The actual and potential impact of residential electrical equipment energy efficiency policies in the OECD

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Abstract
Electrical appliances are the fastest growing energy users, after automobiles. Cost-effective technology exists that could improve the energy efficiency of appliances by more than a third in ten years. The greenhouse gasses emitted by appliances in OECD Member countries alone could be slashed by the equivalent of 344 million tonnes of CO_2 by 2010 with the adoption of least life-cycle cost appliance policies. In OECD Europe, the CO_2 reduction is equivalent to a third of the required reductions under the Kyoto Protocol and achieved at a net economic benefits of around 196 Euro/tonnes of CO_2 abated. By 2030, these savings would amount to a staggering 1 250 TWh/year of electricity and 655 Mt/year of CO_2 in OECD.

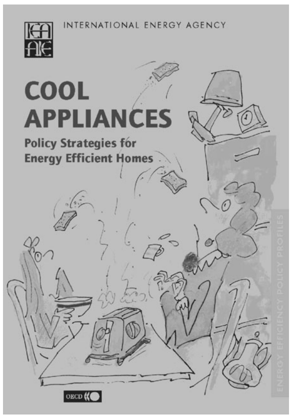
The paper summarises the finding of an OECD-wide study on the potential energy savings and carbon reductions to be achieved through technical improvements to appliances in the residential sector. A detailed stock model allows the analysis of past trends, present situation, and probable trends in the residential electricity demand in OECD countries. The model addresses each individual end-use. Each saving potential is related to a specific combination of policy options that most likely can stimulate greater manufacture and use of energy efficient appliances. The paper suggests ways to strengthen existing appliance-efficiency programmes, and demonstrates how international collaboration can enhance those programmes.

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 more than compensate the potential extra cost of 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 (Ecodrome 1998, Eureco 2001). 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.

The paper summarises the findings of a new study "Cool Appliances: Policy Strategies for Energy Efficient Homes" (Cool 2003) performed by the International Energy Agency



(IEA) to encourage 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 may 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? The new analysis aims to provide concrete answers to these questions.

Ambition

This study 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 study comprises two distinct sets of analyses: 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 study – and the forthcoming IEA publication – relies extensively on literature, surveys, published data, energy statistics and research publications available on residential electricity demand 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 family of end-use and of the level of ownership and use. The model is then used to analyse a range of policy scenarios.

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 major 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 new 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.

Table 1: 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-Conditioners			Space Cooling – Central Air-Conditioners		
Europe	31	0.02	1 714	0	-	0
North America	368	0.52	714	712	0.33	2 172
Australasia	125	0.24	524	-	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

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. 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 co-generation, 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.

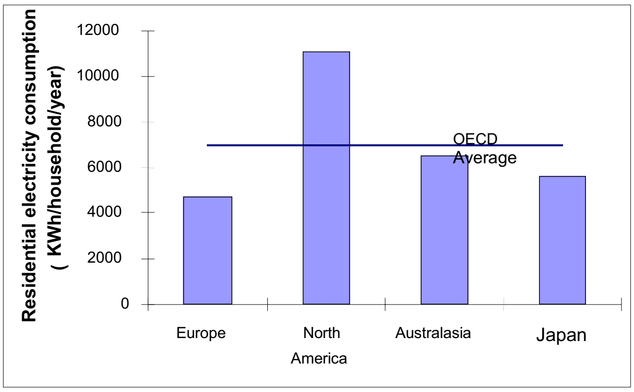


Figure 1. *Residential electricity consumption and growth in four major OECD regions, 2000.*

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 (Figure 1, Table 1). 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.

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 own and are 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 OECD will grow by 14% from 2000 to 2010, and by 42% by 2020 (Fig. 2).

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. In contrast, electricity consumption for clothes washing – an early target of efficiency policy – declined by 9% over the 1990s.

Fortunately, there is very 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 (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 (Figure 3). 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.

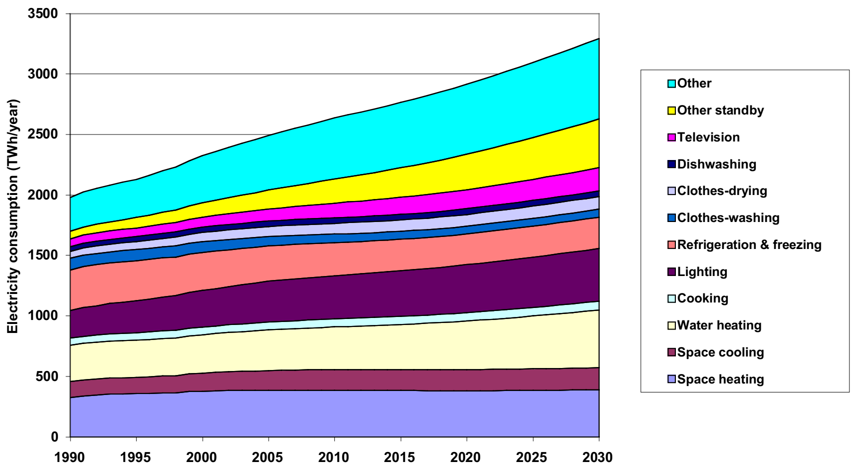


Figure 2. *Projected OECD residential electricity consumption by end-use with current policies.*

