A Case Study for Energy Efficient Home / Office Appliances

When buying an appliance, payment is for both – the initial cost and the operating cost for as long as you own it. Over the life-span of an appliance the energy cost can be many times greater than the initial cost. Therefore it pays to buy energy efficient appliances for home and office

Introduction

Mitigating climate change and achieving stabilization of greenhouse gas atmospheric concentrations – the objective of the United Nations Framework Convention on Climate Change (UNFCCC) – will require deep reductions in global Energy-related Carbon Dioxide (CO_2) emissions. Energy Efficiency improvements in appliances can bring significant GHG emission reductions at low or negative cost to society, by lowering overall Energy use and expenditures for consumers without reducing the quality of service, and by decreasing overall Energy investment needs.

This paper presents case studies touching both on best practices for technology collaboration and on policy collaboration. This case study is particularly relevant, because of its global market varied issues, ranging from refrigerators to standby consumption and upcoming new services (mainly in Information and Communication Technology – ICT).

Residential appliances

Residential appliances and equipments use 30% of all Electricity generated in Organization for Economic Co-operation & Development (OECD) countries, producing 12% of all Energy-related carbon dioxide emissions. They are the second largest consumer of Electricity and third largest emitter of Greenhouse gas emissions in OECD countries. Since 1973, primary Energy demand in the residential sector in OECD countries has grown more than all other sectors apart from transport.

The potential for efficiency improvements is significant, as assessed in the International Energy Agency's (IEA) "Cool Appliances" – IEA, 2002. Implementing best available technologies through policies, leading to a least Life-Cycle Cost for end-users would deliver up to 642 TWh of savings by 2010 (24% of the total related Electricity use of this date) and 1,110 TWh (33%) by 2030, compared with current policies. Related CO_2 reductions would reach 322 $MtCO_2$ in 2010 and 572 $MtCO_2$ in 2030. Furthermore, these savings can be achieved at a negative cost to society. The extra cost of improving appliance efficiency being more than offset by a saving in running costs over the appliance's life. Each ton of CO_2 avoided this way would save consumers $65 in the US and €169 in Europe.

As for the developing and Economies in Transition Countries, comprehensive figures are not available, but some general statements are possible. The range of equipment and use is very wide among these countries. In all cases, potential savings are expected to be high there too. The contribution of residential appliances' uses to overall Electricity consumption, as well as their absolute level per capita is usually less in developing countries than in OECD countries. Nevertheless, relative potential savings for domestic appliances in developing countries should be higher than in OECD countries, at least in the short and medium term. This is because the average level of efficiency is lower in developing countries, both as a result of lower income and less developed markets. Few of these countries have implemented measures to improve appliance efficiency. Also, the ownership rate of appliances is lower, but growing more rapidly than in IEA countries. The potential impact of new and more efficient appliances is higher, because households still have to be equipped, whereas in OECD countries the markets are in a turnover phase. Furthermore, this impact would be felt even more in the developing countries, as they face problems installing generation capacity to keep up with growing demand.

Domestic appliances encompass a variety of uses and technical issues. For the purpose of this study, particular scope will be given to the following:

- Refrigerators and freezers (referred to as "Cold Appliances");
- Standby and off-mode consumption (Which is also related to Office Equipment);
- Some new upcoming end-uses such as TV decoders or multiple purpose "Set-Top Boxes" and other ICT

