermediate" technology and market goals divide up the work of saving energy into more manageable tasks. They reflect the many facets of saving energy and reducing carbon emissions through more efficient appliances. Since no policy, not even higher energy prices, can achieve all of these goals alone, it is necessary to implement *packages* of policies. This gives rise to another challenge, that of achieving *coherence* (or consistency) between the various policies. A certain degree of coherence is necessary to keep the various policies *efficient*, that is acting in a mutually supportive manner with little or no waste of effort and resources.

The technology and market goals are vital for the conceptualisation and implementation of appliance policies, but are also important for their evaluation. They are useful proxies for measuring the success of policies. However, the correlation between these proxies and the real goals of energy savings must be continually monitored.

APPLIANCE EFFICIENCY POLICY AND THE PRODUCT LIFE-CYCLE

Appliance efficiency policies can hypothetically target four distinct elements in the life-cycle of appliances, namely: 1) purchasing, 2) manufacturing and marketing, 3) retirement, and 4) use and maintenance. In practice, most large-scale appliance policies target consumers' purchasing decisions, and, consequently, the manufacturers' production and marketing decisions. The goal is to persuade consumers to buy more efficient appliance models and to encourage manufacturers to offer still more efficient models. The "after-market" elements of retirement, use and maintenance receive somewhat less policy attention.

Purchasing

The purchase decision is an especially critical point in the product cycle for influencing energy efficiency. A certain portion of energy savings potential is on the line with each purchase. Afterwards, the savings or lack thereof are locked in for the life of the product.

Many policies seek to encourage consumers to purchase products with a level of energy efficiency that balances extra first costs with energy savings in a manner commensurate with their other investments. In some cases, the goal is to balance these costs in line with "social" investments.

Hypothetically, policies could also be used to counter trends towards product upgrading. That is, to discourage consumers from purchasing evermore energy-intensive products, such as bigger refrigerators, bigger televisions, etc. However, such policies with their underlying notion of energy conservation are rarely, if ever, used.

Manufacture and marketing

Policies are also directed at encouraging manufacturers to design, build and market more energy-efficient and energy-saving products. There are two aspects to this, acquiring the know-how to produce more efficient products and having enough confidence in the marketability of such products to actually manufacture them. Producers will not build optimally-efficient models if they do not see a large market for these models. General support for R&D addresses only the former issue. Two other strong instruments, regulatory standards and technology procurement, can address both issues.

Retirement – timing and disposition

Most appliance efficiency policies do not address the issue of stock turnover. Nonetheless, there have been programmes to encourage early replacement and retirement of appliances. In some cases, as appliances get older and less efficient compared with new models on the market, the energy savings associated with replacing the equipment early outweigh the capital savings of delaying purchases.

There is also the issue of what happens to the old appliances. In some cases, they continued to be used and do not leave the stock inventory. In the case of refrigerators, with their continuous operation, the old appliances can represent a large energy demand. There have been many programmes to encourage people to take their old "second" refrigerators out of service.

Use and maintenance

Educating and encouraging consumers to use their appliances in a more efficient manner (at optimal levels for the tasks at hand) is also a potential source of energy savings. There have been education campaigns proclaiming the importance of, among other things, load sizes in dishwashers and detergent use and water temperatures in washing machines.

Additional energy savings can be achieved by keeping appliances in good operating condition. With time and normal wear and tear, appliances operate more and more sub-optimally, consuming more and more energy to do equivalent tasks. An ethic of regular maintenance can reduce the energy losses to out-of-adjustment appliances.

LESSONS LEARNED IN PROGRAMME ADMINISTRATION

Most appliance efficiency policies share some common elements. Essentially four specific behaviours or outcomes are being targeted. **First**, manufacturers are encouraged to produce and sell, on average, more efficient products. This can include improving the efficiency of specific models and lines, improving the average efficiency of the "basket" of products produced by that manufacturer, and/or producing less of the least efficient products. **Second**, retailers, importers and other "market intermediaries" are encouraged to sell more of the most efficient models, a greater proportion of efficient models and/or less of the inefficient models. **Third**, consumers are encouraged to purchase more efficient models and discouraged from purchasing less efficient models. **Fourth**, consumers (or others) may be encouraged towards specific post-purchase or use behaviours, such as turning off lights and heating in empty rooms, recycling old refrigerators rather than moving them to the garage to keep beer cold, changing set points on space heaters, etc).

Manufacturers

Many appliance manufacturers place considerable emphasis on energy efficiency as an integral part of their product design process. Even without efficiency labelling programmes, manufacturers are aware that their customers do not wish to pay more than necessary in running costs to use an appliance that they purchase. In principle, a more efficient product or appliance is likely to be preferred over a less efficient one, unless the customer is deterred by some other factor. Also, certain long-standing commercial trends, such as miniaturisation, materials replacement, electronic controls, portability (in some cases) have tended towards gradually increasing energy efficiency with successive models.

At the same time, appliance manufacturers respond to other consumer preferences, such as improved performance and functionality, increased reliability, lower price, in some cases including instructions that reduce efficiency or increase total energy use. Certain appliances, such as refrigerators and freezers, have tended to become larger over the years. Remote controls, electronic displays, sensors, timing devices and specific features such as auto-defrost on refrigerators and freezers, have tended to increase power consumption, in some cases even when the appliance is in “off” or “standby” mode.

In effect, manufacturers receive complex signals from customers, some of which tend towards increased efficiency and some in the opposite direction. Manufacturers must somehow respond to all these signals, while at the same time battling to maintain or increase their own market share and profitability, including through product innovation, productivity gains in the manufacturing process, cost-cutting and innovative marketing strategies.

What factors then influence how much emphasis a manufacturer places on energy efficiency within this complex and noisy commercial environment? How tractable are these factors to different policy approaches?

Demanding customers

Appliance manufacturers, like other businesses, do respond to their customers’ wishes. Strategies designed to increase the awareness of the general public (appliance purchasers) of energy efficiency, climate change and related issues – including public awareness campaigns, energy information services, efficiency labelling, etc. – will tend to focus manufacturers on the need to compete actively in the efficiency stakes. Demanding customers can also be organised customers, such as government procurement schemes. Policies designed to encourage customers to be more demanding, at least with respect to energy efficiency, are covered in more detail in the section on Customers below.

To be effective, these programmes should be designed and managed in close collaboration with the industry concerned, together with other interests such as consumer groups. A strong rapport between the agency administering such programmes and the industry can trigger a virtuous spiral of continuous improvement in efficiency, as manufacturers use the endorsement value of the government programme to steal a march over their competitors. As with labelling programmes, the underlying "currency" that gives value to these policy approaches is the credibility and independence of the "judge" (typically the national energy agency).

Lessons learned with these types of programmes include a need for strict attention to due process, including open access to all market participants, avoiding conflict of interest (for example in product assessment or "judging" processes), and objective performance criteria and assessment processes (often drawing on regulatory requirements elsewhere, such as for labelling or MEPS assessments). Also, such awards processes, to be effective, must be maintained over time, both to provide reasonable certainty that an effort to improve product efficiency will in fact be "rewarded" over time, for example, in a future awards round. In a more subtle way, awards ceremonies, if regular, can become part of the annual planning calendar of an industry and provide a specific focus for innovation, launch of new products, etc. Further, since the essential incentive mechanism for the businesses is recognition, such programmes should involve a high media profile, adequate opportunities for corporate and product media exposure, strong expressions of political support (for example, senior political involvement in awards ceremonies), and finally, an element of fizz and fun, to make sure that the participants want to come back and do better next year.

Product efficiency labelling, while primarily a tool to influence consumer behaviour, can and should also become an important focus for manufacturers. If labels are considered simply as a regulatory cost burden upon business, then manufacturers may be inclined to lobby for their removal. This might happen for example in the following cases:

- If labels became out of date (e.g. with most products "crowding" towards the top of the label range over time and therefore no useful information being conveyed).
- If changes to the label format or other programme design features were made without adequate consultation or if compliance costs become unnecessarily high, perhaps through excessive disclosure or testing requirements.
- Most importantly, if the label fails to adequately communicate the difference between an efficient and inefficient appliance in a way that enables product differentiation to occur, or if too many types of labels are used such that the "brand recognition" of any one label remains low.

Also, labelling programmes must be able to keep up with the rate of commercial innovation (for example, new product types or derivatives for which standard performance assessment procedures may not be appropriate) if manufacturers are to continue to see them as valuable endorsements.

As with reward and recognition programmes above, so too with labelling programmes it is critical that the underlying integrity of the programme be beyond reproach. If labelling algorithms become outdated, or if an unlabelled or mislabelled product is allowed to be marketed, the industry may well quickly become disenchanted with this policy approach. Finally, manufacturers may also not support programmes which are piecemeal, and where, for example, they are required to label, but no supporting information is available to retailers or consumers regarding the meaning and interpretation of labels (see below).

A competitive market

Competition conditions have pervasive influences on the behaviour of businesses. Where there is limited competition in a given market segment, efficiency, along with other performance characteristics, is likely to suffer, or at least improve more slowly, than in a more dynamic, competitive market. The presence or absence of domestic manufacturers may be an important factor in this regard, but importers and retailers can also create more or less competitive conditions and influence manufacturer behaviour (see section on Market Intermediaries below), particularly when import barriers are low or non-existent. Pro-competitive policies can include industry development assistance, technology transfer programmes, careful attention to the removal of entry/exit barriers, business incubators/start-up support, targeted market development measures, including support for risk capital, R&D and commercialisation, etc.

Governments are often important buyers in certain market segments, and therefore the specific purchasing behaviours of governments and their agencies can have significant and market-wide impacts. Conversely, a lack of coherence in government policy/purchasing practices can send confusing signals to manufacturers and hold back innovation and risk-taking. Specification of major government contracts in performance/outcome based terms (including, of course, improved energy efficiency performance), awarding contracts to multiple suppliers where possible, sequential competition (re-tendering at regular intervals) will all tend to encourage greater competition over time.

Encouraging innovation and managing risk

Policy settings towards the innovation process generally, such as the taxation treatment of R&D expenditure and the availability of risk capital, will influence the rate of innovation in energy efficiency. However, specific initiatives that reward specific "behaviours" or outcomes may be particularly effective in encouraging competition between manufacturers on the efficiency of their products, even though they may involve little direct cost and only mild intervention in markets. Policies such as awards, competitions, corporate/product recognition or promotion programmes and efficiency labels may all contribute in a positive way to the marketing efforts of those manufacturers. This helps to explain why, as set out in Chapter 2, many IEA Member countries run such programmes.

Green consumers = green manufacturers

Green consumerism is a well-recognised and commercially important trend. Manufacturers who can respond to consumers' desires for cleaner, greener products – including those that consume less energy – are increasingly successful commercially. Programmes that reward and encourage both green consumerism and strong statements of "green" corporate culture will tend to reinforce this trend. These can include information programmes, product labelling, awards and other reward/recognition programmes, accreditation initiatives (ISO 14000 and related initiatives), through to corporate reporting and disclosure policies that encourage "triple bottom line" accounting. Government leadership in these areas (or a notable lack thereof) can also have impacts on manufacturers' behaviour.

Manufacturers responding to these signals from customers and/or governments will typically demand coherence and integration across government initiatives, including those that straddle agencies and departments. That is, the issues of energy efficiency, recyclability or product stewardship, water or other resource consumption, waste reduction initiatives, should be managed or packaged in a coherent manner – no small challenge for government when these issues are often the responsibility of different agencies and/or different levels of government, sometimes with poor institutional links between them. A product festooned with different, unrelated labels, for example, is likely simply to confuse customers and diminish the effectiveness of them all, as well as increasing costs and the "aggravation factor" for manufacturers. Joint or collaborative initiatives covering these "green" attributes, including energy efficiency, may be more effective and less costly for all involved.

Market intermediaries

Depending on the nature of the market for specific products and appliances, market intermediaries (including franchisees, wholesalers, retailers, importers and local planning bodies) may have a very great influence over the final efficiency outcome implicit in consumer decisions. Intermediaries can influence consumers' awareness of efficiency options, access to efficient technologies, purchasing behaviour and even product usage or maintenance regimes.

First, stemming from the fact documented in Chapter 2 that there are real search costs for consumers, the decisions that market intermediaries make with respect to the range of products available to consumers are critical. Some consumers will spend days searching for specific performance characteristics or features and carefully comparing efficiency as well as price and other product characteristics. But many will not and at best they may choose the most efficient model of those immediately available.

Domestic hot water heaters are perhaps a case in point. In many cases, consumers do not consciously decide what form or model of water heater they purchase. That is, if they purchase an existing home, it will come complete with a hot water service that is unlikely to be replaced until it breaks down. Even when buying a new home, consumers may have no or limited opportunity to choose the water service, particularly if it is a project home where the developer may make such decisions. Second, if the service being purchased is a replacement service, the key requirement of the purchasers may be speed of installation, the physical dimensions of the space available for the service, the availability or non-availability of different fuel options (e.g. natural gas compared to electricity). If your hot water service begins leaking water into the roof of your house and there will be cold showers the next day, choosing the most efficient heater is not likely to be uppermost in your mind. You are very likely to accept whatever replacement model the plumber brings in the back of his van. Even if both the customer and the installer are aware of more efficient options, but there would be a delay involved in their delivery installation, they will very often not be chosen.

In effect, the market intermediary, not the final consumer, may be “sovereign” in the decision-making process over a water heater, even though hot water heating is a major energy end-use in the home. While this may be an extreme example, the advice provided to consumers by intermediaries regarding product performance, reliability and availability, or even basic factors such as the location of certain products relative to others within a shop or showroom, can have a major influence on consumers' purchasing decisions. Retailers may not be sufficiently well informed to be able to answer questions with respect to the relative efficiency of different models, the other performance characteristics of those models, or the interpretation of government or industry label or marks. In some cases, the availability of more efficient products may be affected by commercial arrangements between manufacturers, distributors and/or retailers. Some types of franchise agreements for particular technologies can have the effect of reducing their availability and increasing their price, for example.

From the intermediary's perspective, if there is not yet a large or sophisticated market for high-efficiency products, they will not wish to carry the inventory risk or overheads associated with perhaps high-cost, small-volume products. Some may take the view that it is not their role to educate consumers and argue that if the customer wanted more efficient products, they would ask for them.

The lessons for policy-makers include, at a minimum, the need to give adequate support to labelling, endorsement or other efficiency policies with appropriate point-of-sale materials, training and back-up information (e.g. comparative efficiency assessments located on Web sites). Beyond this, a similar range of reward/incentive programmes discussed above for manufacturers can also be effective for market intermediaries, including awards and endorsements ("appliance efficiency retailer of the year"), but also targeted investments or joint promotions (for example, assistance to set up an "efficiency corner or aisle" in a generalised product store). In the case of stronger market barriers, such as competition constraints or inadequate consumer access to efficient products, voluntary programmes with intermediaries, investment incentives for new entrants, collective or organised purchasing and procurement initiatives, all the way through to competition law remedies, may be explored.

Consumer purchasing decisions

A key lesson learned with respect to the consumer is that point-of-sale information on comparative energy efficiency, and perhaps energy operating costs, can be highly effective. To be useful, the information must be easy to interpret and apply. Energy efficiency labels can be a key instrument in affecting consumer choices when those choices are being made. Of course, labels are not sufficient on their own. While there is some evidence that consumers may respond positively to labels and purchase higher rated machines even without fully understanding the meaning of the labels (for example, they may be treated as a quality mark or endorsement label, regardless of their intended meaning), more often consumers will demand that such point-of-sale information is easily comprehensible and supplied from a source that is independent of the manufacturer and retailer. Government, or government-certified, information programmes often have a credibility factor that commercial information sources cannot emulate.

