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PROMOTING ENERGY EFFICIENCY THROUGH TRADE

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by Keigo Akimoto, Takashi Homma, Junichiro Oda, Fuminori Sano, Kenichi Wada, Rod Janssen, and Ronald Steenblik

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Abstract

PROMOTING ENERGY EFFICIENCY THROUGH TRADE

by

Keigo Akimoto, Takashi Homma, Junichiro Oda, Fuminori Sano, Kenichi Wada, Rod Janssen, and Ronald Steenblik

Improving energy-efficiency is essential to any strategy to reduce global emissions of greenhouse gases (GHGs). New generations of household appliances are becoming ever more energy-efficient due to continuing technological advances, often spurred by government policies. These products are manufactured, sold and used on a global scale not imagined a decade ago. Yet achieving the full market potential of these best-available technologies has proven elusive, due to a variety of factors, some of which are trade-related. This paper considers these factors and looks at ways of addressing them. It examines four products in the residential sector that have considerable potential for significantly reducing GHG emissions: refrigerators, televisions, lighting, and air conditioners. These technologies are also widely traded globally. To develop a better understanding of how improvements in energy efficiency could affect CO_2 emission reductions, the paper draws on work undertaken by Japan's Research Institute of Innovative Technology for the Earth (RITE), using their DNE21+ model. The paper finds that, if the world were to successfully implement every negative- or zero-cost measure identified in the model, the theoretical potential savings would be 8.9 Gt of CO_2-equivalent in 2020 — about 20% of global emissions projected for that year. Numerous barriers exist to achieving such a potential, however. One fundamental barrier for some countries is created by the combination of high import tariffs on energy-using appliances and artificially low domestic prices for electricity or fuels. Clearly, a first step to facilitating trade in energy-efficient products is to encourage developing and emerging economies to reform both their trade and their energy-pricing policies.

JEL classification: C61, D12, F13, F18, H87, L68, O13, O33, Q41, Q48, Q56, Y10

Keywords*:* climate change, energy efficiency, greenhouse gas emissions, energy projections, air conditioners, refrigerators, televisions, light bulbs, lamps, international trade, import tariffs.

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LIST OF ACRONYMS AND ABBREVIATIONS

..	data not available
CCS	carbon capture and storage
CFL	compact fluorescent light
CIS	Commonwealth of Independent States, a regional organisation including participating countries of the former Soviet Union
CLASP	Collaborative Labelling and Appliance Standards Programme
CO_2	carbon dioxide
ECOS	European Environmental Citizens Organisation for Standardisation, based in Brussels
EFTA	European Free Trade Association, includes Iceland, Liechtenstein, Norway and Switzerland
ETP	Energy Technology Perspectives, a major study by the IEA
EU	European Union
GHG	greenhouse gas
Gt	gigatonne (10^9 tonnes)
ICT	information communications technology
IEA	International Energy Agency
JWPTE	OECD Joint Working Party on Trade and Environment
MAC	marginal abatement cost
MEPS	minimum energy performance standard
OECD	Organisation for Economic Co-operation and Development
ppm	parts per million
UNFCCC	United Nations Framework Convention on Climate Change
WEO	*World Energy Outlook*, published by the IEA

EXECUTIVE SUMMARY

Climate-change strategies must integrate and balance a wide array of mitigation options in order to achieve sufficient greenhouse-gas (GHG) emission reductions to meet global obligations. For the purposes of this report, the important issue is that there is growing consensus on the need for mitigation targets for GHG emissions.

One of the major options to mitigate GHG emissions is increased deployment of energy-efficient products — energy consuming appliances or equipment whose overall energy efficiency rating is significantly above the average, or better than a minimum standard. New versions of energy-efficient goods are becoming more efficient due to continuing technological advances, often spurred by government policies. And equipment is being replaced at the end of its life with increasingly efficient options. But there is still significant potential for improvement. In particular, because these products are manufactured, sold and used on a global scale not imagined a decade or so ago, policies that affect trade in these products have gained in importance.