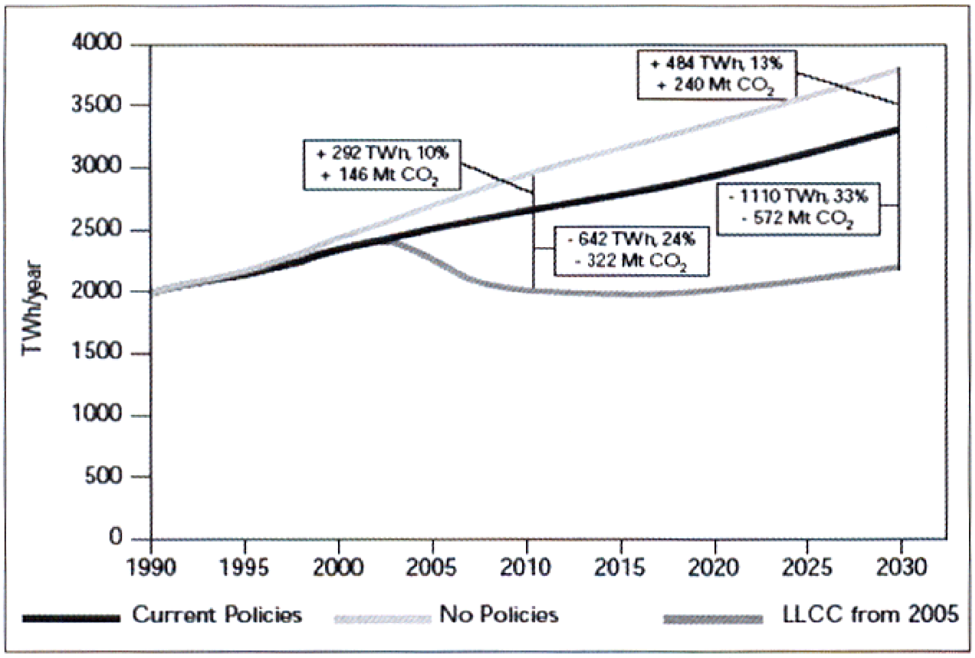

Figure 1: Residential electrical appliance electricity consumption under no policy, current policy and least life-cycle cost 2005 scenarios in IEA countries, 1990 to 2030

Office Equipment

The specific Electricity use in commercial buildings is the fastest growing in Electricity consumption in OECD countries. Specific Electricity uses are those that cannot be supplied by other forms of Energy, for instance lighting and computers and specific cooking and hot water requirements are not. Voluntary standards or Energy-Efficiency endorsement labels such as ENERGY STAR have proven to be very efficient in reducing office equipment electricity consumption. In the case of computers and monitors, the feature when enabled causes the equipment to enter a standby mode, which reduces electricity consumption based on the Energy Star specification, when the equipment is not being used. Other office equipment employs various technologies to reduce Energy use (e.g. copy and fax machines would reduce Energy consumption by cooling down their toner while waiting for the next task). Provided these options are actually implemented, this label offers some Energy saving. However, one important issue is Energy consumption in standby or off-mode. The requirements for standby and off-modes in the Energy Star requirements have long been too high to prevent some kind of negative side effect. That is because when the offices are closed for longer period of time in a year, Computers and screens that are left in standby instead of completely switched off (provided there is an off-mode, which does not have a high off-mode consumption) would consume much more electricity during the period the offices are closed than electricity saved through its compliance with Energy Star. As per the U.S. - EU Agreement on ENERGY STAR, any changes in Energy Star specifications for products covered by the Agreement (i.e. office equipment,) are made only when there is acceptance from both EPA and the European Commission. These changes are then put into force by both Parties simultaneously. The ENERGY STAR specification for screens (also known as computer monitors) was revised and is in effect in both the EU and the US as of January 2005. It has been improved to levels that address this problem.

These illustrate ongoing international technology collaboration: an agreement was signed in December 2000 between the US Government and the European Community to co-ordinate energy-efficient labeling programs for office equipment, through the common use of the Energy Star Program logo and specifications. The European Commission then established the European Community Energy Star Board that has some power to adapt these specifications to its own market.