Since sales staff in appliance stores are a consumer's first point of reference, it is important that those staff are themselves well-informed with respect to the labels. Some basic training of sales staff is advisable, preferably on-site and in a manner that corresponds to the needs of the business; the ready availability of more in-depth explanatory brochures, Web sites, information hot-lines or other information support services is also vital.

Notwithstanding the importance of point-of-sale information, in some cases, for example major white goods, consumers may often prepare for a purchasing decision by reading magazines or advertisements and by referring to Web sites or other information sources. This research may have a major influence on the ultimate decision of the consumer. It may therefore be advisable for communication managers to team up with influential consumer interest groups, lifestyle magazines and programmes, to produce and publicise efficiency and related information.

Since many consumers will value not only energy efficiency, but other "green" performance characteristics of an appliance, it can be effective to present efficiency rating information with other environment or resource use information, such as water consumption, recyclability, noise levels, etc.

A more complex issue arises with respect to the extent to which product classes are segmented for labelling purposes, for example by size or type (e.g. top-loader versus front-loader washing machines; small versus large refrigerators). Industry typically argues for a fine distinction of one product type or size from another, for example arguing that the different products appeal to different buyers, or buyers with specific needs or budgets, and that therefore specific labelling algorithms are needed for each.

Principal energy efficiency policies for residential appliances and equipment

Information and awareness raising

Information and promotional activities – such as energy cost estimation guides, product directories and awareness raising campaigns – are the most basic methods used to encourage appliance efficiency. They help raise the profile of energy efficiency in consumers' purchase decisions and give manufacturers the incentive to produce more efficient appliances. Though they can be used alone, they are frequently, and most usefully, coupled with other policies such as labels, procurement competitions and financial incentives.

Labels

Labels are markings, with supporting directories and promotional materials, which show appliances' energy use or efficiency according to a common measure and testing methodology. They alert and inform consumers to the energy use, energy costs and environmental consequences of their purchase decisions. They are also used to underpin other programmes, such as MEPS, procurement activities and financial incentives. There are three major types of labels. *Comparison labels* indicate the energy efficiency of a particular model relative to similar models on the market and are usually, though not always, mandatory. *Endorsement labels* (or quality marks), affixed only on models meeting or exceeding a certain efficiency level, indicate by their presence models of superior energy efficiency. They show the top of the market (in efficiency terms) explicitly. Endorsement labels are, by definition, voluntary. *Ecolabels* indicate multiple environmental parameters – such as noise, water use, and energy use – associated with the manufacture, use and disposal of products.

MEPS and voluntary energy efficiency targets

Minimum energy performance standards (MEPS) are regulatory programmes stipulating the minimum efficiency levels or maximum energy-use levels acceptable for products sold in a particular country or region. Targets are similar, but commonly refer to voluntary agreement between the industry and government. In some countries, the minimum efficiency levels in MEPS and targets are dictated by what is technically and economically feasible. In others, they are negotiated incremental improvements based on existing products. Though MEPS and targets are usually applied to all products on a given market, they can also by applied according to market-wide averages or a manufacturer-based (fleet) average.

Procurement programmes and competitions

Large organisations (such as military housing agencies, low-income housing authorities and homeowner associations) often have procurement programmes to increase the efficiency of appliances installed in their residences. The large number of appliances purchased means that the information gathering and processing costs for each individual appliance are much lower than for a typical household. Moreover, these organisations can obtain attractive borrowing terms and large price discounts that further increase the financial attractiveness of energy-efficient appliances. Going a step further, these organisations and utilities sometimes conduct technology procurement competitions, using their purchasing power explicitly to influence manufacturers to develop and market more efficient appliances.

Financial incentives

There is a variety of programmes that offer financial incentives to consumers to purchase energy-efficient appliances and retire older appliances. The most common incentive is the rebate, which acts as a sort of financial endorsement of a product's energy-efficiency attributes (and by association, general quality). Financial incentive programmes were particularly popular in the 1980s and 1990s, being offered as part of demand-side management (DSM) initiatives implemented by utilities and local and state/provincial authorities. These programmes are still used, though less frequently in North America more frequently in the European Union and with different operating parameters, in today's more competitive electricity markets.

RATIONALES FOR POLICY AMBITION

Appliance policy-making is not simply a matter of promoting efficient versus inefficient appliances. Rather it involves balancing issues of technology availability, cost-effectiveness, market structures and product development timeframes, as well as cultural preferences and their amenability to change. In practice, appliance policies balance these characteristics in various manners and thus aspire to different levels of energy efficiency improvement. Some policies seek to improve only the least efficient models; others attempt to improve all new models. In some instances, the goal is to attain efficiency levels higher than in any current commercially available product. At present, however, no policy is so ambitious as to offset fully the growth in appliance ownership and use, thus resulting in absolute decreases in energy consumption and carbon emissions *levels*. Current appliance policies only lower appliance energy consumption and carbon emissions *growth rates*.

Certainly, the ambitiousness (or stringency) of real-world appliance policies ultimately reflects the political power of the various stakeholders involved (realpolitik). However, in the policy development process, governments usually set out rationales that frame the concept of efficiency ambition within a solid analytical framework. These rationales provide working rules for the design and conduct of programmes. They help establish economical, as well as ideological, coherence among policies.

Commonly, the rationales follow four themes:

- Life-cycle cost (LCC) reduction/minimisation.
- Correcting market failures and overcoming market barriers.
- Best practice (global and local).
- Simple percentage improvement targets.

Life-Cycle Cost (LCC) reduction/minimisation

Many policies are aimed at reducing the costs of appliance use to consumers, and to society more generally. First, by helping consumers to recognise which appliance models are the most economical (representing their best financial interests) and to make their purchases accordingly. And second, by encouraging manufacturers to produce and promote still more economical and efficient models at reasonable costs.

The efficiency levels at which LCCs are minimised depend heavily on the design options that are considered and their associated cost. discount rates and energy prices are the other factors. Though LCC calculations could be made using many different combination of these factors, there are four major levels (in order of increasing efficiency) that policies seek, or could seek, to attain. These are illustrated in the following table.

Table 4.1 **The four possible levels to set energy efficiency standards based on a least-life cycle cost analysis**

	Level 0 ***status quo***	**Level 1** ***status quo, plus***	**Level 2** ***level 1, plus***	**Level 3** ***Level 2, plus***	**Level 4** ***level 3, plus***
Discount rate	Implicit	Personal		Social	
Commercial availability	Available		Viable		
Energy prices	Existing				Full Cost

Level 1

The goal of Level 1 cost reduction is to minimise consumers' costs of purchasing and using appliances, given commercially available technologies, personal discount rates and existing energy prices. This is commonly referred to as narrowing the “energy-efficiency gap”, the discrepancy between the energy-efficiency of appliances actually purchased and that of the most cost-effective ones available. Consumers consistently purchase appliance models that are less economical and less efficient (compared with others on the market) than is in their best financial interest. The various reasons for this phenomenon are discussed in the section on market barriers below. Significant energy savings can be achieved when consumers choose models where energy savings are balanced against additional first costs in a manner commensurate with their other investments.

In this regard, energy efficiency can be viewed as a personal investment. Typically, energy-efficient appliance models cost more than standard models. As with investments generally, a consumer must decide whether the additional cost (capital) of an efficient model is worth the resulting energy savings (returns). The trade-off is often discussed in investment terms, such as payback periods, break-even points, cost-effectiveness and internal rates of return.

There are, however, several important differences between energy efficiency investments and financial ones. First, appliance consumers may not always realise that they are being asked to make an investment. Energy efficiency is a hidden attribute of appliances, which even labels cannot fully overcome. Actually without labelling consumers usually have no means of knowing the relative energy performance of appliances. Even with labelling they only know the performance under standard test conditions. Second, because energy savings from a particular appliance are difficult to discern on an energy bill, and are dependent on behavioural characteristics (which can vary unexpectedly), there is always some uncertainty about the level of actual energy savings to be realised. Third, energy efficiency cannot be purchased separately. It is bundled with all the other attributes of an appliance, and consumers cannot purchase as much of it or as little of it as they wish without making compromises in other features of the product they desire. Fourth, efficient appliances are not always widely available or even yet commercialised, and there can be significant search costs involved in finding them.

Because of these complications, consumers consistently purchase appliances that are less efficient than optimal (in cost-effective terms).

Level 1 appliance policies seek to get consumers to invest in energy efficiency at discount rates more typical of their other financial investments. Typically labelling and other awareness and information programmes seek to give consumers the information they need to recognise their best financial interests. Another Level 1 policy is mild minimum efficiency standards. That is, standards that ban only the very least efficient, most uneconomical models from the market. These kinds of standards typically do not fully achieve the goal of cost minimisation for all consumers, they just reduce the costs for a portion of consumers. In a sense, they are “introductory” standards employed to get the market used to the idea.

Level 2

Because consumers undervalue energy efficiency in their purchases, manufacturers under produce efficiency. Level 2 policies, such as MEPS and targets, are used to encourage manufacturers to improve the efficiency of the models they offer. The goal is to raise the efficiency to a level where consumers’ costs are minimised as calculated by engineering-economic analyses of the marginal costs and benefits of individual energy efficiency features of appliances. These analyses are carried out as part of MEPS programmes in some countries (most notably the United States). In some cases, the calculations have shown that appliances more efficient than any on the market are commercially viable and in consumers’ best financial interest.

Level 3

The goal of Level 3 policies is to raise appliance efficiencies to levels where social costs are minimised. That is, where the costs of using appliances are balanced against the costs of building new power plants to meet their increased load. Energy savings are balanced against additional first costs in a manner commensurate with social, not personal, discount rates. To date, no appliance policies have actually achieved full cost minimisation at this level. However, the idea underpinned much of the utility-led efficiency programmes carried out under demand-side management (DSM)/integrated resource planning (IRP) activities.

Level 4

A still higher level of cost-minimisation can be imagined, that calculated upon full-cost energy prices. If energy prices correctly reflected their environmental and social externalities, the costs of purchasing and operating appliances would be minimised at higher efficiency levels.

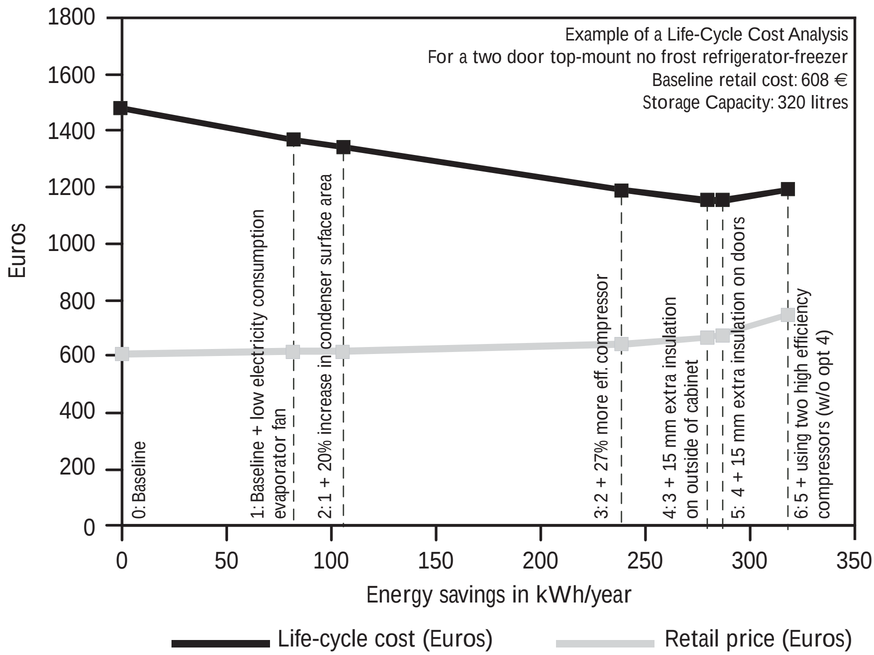
No appliance policies based on the Level 4 definition of cost minimisation have been implemented. However, the idea could provide the rationale for intervention if governments decided to address climate change and other energy demand related problems without implementing full-cost energy pricing. Full-cost pricing is generally regarded as the best option (from an economics perspective) for improving energy efficiency. However, there has been little political will to impose the taxes or permitting schemes stringent enough to reflect energy's externalities. If pressure mounts to address these problems through energy-demand reductions without full-cost pricing, setting the stringency of appliance programmes based on full-cost energy calculations is one option.

Engineering-economic analysis

Engineering-economic models can help predict the efficiency and cost impacts of any one or combination of design options for particular appliances as seen in Chapter 3 and illustrated with a concrete case in Table 3.4 and Figure 3.8. Engineering-economic models are particularly useful in assessing impacts of appliance design options that do not exist in current markets. Their results can be summarised in LCC curves such as that illustrated in Figure 4.1.

Moving along the curves from left to right downward shows that incorporating the most cost-effective design options lowers appliance life-cycle costs to a minimum. After that, the capital costs of additional efficiency options outweigh the energy cost savings they produce, and the curves turn upward. With a rationale of LCC *minimisation*, efficiency improvements should move to point 5. In comparison, with a rationale of LCC reduction, target efficiency improvement levels can be set anywhere from 0 (status quo) to point 6.

Figure 4.1 **Generalised schema showing the relationship of life-cycle costs, energy efficiency and energy prices**



Correcting market failures and overcoming market barriers

The "energy efficiency gap" mentioned in the previous section appears to be a "free lunch". Its size and causes have been the subject of much contentious debate. Some analysts argue it is large; others say it is non-existent or very small. Some say it exists, but that it results from features found in all markets and that government has a limited role in addressing it. The concepts of market barriers and market failures underlie much of the debate. This book does not attempt to resolve the debates, but is written from the viewpoint that the cost-effective energy savings potential is significant and that governments can be instrumental in seeing that the potential is realised. Given the plethora of appliance programmes that governments in IEA Member countries and elsewhere have adopted, this is not an uncommon view.

In some countries, market barriers and market failures provide the primary rationale for government policies to promote energy-efficient appliances. In other countries, they are secondary to other rationales, but are still used to help guide appliance efficiency policies. They are especially helpful in targeting information, financial assistance and R&D programmes. They are less useful in focusing standards and targets programmes, because of the very wide range of customers, manufacturers and market situations (and consequent market barriers and failures) concerned. The concepts of potential and market failures and barriers are, however, very useful in setting the stringency levels for standards and targets.

A **market barrier** is any factor that explains why technologies, in this case energy-efficient technologies, which appear cost-effective at current prices are not taken up. Barriers can occur all along the product manufacture, distribution and purchase stream, but most attention is directed towards consumers and their purchase decisions. The issue of barriers for consumers centres on the market features (lack of information, lack of capital, etc.) that lead consumers to purchase less energy efficiency than is in their best financial interest. Among the barriers put forward to explain this phenomenon are:

Limited information

Energy-use is a "secondary" and "invisible" characteristic of appliances, and so supplementary information is needed to bring it to the attention of the consumer. Markets fail to disseminate information about products' energy characteristics to the extent that is economically efficient. There are two aspects of this under-supply of information. First, information dissemination is in part a "public good", meaning that providers cannot collect a price from all who use it. Second, there must be enough, easily-obtainable information disseminated to surmount the "threshold" required to start consumers' information gathering efforts.