While many studies have pointed to the technical potential for improvements in energy efficiency, it is important to have a realistic appreciation of the impact that such improvements can have on GHG emissions if the deployment of the technologies were to be accelerated. Countries need to be preparing their strategies now, even in the absence of any new global agreement on climate change. Yet achieving the full market potential of energy efficiency has proven elusive, due to a variety of factors, some of which are trade-related. This report takes those factors into consideration and looks at ways of addressing them.

The current report limits itself to four products in the residential sector that have considerable potential for significantly reducing GHG emissions, both in the short and the medium term, particularly in the period to 2020: refrigerators, televisions, lighting, and air conditioners. These technologies are also widely traded globally and increased trade could have a big impact on reducing GHG emissions through the deployment of best available technologies.

To identify abatement opportunities and to develop an understanding of how efficiency improvements can affect CO_2 emission reductions, the paper draws on work undertaken by Japan's Research Institute of Innovative Technology for the Earth (RITE) using their DNE21+ model. This model is a technology-oriented, bottom-up model for global energy system assessment, capable of assessing the six greenhouse gases covered by the Kyoto Protocol in a consistent manner.

The report further assesses the principal barriers that hinder the full potential for energy efficiency from being achieved and discusses the main policy instruments used by governments to help improve the rate of deployment of these technologies.

The main conclusions from this report are:

- If the world were to successfully implement every negative- or zero-cost measure identified in the modelling, their theoretical potential would be 8.9 Gt of CO_2-equivalent in 2020 — about 20% of global emissions projected for that year. By any measure, that is a significant amount.

- Mandatory minimum (or average) energy performance standards (MEPS) and comparative labels remain the two most common policy instruments used by national governments to promote energy efficiency. They are being used for a wide range of traded goods such as household appliances, heating and cooling equipment, home entertainment equipment, ICT equipment for home or office, lighting, building materials and electric motors. MEPS and labels create dependable means for distinguishing between efficient and inefficient products. However, they require replicable procedures for measuring and classifying products so as to ensure that suppliers' claims are not open to question.

- These programmes affect international trade in as much as importers have to meet the same standards and labelling requirements as domestic manufacturers. Until recently, however, efforts to ensure harmonization of standards and mutual recognition of testing results have mainly focussed on intra-regional trade (e.g. within Europe, North America, or South-East Asia). There is considerable potential to promote harmonization and mutual recognition of testing results on a wider scale.

- The situation is more mixed for smaller developing countries. A common problem is lack of capacity and resources to develop and administer energy-efficiency policies. But more fundamental for some countries are the combination of high import tariffs on energy-using appliances and artificially low domestic prices for electricity or fuels. This tends to encourage consumers to opt for appliances at the low end of the purchase-price scale but with poor energy efficiency. As a result, many of the benefits of new energy-saving advances are having little impact on energy use in developing countries. Clearly, a first step to facilitating trade in energy-efficient products is to encourage developing countries to reform both their trade and their energy-pricing policies.

- Trade is fundamental for the deployment of energy-efficient products, and economies need to be open in order to benefit from such trade. The energy performance of traded energy-using products and products that affect energy consumption (e.g. thermal-pane windows, insulation, tires) will have an enormous impact on energy use in developing countries, whose populations are growing and whose markets for energy-using household products are far from saturated.

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by Keigo Akimoto, Takashi Homma*, Junichiro Oda*, Fuminori Sano*, Kenichi Wada**
*Rod Janssen**, and Ronald Steenblik****

1. INTRODUCTION

1. At the G-8's 2009 Summit in L'Aquila, Italy, the leaders committed to a target of achieving at least a 50% reduction in global emissions of greenhouse gases (GHGs) by 2050 and an aggregate reduction target of 80% or more for developed countries. In order to achieve this ambitious target, it is essential to mobilize all available policies and measures. Of all the measures, the promotion of energy-efficient practices and technologies is considered to be among the least expensive. As has been shown in various studies, the marginal abatement cost (MAC) of improving energy efficiency is relatively low, and a huge amount of GHG emissions can be reduced at costs below zero (in other words, in many cases, investment in energy efficiency more than pays for itself).