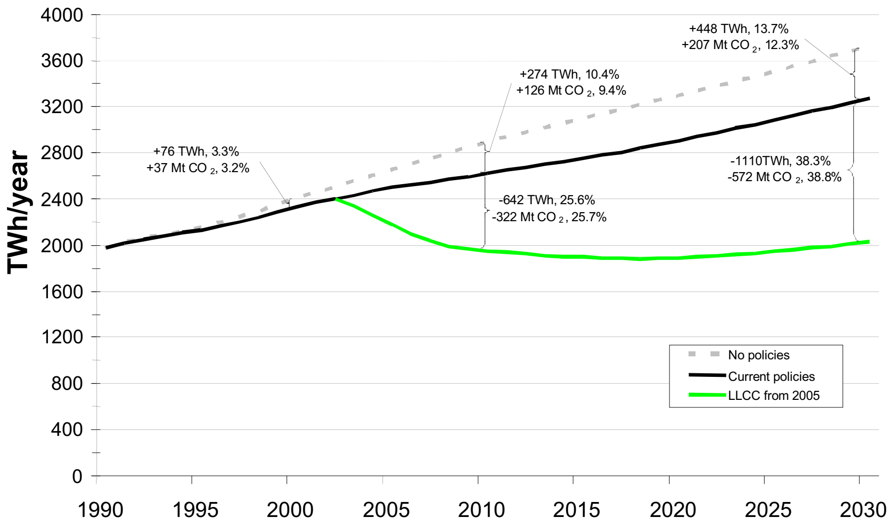


Figure 3. *Residential electrical appliance electricity consumption under the No Policies, Current Policies and Least Life-Cycle Cost from 2005 scenarios in OECD countries, 1990 to 2030.*

ELECTRICITY SAVINGS BY END-USE

The evolution of energy savings for the LLCC from 2005 scenario compared with the Current Policies scenario are indicated in Figure 4.

Not surprisingly the larger savings occur for those end-uses which are currently unregulated, namely: standby power, lighting, TVs 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 are obtained from efficiency improvements in standby power which 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 produces savings of 104 TWh in 2010, 89 TWh in 2020 and 81 TWh in 2030. While those for water heating 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, clothes-washers, clothes-dryers and space cooling rise from 70 TWh in 2010 to 155 TWh in 2030.

Cost-effective appliance energy efficiency policies can therefore 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 US$ 65; while in Europe, each tonne of CO_2 avoided would save consumers some 169 Euro. 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 37 Mt CO_2/year in 2000, avoiding the need for at least 20 gas-fired power stations. Even without further strengthening, these same policies will go on to reduce emissions by 126 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. 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.

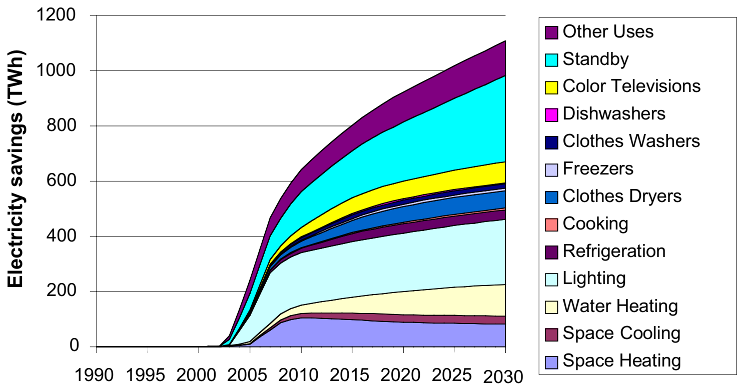


Figure 4. *Projected OECD residential electricity savings by end-use for the Least Life Cycle Cost efficiency levels from 2005 scenario compared with the Current Policies scenario.*

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, as well as 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.

Policy 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 equipment energy end-uses 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 technology learning 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.

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.

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Note: an extensive set of references is given in the full publication (Cool 2003).

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