Limited awareness and interest in energy costs and reducing energy expenses

Not only is energy use a secondary and invisible characteristic, but it is also a "delayed" attribute. An appliance's energy costs, to the extent they can be distinguished in an electricity bill, are only perceived some weeks or months after the purchase. Energy costs are not an immediate concern at the time of purchase. Thus consumers often ignore them in the face of more pressing concerns about products' performance, features and first costs.

Lack of a direct and complete market for energy efficiency

Energy efficiency is not directly sold or purchased, and therefore valued, in any market. In appliance markets, consumers are rarely presented with the opportunity to decide on energy efficiency as an individual attribute, say between two products having identical features except for their energy efficiency. Efficiency is not directly transacted because it is one attribute, present in greater or lesser degrees, among a bundle of other attributes which, taken together comprise the goods or service. In economics, this is known as the problem of indivisibility. Marketing of consumer products including appliances often involves product differentiation, which attempts to build market share by persuading the consumer that Brand X product is not substitutable for Brand Y product, even if the two are functionally identical. Very few markets, if any, are so extensive and diverse that all the sets of attributes that a consumer wishes to purchase are available in a range of products that then vary only with respect to energy efficiency (and price). In effect, each purchasing decision is a compromise which does not necessarily reflect the quantity of efficiency that consumers would like or be willing to purchase.

Transaction costs

Transaction costs are the administrative costs of making and implementing a purchase decision. To the extent that transaction costs are associated with collecting and processing information, there is an overlap between this barrier and information barriers. The transaction costs involved in a new technology can be substantial and, even though they may not be explicitly calculated, decision makers may have a sense of their magnitude and for this reason they can represent an important barrier to investment.

Risk and lack of consumer confidence

Consumers are very much affected by the actual risk and the perceived risk of using a new or unfamiliar technology. At the earliest stage of market penetration, a technology is not yet proven and the costs and benefits of using it are not well-known – it may not work as expected, it may break down, operating and maintenance costs may be higher than promised, or it may be made obsolete by some newer technology.

In addition, past experiences have made both ordinary consumers and more sophisticated decision makers in the business sector wary about the accuracy of forecasts of future energy prices. Calculating the value or payback period of an investment in energy technology also depends on fuel prices.

There can also be a certain distrust of new technologies because of a bad reputation from unsubstantiated claims of early product introductions. Compact fluorescent lamps (CFLs) and heat pumps, for example, had bad reputations in their early periods.

Limited capital and rapid payback requirements

Potential buyers of new energy technologies may find them desirable but still may not buy them because they do not have the necessary funds, or access to a loan at acceptable interest rates. While many appliance purchases are made on credit, it appears that households cannot borrow to finance energy efficiency to an optimal extent. One form of indirect evidence is that most consumers choose to replace an appliance only when it breaks down and cannot be repaired at reasonable cost. Since they are often replacing outdated equipment, this suggests that some people are not taking advantage of all the cost-effective conservation opportunities available to them and this may be because they lack the necessary funds, at least at what they consider to be reasonable interest rates. On the other hand, financial and other institutions argue that interest rates on loans to residential energy investments are high because the true costs of providing them are increased by risk factors in the high administrative costs per dollar associated with small loans to households.

Market organisation, such as separation of expenditure and benefits

This barrier can take several forms depending on the sector involved. For appliances, it most frequently takes the form of a tenant-landlord problem, where neither party pays the full cost of the product. Landlords pay the first costs and tenants pay the energy bills.

Some of these market barriers also involve market failure, in which a barrier exists or is strengthened because the market concerned causes resources to be used inefficiently (that is, the market does not take account of all the costs and benefits involved). The basic theorems of welfare economics state that the allocation of resources will be optimal where:

- A complete set of markets with well-defined property rights exists such that buyers and sellers can exchange assets freely.
- Consumers and producers behave competitively by maximising benefits and minimising costs.
- Market prices are known by all consumers and firms.
- Transaction costs are zero.

Some economists assert that intervention to encourage economic efficiency is only when violations of these conditions lead to four broad types of market failure: incomplete markets, imperfect competition, imperfect information, and asymmetric information. (Adapted from IEA 1997 and Sorrell 2000.)

Simple percentage improvement targets

It is not uncommon, especially when governments are just starting to develop appliance policies, for ambitions to be stated in simple percentage improvement terms. For example, the efficiency of appliance X will be improved by Y%. The origin of these figures is often unclear. They may be based on statistical or engineering-economic analysis, or some other source. Regardless, they take on a life of their own in the form of simple political promises or commitments.

Best practice

The most recent policy rationale is the best practice approach. Here, policy-makers state their appliance efficiency ambitions in terms of: 1) current best available technologies, or 2) current most stringent policies.

Japan uses the best available technology method in its Top-Runner programme. Fleet-average MEPS to be met in a future year are defined by the most energy-efficient model on the current market[17]. In other words, today's best model sets tomorrow's standards.

Australia uses the most stringent policy model. In its standards programme, Australia reviews its major trading partners' MEPS for high energy-consuming appliances and then converts the most stringent ones found into Australian equivalents.

ELEMENTS OF GOOD APPLIANCE EFFICIENCY POLICY

Before examining governments' actual policies in the next chapter, it is worth considering what features distinguish "good" appliance efficiency policy. This discussion, however, must be prefaced by two cautions. First, it is not an attempt to identify best policies. There is no single best policy that works well in all countries or regions, for all appliances and in all market circumstances. Second, no policy embodies all of the elements set out below. There are necessarily tradeoffs. One obvious example is the compromise between keeping data costs low and analytical thoroughness high.

Effectiveness

The foremost measure of good appliance efficiency policy is its effectiveness in saving energy, reducing costs or reducing environmental impacts, or in meeting the various technology and market corollaries outlined earlier.

Policies are only effective to the extent they lead to desired changes that would not have happened anyway. The measurement of policy achievement can be difficult. First, there is the issue of constructing a credible baseline for comparison. This is a hypothetical estimate of what would have happened to appliance efficiency levels, purchasing patterns and use characteristics in the absence of policy. Baselines should not reflect "frozen" efficiency assumptions. Second, there can be interactions between the various factors. The most often discussed is the rebound effect. Rebound refers to the

17. The fleet average is the weighted-average energy efficiency of each manufacturer's and importer's shipments in predefined product categories.

extent to which improvements in energy efficiency cause offsetting energy-use-increasing changes in ownership and behaviour[18].

The great complexity of the technology development, diffusion and implementation process means that no single policy instrument can realistically be expected to deliver all the desired efficiency improvements for a given product. It is therefore necessary to implement packages of multiple policy measures. Also, there must be "coherence" among the measures. That is, the component measures should be integrated and consistent, so that they complement and reinforce each other, and avoid contradicting each other.

The need for coherence extends more broadly, to include integration and consistency with general energy policy, non-energy sectoral policies and the appliance policies of trading partners. For example, appliance policies need to take account of various housing policies and building codes. Efficiency improvements can often be achieved more cost-effectively if there is a degree of policy co-ordination between trading partners. To the extent possible, appliance policies should be co-ordinated among trading partners, or designed so that they can be easily co-ordinated at a later time.

As mentioned, there is no single policy that works best for appliances and in all market, political and cultural circumstances. No size fits all. To be truly effective, policy measures must be tailored to the realities of particular products and their markets. For example, policy measures (such as negotiated agreements) having short administrative lead-times are better than those with long lead-times (regulatory standards) for products whose underlying technology is changing rapidly. Also, standardised testing protocols that underlie many appliance policies should reflect real world product use patterns to the extent possible.

There is a variety of ways to make sure that policies reflect technical and market realities, some work better in some cultures than in others. One way that seems particularly effective is stakeholder consultation to gain a solid understanding of technology and market fundamentals. Consultation acts to increase political and market feasibility, credibility and acceptability.

18. Energy Policy, *Special Issue On the Rebound: the interaction of energy efficiency, energy use and economic activity, guest editor Lee Schipper, June 2000; U.S. Department of Energy, Office of Policy and International Affairs,* The Rebound Effect: A Review of U.S. Literature, *Draft report prepared for IEA Energy Efficiency Working Party, 24 February 1998, IEA/SLT/EC(98)1.*

Appliance policy free-riders and spill-over

Free-riders are market actors who receive programme incentives for undertaking actions (such as purchasing more energy-efficient appliances) that they would have taken even without the incentive. There are many shades of free-riders. With respect to appliance policy, a pure free-rider is a consumer who is aware of the efficient technology promoted by the programme, knows where to purchase it, was planning to buy it soon without any programme influence, and would have installed it at a comparable level of efficiency to that offered by the programme. However, there are also a wide-range of "incremental" or "partial" free-riders who either: 1) were planning to install appliances slightly less efficient than the one promoted through the programme but more efficient than standard practice; 2) would have been willing to install the appliance at a lower financial inducement than the one offered by the programme; or 3) may have installed the appliance on their own without the programme sometime in the future. Costs and benefits associated with both incremental and pure free-ridership should be assessed and included in cost-effectiveness analyses.

Spill-over refers to a variety of indirect impacts stemming from an energy efficiency programme. Spill-over effects can occur through a variety of channels including: 1) a consumer hearing about a programme measure from a participant and deciding to pursue it on his or her own (the so-called free-driver effect); 2) programme participants who undertake additional, but unaided, energy efficiency actions based on positive experience with the programme; 3) manufacturers changing the efficiency of their products, and/or retailers and wholesalers changing the composition of their inventories to reflect the demand for more efficient goods created through the programme; or 4) governments adopting new building codes or appliance standards because of improvements to appliances resulting from an energy efficiency programme.

Excerpt from Daniel M. Violette, "Evaluation, Verification and Performance Measurement of Energy Efficiency Programmes", IEA, 1996.

Costs

For most countries, cost is the second most important element, after effectiveness, of good appliance policy. The private (consumer, manufacturer, distributor, etc.) and public (government and utility) costs should be commensurate with the efficiency improvements achieved. The costs include not only the financial expenditures, but also foregone product amenities. Of course, policy measures with high costs and low results should be avoided.

One cost element that receives particularly close attention is that associated with free-riders, those programme participants who receive some incentive in exchange for doing something (such as purchasing a high efficiency appliance) they would have done anyway. A certain degree of free-ridership is inevitable, but a high rate should be avoided.

On the other hand, there also exist positive spill-over effects from appliance policies. In these cases, consumers or other market actors improve the efficiency consequences of their actions, but receive no policy incentive for doing so. The policy prompts them, but does not reward them, to act in this manner.

Strategic cost-effectiveness

The concepts of effectiveness and costs also embody a relative, strategic element. Some policies may yield cost-effective energy savings, but preclude still greater or less expensive improvements, because of limited policy-making resources. Individual policies should thus reflect an overall strategy for cost-effectiveness. For example, the targeted appliances might be the largest energy users, or those with the highest energy demand growth, or those whose technologies are at key development points.

Priorities should be set with due consideration for the:

- Level of cost-effective energy-saving potential for products (first indications suggest that priorities be given to the largest energy users and those with the highest energy demand growth).
- Trends in product design and product line cycles – when can new energy efficiency features be taken on with minimal marginal cost and disruption?

- Types of measures trading partners are taking.
- Amount of additional analysis needed.
- The ease with which consensus among stakeholders could be achieved (IEA 2000).

Three tasks are indispensable in assessing these issues and developing credible, workable priorities: (1) stakeholder consultation and consensus, (2) market and engineering analysis and (3) a systematic process for integrating stakeholder interests and analytical findings. It is also important that these exercises be carried out in an open, transparent and predictable manner. This helps ensure that programmes are developed in a manner consistent with technical, economic and commercial realities. It also increases the likelihood that stakeholders will support the programme.

Equity

Policies should be designed to distribute costs and benefits in an equitable manner. An example in appliance policy would be that poorer consumers benefit as much as richer consumers. In some cases, a high rate of free-ridership can reflect inequity. If wealthier consumers are using incentives that they really do not need, at the expense of fewer resources for poorer consumers, then the policy is in essence inequitable.

Ancillary effects

Often there are ancillary non-energy effects of appliance policies. Some are foreseen, others are not. Policies should be designed and implemented in a manner that accentuates the positive benefits over the negative ones. Appliance policies should have limited or positive feedback effects on other policy areas (e.g. competition, trade, social welfare) (Pershing and Corfee-Morlot).

For example, many equipment energy efficiency improvements in industry are coupled with productivity improvements. In households, energy efficiency improvements may result in less noise (refrigerators), better lighting quality, etc.

Also, there should be ways of adjusting the policy to deal with unforeseen negative consequences.

Policies should not unduly inhibit technological innovation. However, this should not mean a licence to consider all types of technical designs and behaviour, no matter how wasteful, as potential areas of innovation.

Long-term effectiveness

Policy effectiveness is not a matter of one-time energy savings. Policies should result in "persistent", or lasting, improvements in energy efficiency. In the case of financial incentive programmes, this means that the new more energy-efficient buying patterns and habits remain after the incentives are discontinued. Likewise, policies should not discourage stakeholders for undertaking energy efficiency improvements after initial goals are met.

Similarly, large-scale energy efficiency improvements take time. Policies should remain effective in a range of market and political climates. Policies should be robust to evolving markets and resistant to political meddling. Labels and standards should be updated regularly as technologies and market conditions change. Also, policies should be flexible enough to account for isolated special market circumstances, while being firm enough to prevent every case from becoming a loophole. This requires a policy approach that is clear, consistent, steadfast and dynamic. Uncertainty and ambiguity in policies drain energy, effort and resources away from meeting goals. Governments must be clear about their goals and their expectations of individuals and businesses in attaining them.

The policies should also be routinely monitored, evaluated and revised to keep them tuned to changing consumer demands, technologies and other parameters, and to bolster confidence in their effectiveness.

Continuous progress

As mentioned earlier, policies should be designed to make lasting improvements. In the case of policies such as labels and standards that operate over long periods, they should undergo regular updating to be kept current. Of course, the administrative apparatus behind these policies should be designed to make this updating as easy as possible. In some cases, automatic or self-correcting updates might be possible. Updating procedures should be transparent, predictable and open to all relevant stakeholders. They should be based on sound criteria that are not susceptible to political meddling. Data should be collected on a regular basis to track technology and market trends so as to provide a sound empirical basis for updates.

Policies should be flexible enough to allow for potential improvements uncovered by programme evaluations. An example might be the capability to engage in international policy co-ordination if the opportunity arises.

Measurement and evaluation

Rigorous and routine monitoring, evaluation and reporting is vital to ensure the long-term effectiveness and political viability of any public policy. Monitoring and evaluation help improve the operation, management, overseeing and planning of these instruments by promoting transparency and realism of goals, enhancing financial and managerial accountability, highlighting progress towards goals, and identifying barriers to success. These issues are becoming increasingly important because of tighter constraints on public budgets, greater demands for political accountability and increased pressures of international commitments. Performance measurement and evaluation enable politicians, policy professionals, programme managers and staff, and taxpayers to ascertain whether programmes are meeting objectives and public money is being well spent. In the case of energy efficiency, these stakeholders need to be confident that energy efficiency programmes are resulting in improved energy efficiency, energy savings and/or reduced greenhouse gas (GHG) emissions and whether the programmes might be improved and savings increased (IEA 2000).