2. Growth of energy demand in OECD countries is quickly being outpaced by growth in non-OECD countries. Between 2009 and 2035, non-OECD countries will account for 87% of growth in energy demand, driven largely by China and India (IEA, 2011a). Taking China as an example of emerging economies, China already has the second-largest economy, is the largest CO_2 emitter, the largest coal and electricity user, the largest coal producer, the second-largest coal importer, the fifth-largest crude oil producer, the largest hydrogen power producer, and the largest wind power producer. In designing energy solutions, the importance of emerging economies cannot be underestimated.

3. A large part of the required transformation of the energy system will have to come through supply-side changes – i.e. changes in capital structures, locations, and technologies, all of which would imply large capital investments and a great amount of research and development. Such a transformation could, however, prove to be easier in developing countries, where the energy capital structure is newer and in some cases already more efficient. Nonetheless, simple energy efficiency policies for buildings, appliances, lighting, transport, industry and utilities, could buy countries the much-needed time before more costly and challenging supply-side changes could be implemented.

4. Considering that the global 50% GHG-reduction target by 2050 cannot be achieved without the efforts of all developing countries to reduce emissions substantially below business as usual (BAU), in addition to the huge reductions by developed countries, the diffusion of energy-efficient technology as well as goods and services on a global scale is urgent and indispensable in order to effectively address climate change. Developing nations have been calling for assistance (finance, capacity-building) for technology transfer for adaptation to the adverse effects of climate change and GHG mitigation. The diffusion of energy-efficient technologies will also help to address energy reliability and security issues, and thereby help meet economic and human-development goals (Box 1).

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Box 1. The World Bank's CFL Campaign

The World Bank has been supporting the distribution of compact fluorescent lamps (CFLs) in developing countries since 1994. Since that time, it has worked in 20 countries.

In East Africa, 90% of rural households use kerosene, which is costly and hazardous to human and environmental health. Following severe power shortages in 2008 and 2009, Ethiopia's government decided to transform their national energy policy and switch from kerosene-fueled lighting to CFLs. Within three months of launching the initiative, with half the bulbs distributed, the Ethiopian Electric Power Corporation (EEPCo) saw its peak demand reduced by 80%. Generating this energy with emergency diesel generators would have cost the country an estimated USD 100 million by one estimate. The cost of the CFL distribution amounted to just USD 4 million. Moreover, low-income households, consuming about 20 kWh per month, can reduce their electricity consumption by 55% through efficient lighting. Ethiopia's lighting project was so successful that the government has reduced import duties on some energy-efficiency equipment and is drafting a law to phase-in energy-efficient light bulbs.

A similar success story is unfolding in Bangladesh. Under its "Efficient Lighting Initiatives of Bangladesh" (ELIB) project, the World Bank plans to have distributed some 28 million CFLs throughout the country by the end of 2011. Improving energy efficiency is crucial to economic development in Bangladesh: during peak irrigation season, 6 gigawatts (GW) are demanded, but the power system can generate only 4 GW, leading to outages that cripple productive economic activity. The World Bank estimates that, collectively, the ELIB could nearly halve the current supply-demand gap in Bangladesh's power sector.

Source: Adapted from "CFL Campaigns Help Lower Electricity Bills for Countries Most in Need", by Jenny Corry (11 Jan 2011), accessed at http://ase.org/efficiencynews/cfl-campaigns-help-lower-electricity-bills-countries-most-need on 17 March 2011.

5. Through the light, heat, mechanical power and electronic energy provides, it has become essential for all manner of economic activities, from the mining of ores to the transport of goods and people. Goods that provide these services are manufactured, sold and used on a global scale not imagined a decade or so ago. And although they are becoming more energy-efficient, thanks to technological advances and a variety of government policies, there is still significant potential for improvement.