By fixing the standby power issue, the full potential for Energy saving through Energy Star specifications for office equipment is now addressed and should be realized progressively in the coming years, with the turn-over of existing computers. Savings of 50% can be expected from Energy Star's latest specification compared to less efficient PCs, hence, a reduction of CO_2 emissions. As it is voluntary, the Energy Star scheme may not be able to realize its full potential of the market. However, it can contribute to a large extent, and in the future. No global figures are available for Electricity use of Office Equipment. To assess an order of magnitude, the case of United States can be taken. The Electricity used by PCs accounts for 2% of national US Electricity consumption, hence emissions of 46 $MtCO_2$ could be saved. The worldwide potential could be about 100 $MteCO_2$. Other office equipment uses about 3% of Electricity in the US. Similar saving potentials could be highlighted there too.

The Potential of Energy Efficient Technologies

Cooling appliances

Almost 100% of domestic refrigeration appliances sold around the world use a vapor compression refrigeration cycle to cool stored food. A small market share exists for Gas absorption cooling appliances, which are used almost exclusively for hotel mini-bars, and a very small niche market exists for Thermo-Electrically cooling appliances for camping and mobile home use.

Money Isn't All You're Saving

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) often called "No Frost Systems". 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, frosting on the evaporator is a problem for consumers and requires the use of a fan. Beyond a certain volume and height it is difficult to maintain appropriate internal temperature distribution without using a fan. Whether the appliance is no-frost or cooled by natural convection, its Efficiency is greatly influenced by the compressor and of the heat exchangers and the quality of the control system. All of these have improved significantly over recent years.

Standby Power

Many appliances required a small level of Electricity for standby function – to power a built-in clock, respond to programming or respond to remote commands. In other devices, Energy is simply wasted when the appliance is not doing anything at all, for example when there is not a general switch preventing the system from using some electricity. As illustrated in office equipment section, the standby or off-use consumptions of electrical equipment can contribute to much higher electricity use than actually needed. High standby or idle mode consumption can offset efficiency gains delivered by the newest technology developments.

This standby and off-mode issue relates to both office equipment (e.g. Computers, Printers, Fax machines, Network facilities) and home equipment (e.g. Hi-Fi, TV and Accessories, Various Wireless equipments). In both cases, the impact of standby and off-mode depends on the actual consumption and on the time spent in each mode. However, some implications for office equipment are different to those for home equipment. Firstly, the appliances are different of course, even though computers and other office equipment are often present in households, it is unlikely to see large copiers or Fax machines in private homes.

Secondly, the equipment is used differently. Apart from fax machines and network facilities, the use of most office equipment is limited to business hours, which represents a maximum of about 3,000 hours a year (i.e. 35%) for collective equipment such as copiers or network printers; and 2,000 hours a year (i.e. 25% for personal equipment such as individual computers or printers. On the other hand, the use of home appliances with standby or off-mode consumption is very different and more diverse. For example, VCRs or DVD players are only used for a few hours per week on average, whereas TVs and set-top boxes are more likely to be used 4 to 6 hours a day.

Finally, there is an increased reliance on air conditioning in commercial buildings. As the Electricity spent in standby mode is converted into heat, additional Energy is often required to maintain the temperature at a given level. Consequently, addressing the Energy Efficiency of office equipment may induce additional savings. As for home equipment, most consumer electronics use more electricity in idle or standby mode than during their relatively brief operating time. This is true for VCRs, Set-Top Boxes, most audio and Hi-Fi equipment and most office equipment. The standby and idle-mode electricity consumption of consumer electronics (excluding TV) in IEA countries and of miscellaneous end-uses (excluding major uses such as Lighting, Cold appliances, Clothes and Dish washers, Cookers, etc.) is estimated to have been 61.1 TWh in the year 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 assessment in 2000 and represent emissions of about 250 MtCO_2. In a no policy scenario, this could double in 2010, resulting in 250 MtCO_2 increase in GHG emissions, only for IEA countries. Technology collaboration could play a dramatic role in this regard: development and spreading or efficient technologies could avoid most of these additional emissions.