Data collection and analysis

Many aspects of the policy process rely on good data about technologies, markets and user behaviour. For example, detailed data on appliance energy use trends (preferably based on real world, end-use meter surveys) and opportunities for increased efficiency are needed to develop strategies and set priorities in appliance policy-making. Such data is also needed to update and adapt policies to shifting technology and market circumstances.

There can also be a correlation between analysis and accepted levels of policy ambition. In appliance policy-making, uncertainties about benefits and costs translate into policy reticence. That is, there is a tendency towards overly cautious (less ambitious) policies. Investment in thorough data collection and analysis can inspire policy-makers to reach for higher efficiency gains. Such is the case with the US MEPS programme. The analytical costs of revising the standards for one product group are reported to be about $1 million. However, the thoroughness of the analysis is one of the key factors behind MEPS with very ambitious efficiency targets. In some cases, the MEPS set out levels that were not met by any model on the current market. It was the rigorous engineering cost analysis that convinced stakeholders that attaining these high efficiency levels could be attained in a cost-effective manner.

While good data are costly, and every effort should be made to collect it efficiently, poor data and the resulting poorer policies are even more costly.

Institutional

Policy often needs accompanying institutional infrastructure to become and remain effective. Policies should be implemented in line with the infrastructure that can be provided. For example, regulatory appliance policies require testing procedures, testing laboratories and certification procedures. There should also be adequate compliance monitoring and enforcement capabilities.

There should also be organisational facilities for collecting and analysing data associated with appliance policies. These are necessary not only for compliance monitoring, but also for programme evaluation. Accordingly there is a need to establish and nurture expert institutions or networks to conduct the analysis required by the policy programme. These institutions/networks can act as important repositories for much of the knowledge accrued through the operation of the programme.

Administrative

Long-term policy effectiveness depends in large measure on policy credibility. Major stakeholders, such as consumers and manufacturers, must believe that policy will be represented truthfully and enforced fairly. In this regard, policy should be designed so that compliance can be monitored and enforced effectively, quickly and inexpensively. There should also be mechanisms to address loopholes that result from oversight or arise due to changing technology and market conditions.

There are two major elements to policy credibility – that among programme participants and that among the public, their government representatives and the programme personnel.

First, manufacturers must believe that their products (and their competitors' products) will be held firmly to the policies' rules. Otherwise, the incentives for cheating are not offset by probable detection and penalties. For labelling programmes, consumers need to believe that the information presented is accurate. Otherwise, there is no incentive to consider the information. It is the function of the conformity assessment system described below to assure this market confidence in the programme.

Second, the public and their government representatives must have confidence that the programmes are accomplishing what they set out to do, within the budgets allocated to them. This is vital for programme continuity, which in turn is necessary for sustained market transformation. Programmes that do not meet their goals within their budgets will sooner or later be subject to additional political scrutiny. This may result in revisions towards more realistic programme goals and budgets, but it may also call into question the political consensus underlying the programme, ultimately risking programme discontinuation. It is the function of the programme monitoring, evaluation and reporting system described below to instil confidence in the public and political authorities that the programme is on track. Monitoring and evaluation systems also help keep programme personnel accountable, and provide early feedback on programme problems and opportunities.

Last, all of the aforementioned criteria should be accomplished with a minimum of administrative complexity and overheads (Pershing and Corfee-Morlot). This helps lower costs and also protects programmes from cuts associated with perceptions of bloated bureaucracies and excessive paperwork.

Beyond the residential sector: positive side-effects of appliance energy efficiency programmes on other economic sectors

Appliances energy efficiency programmes, especially those leading to appliance rating and labelling, when properly designed and implemented can generate some interesting and positive side-effects.

As mentioned earlier, appliance programmes will help the setting of a baseline scenario in the UNFCCC flexible mechanism. For instance, appliance labelling greatly facilitates monitoring of the appliance market. In the near future, to allocate greenhouse gas reduction credits to a given Joint Implementation (JI) or Clean Development Mechanism (CDM) project organised in the building sector, countries with equipment labelling will have an easier time to set comparative baselines for energy demand. Unfortunately, very few developing countries are presently running such appliance programmes.

Similarly, demand-side management (DSM) utility programmes can be enhanced when market actors have the possibility, through appliance labelling, to differentiate the most energy-efficient end-use to promote, for instance, through a financial incentive. This remark also applies to energy service companies, or ESCOs. There are today some lost opportunities to invest in energy-efficient technology because of the difficulties to access the energy performance rating of a given product either in use or on retail.

Information, communication, education and motivation campaigns all belong to the same important pillar of any energy efficiency policy. Indicating by a label the energy performance of an energy consuming equipment or system when it is being traded and marketed, is certainly the most powerful communication strategy. Appliances are the most immediate field of application for such a policy. However, other energy consuming technologies or systems can follow the same approach, namely cars and buildings.

Some of the policy tools to transform the appliance market can be adopted for automobiles and buildings. Passenger car labelling or building performance labelling is progressively catching the attention of policy-makers. Some IEA Member countries have already introduced car labelling, for instance the US and Canada, while most European countries are just about to introduce passenger car labelling as specified in the European Directive EC/1999/94[19].

In Canada, since 1999, vehicle manufacturers have agreed to affix a new fuel consumption label to their cars, vans and light duty trucks. The EnerGuide for Vehicles label, which is part of Natural Resources Canada's EnerGuide programme, helps buyers compare different makes and models, and find

19. European Parliament and Council Directive 1999/94/EC of 13 December 1999 relating to the availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars.

the most fuel-efficient vehicle to fit their needs. The label is standardised across the industry and appears on its own or combined with the vehicle options and price label on the side window of each new vehicle.

In the US, a fuel economy guide published annually by the Department of Energy (DOE) explains the information given on a fuel economy label which must be affixed to the window of all new light-duty vehicles in the showroom. The guide allows customers to compare the fuel economy of cars of about the same size, light-duty trucks and special purpose vehicles.

This information is also given on the label, together with estimated fuel consumption for “city” and “highway” in mpg (miles per gallon) and annual fuel costs for 15,000 miles a year with representative fuel costs. The guide provides information on factors influencing fuel consumption. The label also contains the best and worst fuel economies of vehicles in this class, which gives an idea of the fuel economy for a specific model compared to other cars.

In the Europe Union, the aim of car labelling introduced by Directive EC/1999/94 is to provide potential purchasers of new passenger cars with useful information on the fuel consumption and CO_2 emissions of these vehicles. The fuel economy label must be attached to the windshield of all new passenger cars at the point of sale. The label was to be enforced from January 2001. The Directive does not specify the format for the car labelling. Interestingly, the first countries to introduce this new legislation, Denmark and the Netherlands, have chosen the same format as the European appliance energy label.

This is a remarkable “spill-over” effect from the European appliance energy efficiency programme. It was certainly less difficult to develop a label for domestic refrigerators or washing machines than for a passenger car. Now that the European energy label is well established, especially with a unique and colourful design, programmes to promote less energy consuming cars can benefit from the recognition of the appliance label.

As seen in Canada, Denmark and the Netherlands, a similar format can be used for labelling the energy performance of appliances and cars. This certainly enhances the consistency of energy efficiency communication programmes across different sectors and is likely to reinforce the impact of policy to mitigate greenhouse gas emission. Interestingly, appliance labels can also nicely precede building energy performance labels.

In Canada, for instance, EnerGuide for Houses, established by the Ministry of Natural Resources on 1 April 1998, is a labelling and certification programme which seeks to persuade and assist homeowners to make energy efficiency investments in their houses, and to consider energy efficiency when purchasing a house. The initiative builds on the EnerGuide for Equipment labelling programme by using a similar label to guide home energy improvement and purchasing decisions. Participating homeowners receive an on-site inspection and energy analysis of their houses, complete with recommendations for energy efficiency improvements. After the improvements have been made, the EnerGuide for Houses rating offers evidence of the investment, which enables prospective buyers to compare the energy performance of similar houses.

In Denmark, every house-owner may have an audit of his building, describing the present energy conditions with recommendations for possible energy saving measures in the building shell and heating equipment. When dealing in real estate, an audit is required if the building has an area of 1,500 square metres or less. The result of the audit is an Energy Label describing the energy condition on a scale from A1 to C5 (A1 is best). Heating, electricity and water consumption are rated on the basis of a standard calculation.

In the United Kingdom, the building rating scheme – called Standard Assessment Procedure (SAP) – is based on annual energy cost for space and water heating per square metre of floor area, which is calculated from details of the house and its heating systems. It is expressed on an index scale of 1 (worst) to 100 (best).

In Upper Austria, a voluntary building label has been developed and presents the same format as the European appliance label, with seven energy efficiency categories, from A (best) to G.

However, the recent completion of the European Climate Change Programme (ECCP)[20] proposes a Directive on the Energy Performance of Buildings. The objective of this proposal is to promote the energy performance of buildings in all Member States by introducing, *inter alia*, (1) a framework for an integrated methodology for measuring energy performance; (2) application of minimum standards to new buildings and

20. http://europa.eu.int/comm/environment/climat/eccp.htm

certain renovated buildings, and regular updating of these; (3) energy certification and advice for new and existing buildings and public display of certificates in certain cases; and (4) inspection and assessment of boilers and heating/cooling systems. In April 2001, the Commission adopted this proposed Directive.

It may be wise to suggest that the Commission use for this new energy certification a format similar to the European appliance energy label, as applied for example in Upper Austria. Similar energy labelling across different economic sectors – such as described here on appliances, buildings and passenger vehicles – reinforces the efforts to promote energy efficiency in general and will benefit efforts to mitigate greenhouse gas emissions.

FUTURE SHOCK: CHALLENGES FROM A NEW GENERATION OF APPLIANCES

KEY MESSAGES

- *One of the strongest trends in the residential sector is the rapid growth of "information and communication technologies" (ICT) in the home – computing equipment, communications equipment, multimedia devices, entertainment and audio systems.*
- *These devices – many of which continue to use significant power when switched "off" (or in standby mode) or not in use- are projected to be responsible for much of the anticipated growth in residential energy demand and greenhouse gas emissions in IEA Member countries over the next 30 years.*
- *As for the other end-uses, technical options exist to improve the energy performance of home ICT.*
- *Most components of the usual policy package for market transformation apply to domestic ICT. However the measures to promote energy efficiency have to be particularly innovative and dynamic in order to take into account the fast evolving nature of the technologies.*

This chapter explores the challenge created by a new generation of residential equipment: can energy efficiency be promoted in the new generation of electronic appliances?

Appliances belong to a dynamic market. Appliance features, technologies and designs evolve rapidly as they are stimulated by a very competitive business environment. Moreover, new appliances and energy services often emerge quickly. Two related trends explain, affect and support the evolution of the appliance market and technology: information and communication technologies (ICT) – among which Internet machines – and networked appliances. Information and communication technologies comprise the following group of products: office equipment, electronic data processing, radio communication, telecommunication equipment, audio, video, entertainment equipment, and any other consumer electronic equipment. Internet machines include all electronic devices that make possible access to the Word-Wide Web: mainframe, router, hub, terminal, PC, monitor, modem and the usual scanning, printing and audio systems which come along. Networked appliances comprise white goods (refrigerator, clothes washers), brown goods (TV set, audio-video systems), as well as control, security and Heat Ventilating and Air Conditioning (HVAC) equipment that are gradually being connected one to another.

In energy policy analysis, ICT was until very recently treated in the category miscellaneous end-uses. The growing importance of ICT in energy demand in residential buildings today, and in the future, imposes separate analysis. There are many unknowns about the characteristics of the power consumed by ICT.

Driven by the electricity waste from their standby power mode, ICT is responsible for a significant portion of the current growth of electricity demand in the built environment, especially in residences. However, ICT also has the potential to change radically conventional business and numerous economic or personal activities. ICT, and especially the extensive use of the World-Wide Web, can greatly enhance overall business efficiency, for instance by allowing people and goods to travel more efficiently, eventually less. Electrons, as information carriers, travel at the speed of light, with no weight. The Internet Revolution is a global event that has reached all IEA Member countries. It is generally agreed that this electronic revolution may bring about new patterns of social and economic interactions with potentially far-reaching implications.

Table 5.1 presents the time-scale for a selection of ICT to reach their first 10 million customers on the US market. It took 37 years for the telephone to reach 10 million subscribers, 25 years for cable boxes, 7.5 years for PCs and only 4 for Internet. New technologies seem to penetrate the market much faster today than in the past. The number of cellular telephones in European countries has rocketed from a few hundred thousand to tens of millions of users in just a few years. If ICT in buildings, and particularly in residential buildings, combine convenience, service and entertainment, all at a reasonable cost, they should experience a very high speed of market penetration. In this context, is there room for policy-makers to limit the impact of the fast growing use of ICT in building energy consumption?

Table 5.1 **Time scale for a selection of information and communication technologies to reach 10 million consumers on the US market**

Technology	Number of years to reach 10 million users
Telephone	37 years
Cable television	25 years
Fax Machine	22 years
Cellular Telephone	9 years
VCR	9 years
PC	7.5 years
Internet	4 years

Source: Science & Avenir Magazine, France 1999.

The present chapter does not explore the impact of ICT and the related e-business on national GDP nor on overall energy intensity. The objectives of this section are to analyse the current situation of the emerging end-use technologies in the residential sector, to assess their specificity and their related current and future energy demand and greenhouse gas emissions, to size the potential energy efficiency improvements and to discuss the most relevant policy options that will mitigate the GHG in this sector.

CLOSE-UP OF ELECTRICITY DEMAND FROM ICT IN THE RESIDENTIAL SECTOR

In less than two decades, information and communication technologies have gradually invaded a large portion of our daily environment. ITC also catches a significant portion of the time an average person spends on business or at home. This trend is likely to continue, including in the residential sector. Internet is by far the most important driver of the trend in ICT use and related energy consumption.

Access to a personal computer in households has more than doubled in OECD countries since the mid-1990s. In 2001 in most OECD countries, although access was still uneven, more than half of households had PC access (OECD IT Outlook 2002). Although Internet access has lagged PC access, uptake by households has been extremely rapid and regular since 1997. In four OECD countries (Finland, Sweden, Dernmark, USA), more than 40% of households had Internet access in 2000, and in countries where the number is significantly lower, access is also rising rapidly (OECD IT Outlook 2002).

It is difficult to estimate how much electricity is used by ICT and by Internet uses. ICT are estimated to consumed 97 TWh per year in the US commercial sector, corresponding to 3% of the total national electricity consumption (Roth 2002). Office equipment in the residential sector are estimated by Kawamoto & al. (Kawamoto, 2001) to a consume 9 TWh per year in 1999 in the USA. Those figures are low but were not significant only 10 to 15 years ago.

While low today, the total energy demand from ICT in OECD households is likely to increase significantly as the triple effect of growth in the penetration of equipment, the increase in consumers' use and the increase in the unitary energy consumption due to more complex technologies. Three trends may also add to the energy consumed by ICT in the residential sector. Old computers are not necessarily disconnected from the electric mains when they are being replaced by new ones. The older family PC may be given to one child, and start a second life, thus saturation are likely to be far greater than 100%. Also, personal computers are likely to stay on even when they are not used allowing the user to check several times a day his/her emails without rebooting the system. Finally, ICT equipment will be operating in low power modes (“lopomo”) more hours per day.