6. This study addresses several questions relevant to the role of trade in helping to diffuse relatively energy-efficient goods:

- What would be the real impact (not just the theoretical impact) of energy-efficiency improvements on the reduction of GHG emissions if the deployment of technologies could be accelerated?
- Given the potential impact, what is stopping that potential from being achieved?
- What enabling policy framework is needed to achieve as much of the cost-effective potential as possible?
- What is the role that international institutions, such as the OECD and the IEA, can play in fostering that enabling policy framework?

7. This report limits itself to four products in the residential sector that have considerable potential for significant reductions in GHG emissions, both in the short and the medium term, particularly in the period to 2020: refrigerators, televisions, lighting, and air conditioners. These technologies are also widely traded globally and can have a big impact on reducing GHG emissions through the deployment of best available technologies. The report does, however, provide some more general analysis beyond the residential sector, in order to better understand the context.

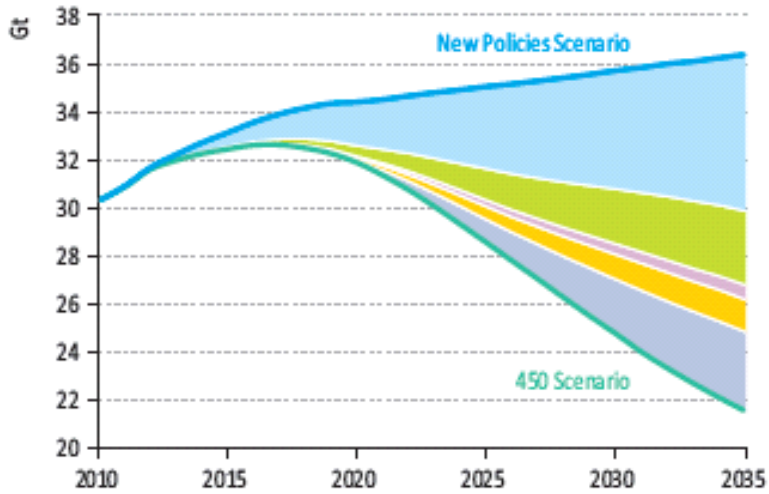
The context

8. As of November 2011, no formal decision had been reached on a new global agreement on climate change, which included both mitigation and adaptation objectives. Work has progressed but it is still unclear what the final outcome will be. The Copenhagen Accord[1], which many countries signed onto, was not adopted, but "taken note of" by the plenary. It is not legally binding. Regardless of the Accord's strengths or shortcomings, which is not the intention of this paper to discuss, more countries are agreeing to set emission-reduction targets (Annex 1).

9. For the purposes of this report, it is important to recognise the growing consensus on the need to reduce GHG emissions. The Cancun agreements reaffirm the long-term goal of limiting global mean temperature rise to below 2°C above pre-industrial levels. This corresponds to roughly stabilising GHG concentrations in the atmosphere at 450 parts per million of carbon-dioxide equivalent (ppm CO2-eq) — the concentration (± 100 ppm) above which, the Intergovernmental Panel on Climate Change (IPCC, 2007) estimates, the planet has in the past always been ice-free (and the sea level has been around 75 metres higher than today) — which can only be achieved though deep cuts in global emissions by mid-century. The broad scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2°C was also recognised by G8 Leaders at the L' Aquila, Italy Summit on 2009.[2]

10. The IEA's "450 Scenario" in its *World Energy Outlook 2011* (WEO 2011) shows that energy-efficiency improvements will need to be the leading pathway to GHG mitigation between now and both 2020 (the date for the Copenhagen Accord targets) and 2035. Energy-efficiency improvements would represent almost three-quarters of GHG-emission reductions by 2020 and almost half in 2035, according to this *WEO* scenario (Figure 1). About half of the contribution made by energy efficiency is expected to come from greater efficiency in the direct combustion of fossil fuels, and the other half from lower electricity demand attributable to greater efficiency in end use.