Technology Focus

Efficiency Techniques in Cooling Appliances

Quality of insulation depends first on the conductivity of the foam or any other insulating material that is used. It also depends on the reduction of “thermal bridges” caused by discontinuities in the insulating layer, either due to bad insulation installation (poor design or poor manufacturing operation) or where structural or functional parts of the appliance have to penetrate the insulation. The latter can be reduced by better design (e.g. reduction of required surface holes, conductivity of the materials used, etc.). Vacuum panels are the latest development in insulation materials. Efficiency of the compressor is related to efficiency electric motors and pumps. Great deployment improvements have been made in recent years, but the most efficient models and technologies still have to penetrate the market. Larger a refrigeration appliance, easier it is to make it more “efficient” that is 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. At the same time, the useful space available for insulation or cooling circuit components is larger and 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. However, this does not completely offset the additional energy use of bigger “cold” appliances, but the variations in energy use and volume are far from being proportional.

Some simple solutions exist to prevent such consumption levels. For TV and related equipment and for hi-fi, the consumer can use a multiple adapter with a general switch. Wall switches may also operate some outlets. However, this implies both technical problems (switching on and off may cause electrical shocks and damage equipment) and behavioral constraints (regularly programming the date and hours of equipment).

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Some products exist on the market that will automatically switch off the equipment while in standby. They detect the signal of the remote control and power the appliance again when operated. These devices consume very low electricity and may provide high savings while not altering the user’s habits. This technology can be inserted directly into the appliance instead of adding some external equipment to fix this problem. There are already some TV sets in the market consuming less than 0.1 W in standby mode (against about 10 W for existing appliances).

When more complicated services are required – such as signal Amplifying or Decoding, Data processing, safeguarding memory etc. – major improvements are still possible as shown by the low Energy requirement of cellular phones, Personal organizers, etc. that provide service over several days from the little amount of Energy available in a battery (typically a few watts, equivalent to the Energy used during one hour by a relatively efficient standby appliance).

New Upcoming End-uses

Set-top boxes are new devices in the field of satellite and cable TV. They provide a multiple purpose service such as satellite signal amplifying and demodulating, data decoding, data storage, and access to a set of individual services. With a fast growing number of appliances and a low energy efficiency of existing products, they offer major potential savings.

There were about 400 million set-top boxes in early 2004, consuming 6 to 12 W on average in standby mode. It is estimated that this figure will rise to one billion in 2010 and as much as 1.5 billion in 2015. Depending on technology development and the policies actually implemented, these boxes could consume from 4 to 25 W in standby the dates mentioned demand implications. These new end-uses are therefore an obvious target for improvements in energy efficiency technology and policies that bring cost-effective and more efficient technologies to the market. In 2015, the global permanent use of electricity of set-top boxes could range from 6 GW to 37 GW. As much as 30 large power plants could be avoided by an efficient design of equipment. There is also a boom in the number and overall electricity consumption of external power supplies, mostly used for new technologies (laptop computers, cellular phones, personal organizers, and other portable device is turned off or disconnected.

A good amount of work has already been done in order to alleviate the problem of Energy consumption in set-top boxes. The issue has been addressed and various recommendations by expert organizations have been implemented in many countries either on a voluntary or regulatory basis. Tough these issues have been addressed partly, more needs to be done as most of the countries still have to implement sets of policies in regard to set-top boxes and this is where the case for international technological collaboration seems to fit in, as it would help under-privileged developing nations to formulate proven policies, as the number of such boxes and their usage increases with their development.

Some of the country and region level initiatives that have been implemented for Set-Top Boxes are:

- Voluntary negotiated agreements as the European Code of Conduct for Set-Top Boxes (part of the EU Stand-by Initiative)
- Mandatory Efficiency CEC standard (California Energy Commission)
- Voluntary endorsement labels like Energy Star (under revision) or the Korean KEMCO label (which is also used for preferential Government purchasing and may anticipate a MEPS)

Reference book:

The Bulletin on Energy Efficiency
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