In Europe, Kemna (Kemna, 2002) estimates that the unitary energy consumption of most information and telecommunication technologies found in the residential sector will be growing, as shown in Table 5.2. When these figures are multiplied by the likely increased numbers of both users and equipment across all OECD regions, the electricity demand for ICT has the potential to exceed conventional end uses such as refrigeration and lighting in the residential sector.

Even with some policy intervention to promote energy-efficient ICT, electricity demand in that end-use is likely to grow in the next decade and be a significant share of building energy consumption. Internet-related ICT will significantly influence that growth. For this reason, it is important to carefully investigate the opportunities for potential savings and their possible impacts on overall energy use.

Table 5.2 **Estimation of the total energy consumption for various information and telecommunication technologies in European households.**

	Average Energy Consumption in kWh/year		
	1996	**2000**	**2010 no policy**
Television	149	155	272
Receiver	18	31	161
Video Appliances	86	87	79
Audio Appliances	158	167	195
Personal computer	32	88	243
PC Monitor	28	42	35
PC network/gateway	1	18	64
Other (games, telephone, etc.)	30	30	30
Total Consumer Electronics (million)	502	618	1,079
Households in EU (million)	147	152	158
Total Consumption in EU (TWh/year)	**74**	**94**	**170**

Source: Kemna 2002.

STANDBY POWER: A GROWING CONCERN

Standby power is the electricity consumed by end-use electrical equipment when it is switched off or not performing its main function. The most common users of standby power are televisions (TVs) and video equipment with remote controls, electrical equipment with external low-voltage power supplies (e.g. cordless telephones), office equipment and devices with continuous digital displays (e.g. microwave ovens). The actual power-draw in standby mode is small, typically 0.5-30 watts. However, standby power is consumed 24 hours per day, and more and more new appliances have features that consume standby power. Although consumption by individual appliances is small, the cumulative total is significant as seen in Chapters 1 and 2: standby power consumption is no longer a negligible end-use and is already approaching refrigeration. The unique position of standby power has become a field for policy-makers and an opportunity for energy efficiency.

The magnitude of the standby power issue seems to be growing. A recent end-use metering campaign in 400 European households indicates that standby power now accounts for the largest potential energy saving among all non-thermal end-uses in the residential sector (EURECO 2002).

Electricity consumption in standby modes is often far higher than necessary. For some products, existing engineering practices could greatly reduce standby power use at relatively low cost and without affecting how the product operates or consumer satisfaction. More widespread use of existing power management technology could reduce total standby energy consumption by as much as 75% in some appliances. The corresponding reduction in carbon emissions could be a cost-effective component in an overall global strategy to reduce greenhouse gas emissions.

Several features of standby power, and the manufacture and marketing of the equipment that consumes it, argue for an international effort to reduce the losses attributable to it:

- Standby power consumption by electrical equipment is a uniquely international issue because the manufacture of many of the appliances that use standby power (TVs, video cassette recorders [VCRs], mobile phones, computers, etc.) typically involves many countries. A computer, for example, may be designed in the US, assembled in China using parts from Japan and Korea, and sold in Europe.
- Electronic devices are marketed internationally, so setting standby power use limits country by country would be unnecessarily difficult and costly.
- New electronic equipment will continue to proliferate at an increasing rate, so the share of energy use attributable to standby power consumption will rapidly increase.
- Governments world-wide are trying to find ways to reduce CO_2 emissions cost-effectively; eliminating unnecessary electricity losses from standby consumption is an attractive strategy. Reducing standby power use may be one of the first opportunities for co-ordinated international action under the rubric of global climate protection.

For all these reasons, the IEA stimulated an initiative to address the specific case of standby power waste over the past year (IEA 2001).

Several policy instruments can be used to tackle the international problem of standby power consumption, ranging from labelling to imposing minimum performance standards, and from voluntary schemes to regulation; individual countries can select the approaches that best fit their circumstances. Many governments have already begun substantial programmes to reduce standby power use. For example, in 1996 the EU introduced a voluntary agreement to reduce significantly standby consumption by TVs and VCRs; the US, along with many partner countries, has invested heavily in the Energy Star® programme to reduce standby power consumption in consumer electronics (and to encourage use of low-power, sleep modes in office equipment). Australia has formally adopted a "1-watt plan" to reduce standby power use. Other countries, such as China, are now seriously considering programmes to address standby power consumption (Power Integration 2003).

Despite the fact that a new product coming on the market is likely to have a lower standby power level, the model it eventually replaces is not necessarily disconnected from the grid. A new PC coming into a home does not necessarily move the old one away very far. A DVD player does not replace a VCR. It is likely that the old VCR will remain plugged into the wall for quite some time. There exist some retrofitting devices that bring to zero the standby consumption of much equipment, but few are cost-effective solutions. Instead, information campaigns to change behavior appear to be the appropriate policy to address existing standby power waste.

Standby power remains a concern and a challenge not only for OECD countries but also for the rest of the world.

POWER SUPPLIES: A HIDDEN OPPORTUNITY FOR ENERGY SAVINGS

Reducing standby power waste is not the only energy saving opportunity that exists across the range of information and communication technologies. More energy-efficient power supplies will not only reduce standby power waste in electronic equipment, they can also save significant amounts of energy when appliances are "on" and hence perform their intended services. This section is largely inspired by a report by C. Calwell and T. Reeder (Calwell 2002).

Although nearly all home electronic products and office equipment plug directly into wall outlets and draw 120 or 230 volts of alternating current (AC), most of their circuitry is designed to operate at a much lower voltage of direct current (DC). The devices that perform that conversion are called power supplies. Power supplies are located inside the product (internal) or outside the product (external). Most external models, often referred to as "wall-packs" or "bricks", use a very energy-inefficient design called the linear power supply. Measurements of linear power supplies confirmed energy efficiencies of 20 to 75%. Most homes have five to ten devices that use external power supplies, such as cordless telephones and answering machines.

Internal power supplies are more prevalent in devices that have greater power requirements, typically more than 15 watts. Such devices include computers, televisions, office copiers and stereo components. Most internal power supply models use somewhat more efficient designs called switching or switch-mode power supplies. Measurements of internal power supplies confirmed energy efficiencies of 50 to 90%, yielding wide variations in power use among similar products.

Power supply efficiency levels of 80 to 90% are readily achievable in most internal and external power supplies at modest incremental cost through improved integrated circuits and better designs. More efficient power supplies could save an expected 15 to 20% over the current energy consumed by most ICT.

More than 6 billion electrical products containing power supplies are estimated to be currently in use in OECD Member countries, two-thirds of which are in the residential sector. More than 1 billion new power supplies are sold each year. The total amount of electricity that flows through these power supplies is estimated to be a minimum of 320 billion kWh/year in OECD countries, or about 4% of the total electric bill. In most cases, the incremental cost for the improved power supply is less than $1. The resulting electricity savings for these products pay for their incremental cost very quickly – typically in six months to a year. More efficient designs could save an expected 50 billion kWh/year.

Unlike many other energy efficiency technology challenges, the efficient power supplies and the components that go into them are widely available. The need is not to invent better components or finished power supplies, but simply to encourage the market to use the better designs already existing. This primarily means convincing assemblers of electronic products to specify more efficient power supplies in their product design process.

Though the energy efficiency benefits of better power supplies are compelling, the non-energy benefits may be even more important to the companies that purchase power supplies for their finished products, the retailers who sell them and the consumers who buy them. Highly efficient power supplies tend to be smaller, lighter in weight and more convenient. They operate at cooler temperatures, contain fewer parts and are likely to result in greater product reliability.

The market for power supplies fails to capture these energy savings at present because the products are obscure and their energy efficiency is generally unknown. No clear labelling of efficiency is currently done, and power supplies are often oversized to minimise liability, wasting additional energy when the products operate at part load. The highly competitive electronics industry places a premium on very low manufacturing costs, so even technologies that increase costs by pennies can be rejected as too expensive.

Energy efficiency power supplies appear as a new opportunity for large-scale energy savings. The generic nature of the technology and the obvious global dimension of both the market and the stakeholders involved, make power supplies an interesting candidate for an internationally co-ordinated effort to save energy. There does not exist a simple policy path to encourage the use of energy-efficient power supplies. However, the policy recommendations to promote energy-efficient ICT discussed at the end of the present chapter are particularly relevant to power supplies.

CURRENT INTERNET USE AND ELECTRICITY DEMAND

In all OECD countries, Internet use increases in terms of frequency of access and time spent on line as well as in the number of users. In Norway, only 20% of Internet users used Internet on a daily basis in 1996. In 2001, the number of daily users increased to 60%. In Finland, regular Internet use on a daily or weekly basis has increased, and the relative gap between daily and occasional use has narrowed as daily use has grown faster. In Australia, regular and frequent use is also increasing as a share of on-line activities although in all countries, as in Italy, occasional use is still considerably higher than daily use (OECD IT Outlook 2002).

Researchers with Japan's Institute for Global Environmental Strategies (IGES) and Germany's Wuppertal Institute joined forces on two occasions in 2000, with a series of papers and through workshops especially focused on "International Climate Policy and the Information Technology Sector" (IGES and Wuppertal 2001). This work is part of a "policy dialogue between Japan and Germany to facilitate co-ordinated action to combat climate change". The study focused on the impact of internet on electricity demand. The following paragraphs comprise many extracts from this work.

In Germany, PCs alone account for 1.7 TWh per year during their connection to Internet. The total power needed to run Internet amounted to approximately 4.2 TWh in 2000. A quarter is due to the consumption of information suppliers (dot companies, Web servers), and a third comes from consumption by the network. This 4.2 TWh represents less than 1% of Germany's total electricity consumption, and therefore does not seem very relevant today (Barthel et al. 2001). However, the expected explosion of Internet use during the coming five to ten years could change the situation dramatically.

Assuming the continued use of today's technologies with no efficiency improvements, this number is estimated to increase more than eight-fold in the next two decades. Internet would then consume about 35 TWh per year, and emit about 20 million tons of CO_2 in Germany alone, representing more than 6% of Germany's current electricity consumption, and 2.5% of its CO_2 emissions (Barthel *et al.* 2001).

The number of Internet users in Germany was increasing by about 50% every six months (Barthel *et al.* 2001). Internet experts predict that, by the end of 2003 Germany will have 60 million private users, by the end of 2003. Three out of four Germans will be on-line. E-commerce is expected to be the fastest growing business, expanding its sales from €2.9 billion in 1999 to €65 billion by 2005 (Struve 2000). The year 2010 might already see saturation for Internet access with 95% of all households being on-line, 80% with PCs and 15% with newly developed digital TV reception platforms. For the office sector, including home offices, Internet accesses are estimated to double by 2010.

In Japan, it is estimated that some 27 million people were using the Internet at the end of 1999. This figure had grown by 60% from the previous year. The number of Internet users in Japan is most likely to continue growing, and is expected to reach nearly 80 million in 2005 accounting for more than 60% of the total population in Japan.

The percentage of households with an Internet connection has been rapidly increasing over the past few years. Table 5.3 presents the number of households with a PC and with Internet access in a selection of IEA Member countries.

Table 5.3 **PC and Internet equipment diffusion in households in selected IEA Member countries**

	PCs in home 1990 (%)	PCs in home (with modem) 1995 (%)	PCs in home 1998 (%)	Internet in home 1998 (%)	PCs in home 2000 (%)	Internet in home 2000 (%)
Australia			46	40	53	
Canada	16	29 (10)	36	13		40
Denmark		32 (12)	52	31	65	45
Finland			42	22	47	34 (2001)
France		14.3 (1)	19	10	27	12
Germany		25 (3)			47	16
Italy		14	17.5	2.3	28	18
Japan	11.5	15.6	26	15	38	33 (2001)
Netherlands		27				
Norway			50	13	60	55(2001)
Sweden			68		68	65(2001)
United Kingdom		20 (4)	58	28	45	35(2001)
United States	15	25.5 (15)	42	26	51	51(2001)

Source: OECD 2001, OECD 1998, OECD IT Outlook 2002

FROM INTERNET TO INTRANET AND NETWORKED APPLIANCES

With the rapid increase of Internet use, especially in the residential sector, it is possible that the concept of an "intelligent home", which has been a matter of wishful thinking for many years now, will become reality in the very near future. The fusion of the various media is both the catalyst and, at the same time, the first visible sign of this evolution. The development of user-friendly people-to-machine interfaces and new services, together with the possibility to "have a look" back home and intervene from any location at any time, will also foster the interconnection of white goods and the intelligent control of other building equipment and services.

With Internet-connected appliances, homeowners will be able to pre-heat the oven from the upstairs bathroom or contact the refrigerator manufacturer about a leaky connection. With Web cameras and audio equipment, they can check in on their children from the office or communicate with delivery people who knock on the door when they are away. These examples suggest a host of new phrases that will need to be coined, including: "distance parenting", "virtual homebody" and "cyber snooping".

Besides the expected enhanced communication inside and outside a home, initial promoters of home automation system aim to offer the homeowner the following:

- Integrated control of the alarm and security systems to protect the home.
- Integrated control of the space heating and air-conditioning system for optimal comfort.
- Intelligent control of the lighting level, using an automatic shading device, or light sensor.

The impacts of this development on energy demand are wide-ranging. Home automation systems may have the potential to reduce some waste of energy by, for example, turning off the light when a room is empty and automatically reducing the space heating output at night. However, in the last decade, home automation techniques have not kept all their promises. Common weaknesses are the lack of flexibility, the user's slow learning, the complexity of the communication system, and the significant cost of the control and network equipment. Finally, it proved to be a mistake to consider homes as a complex system. Simple command and control devices are enough to allow the homeowner to manage internal comfort. Also, regarding the possibility to save energy through autonomous control of the heating system, the cost-effectiveness of home automation becomes less obvious as the building shell becomes better insulated and heating systems more efficient. According to a recent study in Switzerland (Aebisher 2000), the induced increase in energy demand inside the house is far more significant than the quantity of energy saved by more efficient control. Hence the drivers of home automation systems appear nowadays to mean less the autonomous management of home comfort and more the possibility to benefit from enhanced telecommunications via Internet technologies. Multimedia applications and the requirement to use the Internet from various locations within the home may particularly drive home networking.

In terms of energy consumption, a primary concern with home automation is to see appliances or devices draw power constantly, while previously they were not consuming any electricity when not in use. Many electrical products may tomorrow become permanently connected to a local network in order to receive or send signals, for turning on or off, for instance. The appliance will therefore have a standby power mode. Top of the line, "Internet-ready" washing machines or dishwashers are already hitting the market. This new generation of machine can be remotely reprogrammed to adjust their washing cycle to the user's future requirements, new type of cloth or to adapt to a new type of detergent. Prototypes of "Internet-ready" refrigerators or microwave ovens have already been exhibited in trade fairs. They present a touch-sensitive LCD screen that is connected to a computer. The user has direct access to Internet, eventually to the television or home security network or can also, via an intranet system, control the heating, cooling and lighting systems of the whole house. In prototype, it appears that the internet component, including the display, are responsible for more energy than the refrigerator itself. The technology is ready to enter the market.

Prediction of the impact on the electricity demand of the generalisation of home networks is not easy. Despite the desire by the electronics industry to stimulate what could become a huge market opportunity, it is the acceptance by the end-user that will decide if the benefit of a smart networked home is worth the financial investment.

Aebisher et al. (2000) make a series of simple assumptions on the level of power of the network features progressively appearing in the main domestic appliances, lighting and security fixtures as well as on the power for running the network, such as a high-capacity broadband gateway. The extra electricity consumption ranges from 600 to more than 1,000 kWh a year per household at the horizon 2010-2020. Standby power accounts for 50 to 70% of this new consumption. Considering that each extra kWh in an OECD household can translate into an average of 450 g CO_2 emissions sent to the atmosphere, a large penetration of home net work systems will have a visible impact on a country's greenhouse gas emissions.

Overall, Aebisher et al. estimate that electricity demand in the private household sector in Switzerland will increase by a maximum of 1.3% per annum over the next two decades because of the expected penetration of ICT in homes. This corresponds to an increase of 20% in total residential electricity by 2020. Even if this Internet-induced increase should only be half as fast, the interconnection of equipment and services is likely to be the most important driver of electricity demand in the residential sector.

ELECTRICITY DEMAND FOR DOMESTIC MULTIMEDIA

Household penetration of ICT applications (telecommunications, consumer electronics, and office equipment) is already very high in most IEA Member countries. Practically all households have a telephone, television set and a radio.

Multimedia refers to the combination of previously separate areas such as computer technology, telecommunication, audio and video consumer electronics. In the field of communication, multimedia is used in a broad sense to describe all applications that integrate voice, text, data and image communication, or parts thereof.

The trends of electricity demand to fuel domestic multimedia applications will remain driven by the increase of Internet use, hardware technology, especially for video display, and the amount of standby power waste in numerous pieces of electronic equipment.

There is no doubt that Internet equipment and use will grow in the next decade. The share of households connected to Internet, either through a

PC or a Web TV, will converge across IEA countries. It is not unreasonable to say that by 2020, broadband connector will be present in 95% of homes. In 2010, we can also assume that at least 50% of households will be connected and even up to 90% in North America, Japan and North European countries.

There are many technical possibilities for Internet access in tomorrow's buildings: through a regular PC, a dedicated PC, a Web TV, a Web touch pad.

According to Aebischer (2000), electricity consumption for a typical home multimedia platform may grow from around 350 kWh a year per household in 2000 to 1,400 kWh a year per household in 2020. The implications for the related greenhouse gas emissions are therefore large. All else being equal, i.e. household population, electricity carbon mix, etc., this increase implies an extra 220 million tons of CO_2 emission from OECD countries as reported in Table 5.4.

Table 5.4 **Estimated CO_2 emissions from the multimedia platform electricity consumption in some OECD countries**

Country	Number of Households in 1998 millions	Estimated Emissions CO_2 from Multimedia million tons/year in 2000	Possible Emissions CO_2 from Multimedia million tons/year in 2020
Australia	7	2.3	9.3
Canada	11.7	0.8	3.1
Japan	41	6.4	25
European Union	149	25	102
United States	101	23	92
OECD	386	75	295

THE SPECIFIC CASE OF DIGITAL TELEVISION RECEPTION PLATFORMS

The analysis of the development of the digital television reception platform, also called integrated receiver decoder (IRD), is a concrete illustration of the whole discussion of the present chapter. IRDs allow any television set to receive channel that are digitally broadcast and aired. The quality of the image and sound is far superior to the analogue broadcast system that the digital technology replaced. The number of channels is multiplied by six. IRDs and digital TV broadcast are just entering the market in Europe and have already met with great success in British homes.

The first generation of IRDs presented a high level of standby power, a permanent 34 W load in 1995. Models being marketed in the UK have an average 16 W standby power load. Best technology practice is around 12 watts in standby power. In less than two years, 17 millions British households bought an IRD. The corresponding power demand reaches 270 MW on the UK grid, and 2.4 TWh/year.

At the European Union level, negotiations have taken place to create the conditions for a voluntary code of practice by 2003/2004 with an electric power consumption level of 9 W in the standby active mode.

However, the trend tends towards making the IRD an integrated communication platform, including Internet, Intranet links with other household appliances, etc. As a result, the following features with their respective consumption are being added to the IRD:

- The Local Network Bus may quadruple its capacity to provide four channels at any given time (for instance a TV receiver, Internet receiver, storage disk and an open channel for connection to other boxes in the house) compared to today's single TV receiver channel of the present IRD boxes; this would roughly double standby power.
- The dual tuner requirement would add 3 to 5 W.
- The processor and memory requirement would add PC functions, and perhaps considerable standby consumption. However, it is expected that the technology from portable PCs is likely to be used with much lower standby power.
- A hard disk drive might consume at least 6 W, but in the long term it could replace VCRs and DVDs.
- A wireless interface might consume an additional 3 to 5 W, but would replace the present cordless telephone, which on average in the UK consumes 6 W.
- A modem would add a few watts.

Taken together, if no attention is paid to the energy efficiency of the components, or to power management, it is likely that an integrated IRD with all the functions would continuously use at least 40 W of standby power. Assuming that two-thirds of the 150 millions households in the European Union purchase such an IRD before 2010, the resulting extra power demand will be 4,000 MW and 35 TWh/year.

Average electric power consumption of the same IRD, however, could be as low as 9 W in 2010. This can be achieved with more efficient components, and particularly with an intelligent power management, which ensures that each function uses zero or at least less than 1 W when it is not in use.

Bringing the power consumed by future IRDs from 40 down to 9 W, would avoid 8 million tons CO_2 in the European Union in 2010.

ELECTRONICS CAN MAKE APPLIANCES MORE EFFICIENT, BUT ALSO MORE DIFFICULT TO ANALYSE

Appliances are increasingly controlled by microprocessors. Unfortunately, energy test procedures and appliance energy efficiency policy have not been modified to capture the positive and negative contributions of the microprocessor to the appliance's energy use. The technologies employed in major appliances are undergoing a major transformation. In the past, the user controlled most aspects of an appliance's operation. New appliances, however, have microprocessor controls which may adjust the appliance's operation without any action by (or even knowledge of) the user. The microprocessor can gather information through sensors or from memory of previous cycles to select an operating strategy that results in enhanced amenities or services to the user (Meier 2000).

This trend has the potential to save energy, water and other resources in many different ways. For example in washing machines, sensors may measure the weight of clothing and the extent of soiling. The microprocessor will use this information to select the minimum amount of water and detergent to achieve clean clothes. Microprocessors can also control variable-speed motors in air-conditioners and refrigerators; this will allow better temperature regulation, dehumidification, often with less energy than traditional approaches.

Unfortunately, the energy savings from microprocessor controls are not fully captured in the present energy test procedures. Some omissions in the present tests are that they:

- Fail to include part-load conditions (less than full loads in washing machines, cooling or heating at less than steady-state output, etc.).
- Ignore learning capability from previous cycles.
- Ignore sensing special conditions for service (such as level of soiling and type of fabric).
- Fail to recognise communication between the appliance and a network (including the Internet).

In some cases these omissions lead to only a small discrepancy between the laboratory measurements and actual use, but this discrepancy is likely to grow as microprocessors become more sophisticated.

At the same time, some manufacturers are programming the microprocessors in appliances to recognise when the appliances are being tested. When the unique test conditions are identified, the microprocessor modifies performance in such a way that it uses less energy than it would under ordinary conditions.

Microprocessor control (coupled to extensive use of sensors) appears as a challenge to appliance testing and certification as well as to energy efficiency programmes. When designing an energy efficiency policy, it may be very important today to understand fully the impact of advanced electronic controls on the appliance cycle. There is not a unique path to incorporate the benefits of an enhanced control in appliance use. Meier (2000) proposes a general design to improve energy test procedures.

PROMOTING ENERGY-EFFICIENT ICT

Domestic network systems, like home multimedia, personal computer, etc…, appear as a major electrical end-use in the building system for the near future. It is vain at this stage to attempt to assess further and in more detail the electricity and environmental implications of information and communication technologies. There are too many unknowns as to the type of technology, the speed of penetration of the system in OECD homes, on user behaviour vis-‡-vis new media, ICT and their network. However, analysis of the candidate technologies for both network and multimedia applications now should be encouraged and performed thoroughly.

Once the new technologies are in place, the impact of the user's behaviour on energy consumption is likely to be limited: ICT will consume energy even in the absence of a user. Therefore the challenge is to promote energy efficiency in the design and installation of the technologies themselves. The usual policy package for market transformation, as discussed in Chapter 4, applies to information and communication technologies. The sector presents some specific characteristics: a fast developing market, innovative technology and dynamic evolution of the multimedia fixture. Therefore, measures to promote energy efficiency also have to be innovative and dynamic. They are complementary in nature and consist in the following:

- Member countries should closely monitor the trends of the technologies and their market. Too little is known today, for instance, about the current energy consumption and implications of Internet and of multimedia platforms. Studies should be encouraged immediately to monitor permanently a representative sample of buildings and equipment in order to understand energy consumption patterns. A new series of energy efficiency indicators could explain the evolution of building energy consumption. The networked dimension of ITC could be used for that purpose.
- Member countries should encourage research and development activities on the energy consumption of ITC. Energy efficiency features must be considered at the earliest stage of product design. Governments ought to convey this message to industry through an open dialogue, stimulated by, for example, joint public-private R&D activities.
- Power supplies are a hidden opportunity for energy savings. An internationally co-ordinated effort among governments, manufacturers and their international suppliers of power supplies is likely to have maximum impact.

- Television broadcasting is rapidly moving toward digital technology. Set-top boxes are likely soon to represent a visible residential load in most economies. Countries should rapidly co-ordinate their efforts to ensure that set-top boxes are as energy-efficient as possible during both their on mode and standby power mode.
- Standby power levels have already fallen for many of the products targeted by mandatory and voluntary programmes. Extension of these programmes will yield even greater savings.
- A global voluntary scheme to recognise the top of the range energy-efficient models or systems should be encouraged.
- Government or public procurement programmes should encourage of only the top of the range energy-efficient products.
- Member countries should co-ordinate their policies in order to gain from the international nature of the ITC market.

NECESSITY AND BENEFITS OF INTERNATIONAL POLICY CO-ORDINATION

KEY MESSAGES

- *With increasing globalisation of appliance and technology markets, international collaboration and co-operation on appliance policy is becoming an essential element of product markets.*
- *International policy co-ordination can generate a greater transparency and comparability in appliance standards, test procedures and labelling which would bring benefits for producers, consumers and governments alike.*
- *There exist several avenues for enhancing international collaboration and co-operation on appliance policy. This requires recognition of the stakes, more attention and some specific additional support compared to the current situation.*

This last chapter discusses the benefits of international collaboration in appliance energy efficiency programmes.

In OECD countries, the appliance market is open, competitive and dynamic. As opposed to building construction or components, appliances no longer belong to a local market. The physical dimensions of appliances allow them to be traded across borders. Over the past two decades, the world's appliance industry has been marked by a trend of consolidation. Through a series of mergers and take-overs, a handful of large, sometimes multinational, manufacturing groups have emerged to dominate the market place. Some appliances, such as microwave ovens, room air-conditioners or audio systems have become true global products for a global market. Other appliances may propose different services or features on different continents, but still evolve within a wide market.

Previous chapters and a recent IEA publication (IEA 2000)[21] describes how appliance energy efficiency programmes, particularly labels and standards,

21. IEA 2000. "Energy Labels & Standards", Energy Efficiency Policy Profiles ISBN 92-64-17691-8.

are being used by more and more governments to increase the efficiency of more and more products. As the programmes proliferate, the potential advantages of international co-operation are apparent. Several levels of co-operation are conceivable, including: collaboration in the design of tests, labels and standards; co-ordination of the programme implementation and monitoring efforts; harmonisation of test procedures; and harmonisation of the energy set points used in labels and standards. Moreover, in the context of the UNFCCC mechanisms to help countries meet their objectives of greenhouse gas emission reductions as agreed in the Kyoto Protocol, there exists a growing need to set a sound baseline scenario for energy demand. Appliance rating and labelling can be instrumental to understand better the structure of a given appliance market and hence its related energy demand. Appliance energy efficiency programmes, when co-ordinated among regions sharing the same appliances market, will not only help countries mitigate their greenhouse gas emissions, they will also greatly facilitate energy demand scenarios and monitoring.

RATIONALE

The usefulness and feasibility of international co-operation vary from product to product, but the previous IEA publication (IEA 2000) presents five general benefits: greater market transparency, lower costs for product testing and design, enhanced technology transfer, reduced costs for developing government and utility efficiency programmes, and enhanced international procurement.

Greater market transparency[22]

International co-operation would improve information comparability from market to market, or market transparency. This would enable consumers, producers, retailers, government and utilities to better inform themselves about a wider range of a particular product and its component technologies. How foreign models and technologies might function under local conditions, for example. With this information, governments and utilities could better design programmes that promote the most cost-effective available technologies for their markets.

22. This section (and the following paragraphs) is directly taken from "Energy Labels & Standards" IEA 2000 (IEA 2000).

Transparency would also give government and utilities better – clearer and more independent – information about technological capabilities and limits. This would improve their ability to work with manufacturers, both domestic and foreign, in encouraging the development of more efficient products.

Reduced costs for product testing and design

If tests, appliance energy efficiency programmes and especially energy labels and standards can be harmonised, the cost to manufacturers of testing and design can be reduced. The current multiplicity of tests required by national programmes is very costly for manufacturers wishing to sell in more than one market. Moreover, since products are designed and manufactured to meet tests, labels and standards, the dissimilar national programmes also increase design costs.

Enhanced prospects for trade and technology transfer

International co-operation would improve conditions for trade and technology transfer. Among other things, this would enlarge the energy-efficient segments of product markets. This applies not only to the products themselves, but to 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. Harmonisation of tests and energy labels and standards would also discourage protectionist mischief.

Reduced costs for developing government and utility efficiency programmes

International co-operation would assist governments and utilities in their efforts to design, implement and monitor efficiency programmes related to tests, labels and standards. By sharing data and analytical tasks, governments and utilities could reduce the cost of developing test protocols and analysing potential labelling and standards programmes or alternatively enhance their quality. Moreover, reducing the number of demands made on manufacturers might make possible greater improvements in efficiency. In other words, fewer demands might allow stronger demands.

Also, internationally accepted analytical methods, test protocols, labels and standards, would be a model that other countries – be they developed, developing or transition economies – could use to develop efficiency programmes. The pace of market developments in some countries justifies early actions to ensure a more sustainable pattern of development. The model would not only be a useful starting point for programme development and implementation, but would also increase the likelihood that such programmes are pursued in the first place. It is easier to implement these programmes if other countries are doing the same. It is easier to follow suit than be first.

Enhanced international procurement

International co-operation, if it leads to harmonised or compatible test protocols, could improve the energy efficiency of products developed and purchased through international procurement programmes. For example, common testing protocols would increase the number of potential suppliers that could compete for bulk purchase contracts issued by the World Bank and other development institutions. Likewise, common tests would raise the number of competitors for innovation procurement programmes, such as Golden Carrot contests. The greater level of competition in these cases would generate a wider variety of product and technology choices from which to choose the most cost-effective for the particular market being served.

Types of international co-operation

As already mentioned, several levels of co-operation are conceivable – collaboration in the design of tests, labels and standards; co-ordination of the programme implementation and monitoring efforts; harmonisation of test procedures; and harmonisation of the energy labelling and standards levels used in the various programmes.

Co-operation in the form of collaboration and co-ordination presents few, if any, disadvantages. Such efforts may slow programme development in some countries, but will no doubt speed development in others. Harmonisation of test protocols, labelling and standards, though, has a more fundamental potential weakness. Labels, targets and regulatory standards might be set at sub-optimum levels if the regional and national differences are not properly assimilated. The issues associated with harmonisation are discussed in the next section.

HARMONISATION OF TEST PROTOCOLS

Harmonisation of test protocols would bring four principal benefits. First, and foremost, it lays the ground work for reduced testing and compliance costs for manufacturers. If common test protocols are adopted, and trading partners grant mutual recognition of tests conducted in each other's jurisdictions, multiple testing of products could be eliminated or reduced. Second, common test protocols lay the ground for comparing the performance of products across national boundaries, so that consumers can be better informed of the range of product choices available to them. Likewise, such comparisons could enable energy efficiency programme managers to choose from a wider range of models when developing their promotion efforts. Third, common tests could encourage the transfer of more efficient components among manufacturers. Last, common test procedures would be a necessary first step if labels and standards were ever to be harmonised:

- Developing common definitions of energy use metrics, test methods and conditions, and product categories for energy test protocols.
- Developing common definitions of performance metrics, adjustments for service features and product categories for product characterisations.

If countries were to decide to harmonise their labelling and standards programmes, their differing, and sometimes firmly established, product test protocols would need to be reconciled. If parties cannot agree on common tests, they will find it nearly impossible to harmonise their systems of labels and standards. For international harmonisation of test protocols to work properly, they must take into account regional and national differences in electricity, climate and local environments, product service features, and behavioural and product usage patterns.

Electricity – The supply current has different voltages and frequency around the world (e.g. 120 V and 60 Hz in North America; 230 V and 50 Hz in Europe), so testing is performed at these local electrical conditions. Appliances are manufactured to work at the local electrical conditions and must be tested according to the specified input requirements.

Climate and local environments – Local conditions affect the testing parameters of some products, in particular space heating and cooling products. For example, for room air-conditioners, North America uses one set of conditions for temperature and humidity whereas most of the world uses the ISO protocol which allows for any of three possible sets of conditions. For central air-conditioners and heat pumps, the difference in test protocols is greater – the United States uses a seasonal energy efficiency ratio (or SEER) whereas the ISO protocol uses a single point rating. Local conditions regarding water hardness affect the testing of wet appliances.

Product service features – For example with refrigerator-freezers, there are multiple doors in Japan, multiple freezer compartment temperatures in Europe, and through-the-door features in the United States.

Behavioural and product usage patterns – For example, wash temperatures for washing machines vary in different parts of the world: European and North American temperatures are higher than in Japan and OECD-Australasia.

Non energy performance criteria – For example European clothes-washers and dishwashers are tested for their cleaning performance whereas North American ones are not.

The barriers to harmonisation can be overcome through definitions of product classes flexible enough to accommodate differences in product characteristics and use. Take the example of room air-conditioners. The ISO protocol allows for a rating under a choice of three operating conditions, one of which is identical to the US test protocol. Harmonisation could allow for the status quo, but also requires all countries to provide a rating under a common operating condition, and others as they wish. Ideally, one condition would be sufficient, but the wide variation in climate across the countries using air-conditioners could make it difficult to agree on one set of operating conditions. In some cases it may not be possible to attain harmonised test procedures that satisfy all requirements at the local level. A means of surmounting this could be the development of algorithms that allow the conversion of energy and performance values recorded under one set of test conditions into those that would apply under another set of conditions. APEC has been leading the way in exploring this option over the last few years for refrigerators and room air conditioners; however, it would be beneficial were other regions to also become involved in this subject.

Flexibility is also needed in international testing protocols to account for the energy use of special features, such as through the door ice-makers on refrigerator/freezers and power drying cycles for dishwashers. Protocols should give credit to features that reduce energy use; for example, washing machines that have higher spin speeds on the spin dry cycle take more moisture out of clothes, reducing the energy needed to dry them in a clothes dryer.

The timing of protocol harmonisation is hard to estimate because it depends very strongly upon the degree of agreement between the harmonising parties. In the current climate there is no necessity to harmonise protocols between the major markets; thus, it will only happen if all the parties agree. Assuming that agreement is possible, protocol harmonisation could take as little as two years.

HARMONISATION OF LABELS AND STANDARDS

There are a number of factors that would complicate, and in some cases render infeasible, common labels and standards. First, differing socio-political attitudes toward voluntary versus mandatory measures would need to be accommodated. Second, differing cost-effectiveness of labels and standards would need to be resolved. Regional and national differences in cost-effectiveness of labels and standards arise from the same factors that affect the appropriateness of tests described above: climate, product service characteristics, and behavioural and product usage patterns. But other factors are also involved: electricity and fuel prices, private and social discount rates and other economic factors, manufacturing costs, and the state-of-the-art of the manufacturing industry. Also, in the case of labels, differences in consumers' perception and comprehension, which can vary from country to country, would need to be accommodated.

The perceived need for efficiency programmes such as regulatory standards varies to some degree with prevailing electricity and fuel prices. Regions with low energy prices and surplus capacity are generally less disposed toward efficiency measures. Additionally, the level of an efficiency code that is cost-effective is strongly dependent upon the price of energy (and also behavioural patterns and climate).

Policy preferences for mandatory and voluntary measures are another important factor in harmonising energy programmes. In some countries, such as Japan and Sweden, voluntary measures fit well with policy predilections. Achieving harmony among all stakeholders is a particularly important policy objective in this kind of environment. Therefore, it is undesirable to impose regulations on appliance and equipment manufacturers if effective voluntary measures can be agreed to. It should be possible for countries to co-operate on energy programmes regardless of whether they prefer mandatory or voluntary approaches to product labels, targets and regulatory standards.

Product service characteristics and operating behaviour differences also affect the ability to harmonise performance specifications. For example, if washing machines are used more often in some regions than others, more stringent efficiency standards would be economically justified in those regions of greater use. There may be little to be gained by harmonising energy labels and standards across products that are very different, European models are generally smaller and offer different services to US models. Other parameters such as freezer compartment temperatures are also different in Europe and North America.

In short, harmonisation of labels and standards makes most sense for products in which product characteristics and usage patterns (behaviour) do not vary greatly from country to country, and where the level of efficiency that is economically justifiable is rather insensitive to energy prices.

OPPORTUNITIES FOR INTERNATIONAL HARMONISATION

Global harmonisation of test protocols and possibly regulatory standards for refrigerators and freezers would take a great amount of effort and a very long time. The net benefits of global regulatory standards are not clear. The potential gains from extending existing regulatory standards to new areas or regions may be offset by the regulatory standards being lower than they might otherwise be. Some experts feel harmonisation of testing procedures could be worthwhile. Others stress the opportunities for work without the need for fully harmonised test protocols. For example there are great opportunities for energy savings from refrigerators and freezers in China, India and the Central and Eastern European Economies.There is perhaps a greater need for and net benefit to be gained from encouraging the development of "regional" regulatory standards, rather than global regulatory standards, given the different characteristics of products in each market In fact, the type of appliances, say refrigerators for instance, may not be very different between markets although the strength and organisation of the respective industries and government authorities may well be.

Air-conditioners are a potential area for "regional" regulatory standards, in particular in South-East Asia.The attractiveness stems from the growing market, the similarity of testing protocols world-wide and the fact that the product characteristics do not vary greatly from country to country.

From the viewpoint of achieving early success in harmonisation of regulatory standards, efforts aimed at micro-wave ovens might be worthwhile.The test protocol is already the same throughout the world. There may be limited interest, though, because the magnitude of the energy saving potential in this area is considered small.

Wet appliances (washing machines, clothes dryers and dishwashers) are a difficult area for harmonisation efforts because, among other things, the energy use of these appliances is heavily influenced by behavioural characteristics. However, there might be opportunities for international co-operation of some other kind, perhaps in sharing tasks in analytical efforts.

IEA MEMBER COUNTRIES' LEADERSHIP IN APPLIANCE ENERGY EFFICIENCY PROGRAMMES

Leading economies have developed the most robust appliance energy efficiency policies. The potential from global application of such programmes in the rest of the world, especially in developing countries, is several times larger than the energy savings that have been achieved so far in OECD countries. As appliances are more and more traded regionally and internationally, appliance energy efficiency programmes can also gain from adequate harmonisation efforts. Countries – or markets – without state-of-the-art standards can take advantage of work done in other countries, including work by governments to develop standards and work by manufacturers to produce products that meet these standards.

However, while harmonisation is a laudable goal, in practice it is often not a straightforward task. For instance, test standards are frequently different among countries and products have been optimised to the particularities of each country's test standard. Similarly, minimum energy efficiency levels vary among countries: countries requiring a high level of efficiency are unlikely to want to weaken their standards in the interests of international harmonisation, and countries that currently have minimal efficiency requirements may be reluctant to increase the stringency of their standards.

In the near and medium-term, work on harmonisation is likely to proceed on two levels. First, test and minimum efficiency standards will become increasingly harmonised within trade blocs. Second, work towards developing truly international test procedures will proceed for some products, particularly products where features do not vary dramatically among countries.

Any developing country may decide to implement its own appliance energy efficiency policy. However, this is not what is currently being observed. Countries desiring an energy efficiency label or a minimum standard for its appliance market usually seek the support of the most advanced countries in the field. As an illustration of this, Mexico has been developing a national appliance energy standard programme that is very similar to the one in force in the US although their label is quite different. Most East-European countries, including the Russian Federation and Turkey have adopted or are adopting, the European Union's appliance energy labelling programme. Many appliance labels adopted in Latin America, the Middle East and North Africa are the same as or resemble the EU label.

In the efforts necessary to limit greenhouse gas emission, this spill-over effect of appliance energy efficiency policies in OECD countries outside their borders is to be encouraged and accelerated. This will not only benefit the global environment. It will also positively affect the world industry and potentially reinforce the trade of appliances on the regional or global market.

As a corollary, if appliances energy efficiency programmes are not fully implemented or partially applied in leading economies, it is very unlikely that developing nations will develop their own programmes.

Appliance energy efficiency programmes in OECD countries do present a unique and highly positive rebound effect: ignoring this effect reduces the opportunity to obtain further energy savings and their related greenhouse gas reduction on a larger scale, building on this rebound effect.

POSSIBLE ROLE FOR THE IEA IN APPLIANCE ENERGY EFFICIENCY PROGRAMME

The International Energy Agency is the main international forum on energy issues for developed countries. IEA is well-placed and already equipped to facilitate international collaborative activities to promote appliance energy efficiency programmes. The IEA hosts a wide range of targeted collaborative activities called implementing agreements (IEA 1999)[23].

An IEA forum could provide co-ordination between existing schemes and opportunities for discussion of items of common interest in appliance energy efficiency programmes. IEA activities might include sponsoring newsletters and electronic bulletin boards to facilitate information exchange; the promotion of networking among individuals and organisations; hosting *ad hoc* working groups, workshops and conferences; and co-sponsorship of a policy science journal on energy efficiency. If a more activist role is envisaged, the IEA could organise government-industry roundtables on testing procedures and levels, and host negotiations on target values.

Other IEA-sponsored or co-ordinated activities might include research studies on market transformation and technology issues; preparing evaluation reports or case studies on the various programmes and policy approaches that address appliance programmes; and comparative studies of efficiency labelling, quality labels, standards and comparisons of energy testing and rating methods. Activities could also include defining the methodology for how appliance energy consumption base lines should be established for use under the Clean Development Mechanism of the UNFCCC process (Kyoto Protocol).

23. IEA 1999. "International Collaboration in Energy Technology" ISBN 92-64-17057-X.

Given the IEA's expertise on global energy matters, and its reputation for facilitating consensus building, the Agency is well positioned to play an important role in facilitating progress on appliance energy efficiency programmes and thus countries' efforts to mitigate greenhouse gas emissions.

IEA Demand-Side Management implementing agreement

Technology procurement as a means of stimulating the production and marketing of new energy saving appliances was extended to an international scale by the IEA Demand-Side Management Implementing Agreement. Its Task for Co-operative Procurement of Innovative Technologies developed a process for organising international co-operative procurements and tested that process in several pilot projects. The process focused on a combination of procurement and promotion – towards alternative ways of recognising successful new products, not necessarily through guaranteed large-volume purchasing. An award – the "IEA DSM Award of Excellence" – was introduced.

In the residential sector, the effort was directed towards the development of a low-energy tumble clothes dryer. The winner, the world's first dryer based on heat pump technology, uses 50% of the energy of an average conventional dryer and was the first dryer to qualify for an A rating in the EU labelling scheme. It received the IEA DSM Award of Excellence and promotional activities, but no guaranteed sales. The dryer is promoted by the participating countries through rebate campaigns with varying degrees of subsidy (the Netherlands, Denmark, Sweden and Spain) and through information activities (Finland)[24].

IEA Heat Pump Programme (research, development and demonstration)

For the most part, governments influence appliance efficiency indirectly rather directly. That is, appliance efficiency policies, standards, technical procurement and design competitions, push manufacturers to develop new, less expensive ways of making their products more efficient. There is very little government funded R&D for appliance efficiency.

24. IEA Implementing Agreement on Demand-Side Management Technologies and Programmes, Final Management Report, Annex III Co-operative Procurement of Innovative Technologies for Demand-Side Management, May 2000.

There is some support, however, for R&D and information dissemination concerning generic component technologies that are used in efficient appliances. One such government-supported effort is the IEA Heat Pump Programme, a non-profit organisation under which participants in different countries co-operate in projects in the field of heat pumps and related heat pumping technologies such as air-conditioning, refrigeration and working fluids (refrigerants). Under the management of an Executive Committee representing the participating Member countries, the programme carries out a strategy of:

- Quantifying and publicising the environmental and energy efficiency benefits of heat pumps.
- Developing and delivering information to support appropriate deployment.
- Maintaining and developing international technical RD&D collaboration that furthers the environmental and market objectives.
- Providing effective collaboration and flow of information to, from and between stakeholders and other relevant bodies[25].

APEC energy standards and labelling co-operation initiative: a concrete international collaboration on Appliance Energy Efficiency Programmes

Asia Pacific Economic Co-operation (APEC)[26] was formed in 1989 to promote regional co-operation in the Pacific Rim area, an area accounting for nearly half of world population, GDP and trade. APEC operates by voluntary co-operative action among its 21 member economies.

The energy component of APEC's activities is handled by the Energy Working Group (EWG), which has an active programme of co-operation[27] under the directions set by APEC Energy Ministers.

One of the most prominent and tangible components of the APEC EWG work programme is the projects and co-operative activities on energy performance standards for traded appliances and equipment. This strong

25. http://www.heatpumpcentre.org/network/hpp.htm
26. see http://www.apecsec.org.sg/
27 see http://www.apecenergy.org.au/welcome/home/index.html

EWG focus is due to the strong trade in energy consuming appliances and equipment within the APEC region. As APEC member economies develop and implement their energy efficiency improvement programmes, energy performance standards and labelling activities are invariably a key and growing part of such programmes. The need to avoid duplication and reduce technical barriers to trade from such expanding standards and labelling programmes is thus a strong driver for enhanced APEC regional co-operation.

Demonstrating the success and continued relevance of APEC standards and labelling activities, the Energy Ministerial Meeting held in Mexico City in July 2002 endorsed the following declaration:

"We acknowledge the importance of sharing information on energy standards, and the desirability of reducing barriers to trade in energy- efficient appliances and products to enhance energy efficiency. We therefore endorse the Energy Standards and Labelling Co-operation Initiative as a timely and effective policy instrument. We also welcome the Pledges of fifteen economies under the Pledge and Review process for achieving energy efficiency gains. We further encourage all economies to consider a Pledge."

The APEC work on appliances has covered:

- Quantifying the trade in energy consuming appliances and equipment.
- Categorising the range of applicable energy standards and their technical requirements.
- Clarifying the adequacy of mutual recognition arrangements of test results.
- Investigating testing requirement equivalence and potential for alignment and harmonisation.
- Determining the potential for conversion algorithms between different testing requirements.
- Running symposia, workshops and colloquia on various aspects of standards and labelling.

A concrete achievement of the APEC energy standards and labels co-operation initiative is the establishment of an on-line Energy Standards Information System (ESIS), described in more detail below.

Co-operation on energy standards is almost certainly the single most important and visible APEC co-operative activity in the area of energy efficiency and conservation. This is because such co-operation is a tangible activity that facilitates the development and trade in energy-efficient appliances and equipment and reduces the technical barriers to trade in such energy-efficient products. Such forward-looking co-operation is also a good area for ongoing co-operative work as it is not threatening to any national or sectoral interests, and thus is a good fit with APEC's primary voluntary trade facilitation focus.

SUGGESTIONS FOR INTERNATIONAL SHORT-TERM COLLABORATIVE ACTIVITIES

The following section suggests some avenues for possible international collaboration in the field of appliance energy efficiency policies and measures.

Appliances on the World-Wide Web

The World-Wide Web offers powerful features to enhance international collaborative activities on energy-efficient end-use programmes, especially the one addressing end-use equipment such as residential appliances. The Web is extensively used by numerous energy efficiency institutions. There already exist several database activities solely dedicated to appliance certification, labelling or MEPS:

- The European Appliance Information System (EAIS http://www.eais.eu.com) is a product database of appliances available in all European markets. This on-line database is designed to help European consumers make an informed choice when buying new household appliances. At the present stage, the database gives information on all refrigeration, dishwashing and laundry appliances available in each individual country. The database also gives information on economic and environmental savings any consumer can make by using energy-efficient appliances. As further appliances and products are added to the EU energy labelling system, the database will be extended to include them. Additional information on energy, the environment, the EU energy labelling system and appliance fiches are also included.

- In Europe, SHARE is a project between several EU countries designed to facilitate the verification of manufacturers' claims across several markets. SHARE is a tool for policy-makers who are running appliance policy programmes in their own countries. So far, this Internet based tool is accessible only to participating institutions.
- The Asia Pacific Economic Co-operation (APEC) forum has established an important database on energy performance testing standards, energy labels and minimum energy performance standards for the 21 economies in the APEC region, which includes the US, Canada and Mexico. The purpose of APEC's Energy Standards Information System, called APEC-ESIS, is to establish a system for systematically and simply tracking and updating information on energy-efficiency performance standards that are either in use or under development (www.apec-esis.org). The database could easily be extended to cover appliance energy performance regulations in other parts of the world.

There exist several opportunities for developing or expanding database activities in the field of end-use energy efficiency, such as:

- Facilitate information sharing on appliance energy efficiency programmes.
- Consolidate appliance certification, compliance and energy efficiency ratings across markets.
- Benchmarking and monitor energy efficiency improvements within and across national appliance market.

Promoting energy-efficient ICT

There exist at least three areas, that could eventually be combined for international collaborative activities to promote energy efficiency in information and communication technologies.

International Energy Star for office equipment and consumer electronics

The US EPA's Energy Star label is seen as a de facto "international" label for office equipment. The US EPA manages a series of bilateral agreements or licence agreements with different countries wishing to use Energy Star on their market. Several IEA Member countries are engaged with US EPA on such agreements and already use the Energy Star scheme to promote energy-efficient information and communication technologies. An international dialogue is being established progressively among the managers of the Energy Star programme in different IEA Member countries.

The IEA seems to be well positioned and equipped to support a more formal international Energy Star programme. For instance, through administrative support, analytical support to update the international programme, co-ordination of Web-based Energy Star database, etc.

Policy assistance to reduce standby power waste below 1 Watt

Reducing standby power waste below 1 Watt has progressively become the ultimate international benchmark at which governments or institution are aiming. The IEA Standby Power Initiative has inevitably generated a unique momentum to tackle inefficient standby power modes. Consolidating the dialogue between the different policy-makers and stakeholders across OECD and non-OCED countries is likely to accelerate and enlarge the impact of this project.

Promoting energy-efficient power supplies

As described in the previous chapter, power supplies appear an excellent candidate for a concrete and immediate international energy efficiency collaboration. Engaging key non-OECD countries, like China – hosting by far the largest number of manufacturers of power supplies – will inevitably generate the most significant outcome.

Fostering end-use metering activities

Several institutions within IEA Member countries are running end-use metering campaigns in the residential sector. The data collection techniques may be different among the research groups, but the objective is the same: to understand better the electricity demand and the associated load pattern.

End-use metering makes it possible to access very precise information on electricity consumption: where, when and in which end-uses electricity is being consumed. End-use metering campaigns are usually expensive and the panels of customers surveyed are usually limited. However the high quality of the data collected may be instrumental, for example, to help:

- Calibrate energy demand models.
- Utilities better understand the load profile of their customers.
- Research institutes identify new behaviour, new energy trends.
- Collect pertinent information on end-use patterns while designing MEPS and labelling policies, particularly for performing life-cycle cost assessment.
- Countries assess the real impact of national appliance energy efficiency strategies.
- Governments better assess the evolution of electricity being consumed.

Over the past few years, an informal group has been sharing information on end-use techniques and opened several debates on the main findings from end-use surveys. The main benefits of formalising an international collaboration can be summarised as:

- To produce a series of reports describing the key findings on power demand, energy consumption and the user's behaviour vis-à-vis each individual end-use. Such specific reports could be prepared on cold appliances, lighting, standby power, washing machines, space conditioning, use of ICT, clothes drying, cooking, etc.

  Such reports could be useful to the whole energy community: utility companies, appliance and equipment manufacturers, energy efficiency policy-makers, energy analyst and modellers, etc.
- To harmonise the way the data analysis is done in order to facilitate exchange of findings.
- Reports on lessons learnt from setting up a monitoring programme (pilot study, sample size etc.).
- Compilation of a guideline on how to monitor different forms of energy (electricity, gas, LPG, solid fuel), but also temperature, climate conditions, etc.

- To develop guidelines on how to analyse data (How to determine standby load for instance).

Outreach activities, technical and policy assistance in appliance energy efficiency

From previous chapters, appliance energy efficiency programmes such as MEPS and labels appear as one of the best energy efficiency policy practices. IEA Member countries experiencing and benefiting from such policies have a leadership role vis-a-vis many developing nations or countries with economies in transition. A growing number of economies are seeking international technical and even policy assistance in order to introduce or duplicate successful appliance energy efficiency MEPS and labels programmes in OECD countries.

The progressive expansion of policies and measures to mitigate greenhouse gas emission in all sectors and all economies is likely to stimulate further such a need for technical assistance.

Interestingly, in 1999, three US-based organisations formed the Collaborative Labelling and Appliance Standards Program (CLASP www.clasponline.org) to facilitate the design, implementation and enforcement of energy efficiency standards and labels for appliances, equipment and lighting products in developing and transitional countries around the world. CLASP's approach consists in promoting MEPS and labels through partnerships with agencies, stakeholders and relevant institutions in those countries. CLASP invites and relies on representatives of countries that have successfully adopted standards to join the programme in reaching out to neighbouring countries. CLASP will also form partnerships with a variety of policy and technical specialists from around the world, including representatives from American, European, Japanese and Australian organisations, developing country non-governmental organisations (NGOs), testing laboratories, manufacturers, research organisations and universities. CLASP proposes a format for facilitating concrete transfer and adoption of best policy in energy efficiency. CLASP's approach and activities should be encouraged further in bilateral or multilateral efforts to mitigate greenhouse gas emissions. For that purpose, CLASP has signed a partnership agreement with the Climate Technology Initiative (www.climatetech.org).

CLASP or a similar organisation could also help put in place and host a forum of international experts to peer review appliance energy efficiency analyses, e.g. standardisation and bench-marking of statistical or energy-engineering analyses.

ELEMENTS FOR A CONCLUSION

Energy efficiency policies on end-use equipment, especially appliances in the residential sector, present all the attributes for becoming a role model in government portfolios to help mitigate greenhouse gas emissions. Mandatory appliance labelling combined with minimum energy efficiency standards are two clear best practices in energy efficiency policy setting. When programmes are designed under the principle of least life-cycle-cost, they will not only deliver quantifiable energy savings, but also large and lasting reductions in the associated GHG.

Appliance programmes in the residential sector are an opportunity not only for governments but also for the appliance industry which can benefit from a more transparent market.

However, there is nothing like a free lunch: appliance programmes must be fuelled with sustainable resources, both human and financial, to deliver.

Based on a critical analysis of current energy efficiency policies in IEA Member countries, it is possible to propose a framework model for an ambitious but realistic appliance energy efficiency programme. Most policies and measures designed to promote energy-efficient appliances can be exported and adapted from one country to another and from one region to another. More and more appliances are evolving in markets that are every day more global, hence the international nature of appliance energy efficiency programmes. This book makes a call for a greater and more profitable international co-ordination on energy efficiency policy design and implementation.

ANNEX

Summary of the IEA Appliance Stock Model electricity demand in 22 IEA Member Countries* in TWh/year

Scenario: Current policies	1990	1995	2000	2005	2010	2020	2030
Clothes-drying	58.1	67.4	77.1	83.7	88.9	97.8	104.5
Clothes-washing	96.3	92.2	87.6	77.8	69.6	63.5	66.2
Cooking	64.0	70.5	79.6	81.3	83.8	88.9	94.4
Dishwashing	37.0	40.1	44.1	45.3	46.0	46.6	47.2
Lighting	227.9	265.7	301.7	337.9	358.5	396.2	435.7
Other	281.2	317.1	390.9	452.8	504.5	579.9	664.9
Refrigeration & freezing	335.3	330.8	314.6	292.5	273.7	254.8	259.0
Space cooling	132.2	136.0	149.2	163.7	172.5	176.0	181.1
Space heating	325.1	356.0	377.2	383.2	383.7	380.4	390.4
Standby	61.1	85.0	120.0	156.8	198.8	293.8	403.8
Television	66.2	71.8	82.1	98.1	121.4	157.0	190.4
Water heating	300.7	306.6	317.1	335.7	352.3	401.2	476.8
All	**1,985.0**	**2,139.2**	**2,341.1**	**2,508.8**	**2,653.5**	**2,936.2**	**3,314.3**

Scenario: LLCC	1990	1995	2000	2005	2010	2020	2030
Clothes-drying	58.1	67.4	77.1	78.3	65.3	41.8	40.7
Clothes-washing	96.3	92.2	87.6	76.8	60.3	48.8	50.4
Cooking	64.0	70.5	79.6	80.7	81.6	82.7	86.7
Dishwashing	37.0	40.1	44.1	45.1	44.0	40.8	43.9
Lighting	227.9	265.7	301.7	242.4	168.4	184.3	199.9
Other	281.2	317.1	390.9	404.7	425.6	471.4	539.6
Refrigeration & freezing	335.3	330.8	314.6	286.4	254.0	211.9	215.8
Space cooling	132.2	136.0	149.2	161.1	157.1	149.0	152.1
Space heating	325.1	356.0	377.2	375.2	279.3	291.6	309.0
Standby	61.1	85.0	120.0	96.8	67.8	79.8	90.9
Television	66.2	71.8	82.1	91.1	86.8	93.1	113.9
Water heating	300.7	306.6	317.1	328.8	321.5	318.1	362.1
All	**1,985.0**	**2,139.2**	**2,341.1**	**2,267.5**	**2,011.8**	**2,013.1**	**2,205.0**

Total Savings	**1990**	**1995**	**2000**	**2005**	**2010**	**2020**	**2030**
Clothes-drying	0.0	0.0	0.0	5.5	23.6	56.0	63.8
Clothes-washing	0.0	0.0	0.0	0.9	9.3	14.7	15.8
Cooking	0.0	0.0	0.0	0.6	2.2	6.2	7.7
Dishwashing	0.0	0.0	0.0	0.2	2.0	5.8	3.3
Lighting	0.0	0.0	0.0	95.4	190.0	212.0	235.8
Other	0.0	0.0	0.0	48.1	78.9	108.5	125.3
Refrigeration & freezing	0.0	0.0	0.0	6.1	19.7	42.9	43.2
Space cooling	0.0	0.0	0.0	2.6	15.4	27.0	29.0
Space heating	0.0	0.0	0.0	8.0	104.4	88.8	81.4
Standby	0.0	0.0	0.0	60.0	131.1	214.0	312.9
Television	0.0	0.0	0.0	7.0	34.5	64.0	76.4
Water heating	0.0	0.0	0.0	6.9	30.7	83.1	114.7
All	**0.0**	**0.0**	**0.0**	**241.3**	**641.8**	**923.1**	**1,109.3**

* Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

ABBREVIATIONS AND ACRONYMS

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie, France
AHAM	Association of Home Appliance Manufacturers
APEC EWG	Asia Pacific Economic Co-operation Energy Working Group
CDM	Clean Development Mechanism
CFC	chlorofluorocarbon
CEE	Consortium for Energy Efficiency
CEF	Clean Energy Future
CFL	compact fluorescent lamp
CLASP	Collaborative Labelling and Appliance Standards Program
CO_2	carbon dioxide
DD	degree days
DOE	Department of Energy
DSM	Demand-side Management
DVD	digital video disc
EEI	Energy-efficiency index
EERAC	energy efficiency rating for air conditioner
EHPA	European Heat Pump Association
EPAct	Energy Policy Act
ESCO	energy service company
EU	European Union
EVA	Energieverwertungsagentur (Austria)
GEEA	Group for Energy Efficient Appliances
GHG	greenhouse gas
GWh	gigawatt-hour (1 watt x 10^9)
HVAC	heating, ventilation and air-conditioning
ICT	information and communication technology

IEA	International Energy Agency
IRD	Integrated receiver decoder
JI	Joint Implementation
kW	kilowatt (1 watt x 1,000)
kWh	kilowatt-hour
LCC	life-cycle cost
LLCC	least life-cycle cost
LPG	liquefied petroleum gas
MEPS	mandatory minimum energy performance standards
Mtoe	million tonnes of oil equivalent
MW	megawatt (1 watt x 10^6)
NAECA	National Appliance Energy Conservation Act
NAEEEC	National Appliance and Equipment Energy Efficiency Committee (Australia)
NEEA	Northwest Energy Efficiency Alliance
NGO	non-governmental organisations
NRCan	Natural Resources Canada
OECD	Organisation for Economic Co-operation and Development
RMIT	Royal Melbourne Institute of Technology
SERP	Super Efficient Refrigerator Program
STEM	Swedish National Energy Authority
SWEEP	Save Water and Energy Education Program
TTS	TTS Institute, Finland
TSD	Technical support document
TWh	terawatt-hour
UEC	unit energy consumption
UNFCCC	United Nations Framework Convention on Climate Change
VA	Voluntary agreement
VCR	Video cassette recorder
WEO	World Energy Outlook
Wh	Watt-hour

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