Figure 1. World abatement of energy-related CO_2 emissions in the IEA's 450-ppm scenario



Abatement source	Year 2020	2035
Improvements in energy efficiency	72%	44%
Increased use of renewable energy	17%	21%
Biofuels	2%	4%
Nuclear energy	5%	9%
Carbon capture and storage	3%	22%
Total (Gt CO_2)	2.5	14.8

Source: IEA, World Energy Outlook, 2011.

1 For more information, go to http://unfccc.int/home/items/5262.php.

2 G8 Leaders Declaration: Responsible Leadership for a Sustainable Future, www.g8italia2009.it/static/G8_Allegato/G8_Declaration_08_07_09_final,0.pdf.

11. The IEA's findings are underscored by a report released by the Asia-Pacific Energy Research Centre in 2010, *Pathways to Energy Sustainability*, which showed that GHG emissions in the APEC region could be held to a level consistent with a 2ºC temperature rise *if* by 2030 APEC members reduced their energy intensity by 50% (compared with 2005), and *if* some 30% of the region's primary energy supply and 59% of its electricity generation would be derived from non-fossil energy sources (APERC, 2010). In response to these findings, in June 2010, at their meeting in Fukui, Japan, Energy Ministers from the Asia-Pacific Economic Cooperation (APEC) economies instructed APEC's Energy Working Group (EWG) to assess "the potential for reducing the energy intensity of economic output in APEC economies between 2005 and 2030, beyond the 25% aspirational goal already agreed by the APEC Leaders." Improvements in efficiency are certain to form a central part of this assessment.

Role of increased energy efficiency

12. Probably the first OECD country to make the link between reducing GHG emissions and the importance of increased energy efficiency was the Netherlands, with its 1990 *Memorandum on Energy Conservation*.[3] The IEA (1991) made a similar connection in its landmark 1991 publication, *Energy Efficiency and the Environment.* The report stated (p. 9), "Improving the efficiency of energy use is a promising strategy to both achieve energy security and environmental goals, particularly the reduction of carbon dioxide emissions that contribute to global climate change." While accepted today, back in 1991 this was breaking new policy ground. Two years later the European Community approved Council Directive 93/76/EEC, with the objective "of limiting carbon-dioxide emissions by improving energy efficiency." The Directive formed part of the Community-wide strategy to reach stabilisation of total carbon-dioxide emissions by the year 2000 at the 1990 level.[4] In the 1990s, the activity level increased significantly, culminating in the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. The objective of the treaty was to stabilise greenhouse-gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The treaty entered into force on 21 March 1994 and, as of December 2011, the UNFCCC had 195 parties. This treaty led to the Kyoto Protocol that is currently being implemented.

13. Increasingly, the link between climate change and energy efficiency became more pronounced and all climate-change discussions include reference to energy efficiency. Similarly, energy-efficiency policies make direct reference to the derived co-benefits of mitigation of climate change.

What it means to be more energy efficient in the context of climate-change policy

14. Energy efficiency refers to obtaining the same useful outputs (energy services) for less energy input. Energy-efficient technologies include both those energy using devices (e.g. refrigerators, televisions, computers, heating systems and compact fluorescent lights) that are relatively more energy-efficient than others that provide the same level of service, and those that influence the use of energy (e.g. insulation, tires, energy-efficient windows).

15. Achieving gains in energy efficiency depends on the development and deployment of a wide range of energy-efficient technologies. Innovations come about through government support for research and development as well as R&D undertaken by the private sector itself. Household appliances and other energy-consuming devices today are certainly much more efficient than those even a decade ago and many

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3 Ministry of Economic Affairs, *Memorandum on Energy Conservation, Strategy for energy conservation and renewable energy resources*, The Hague, June 1980.

4 While the Directive reiterated the Community-wide target to stabilise carbon dioxide emissions by the year 2000 at the 1990 level, it did not specify how much the implementation of Directive 93/76/EEC would contribute to that target.

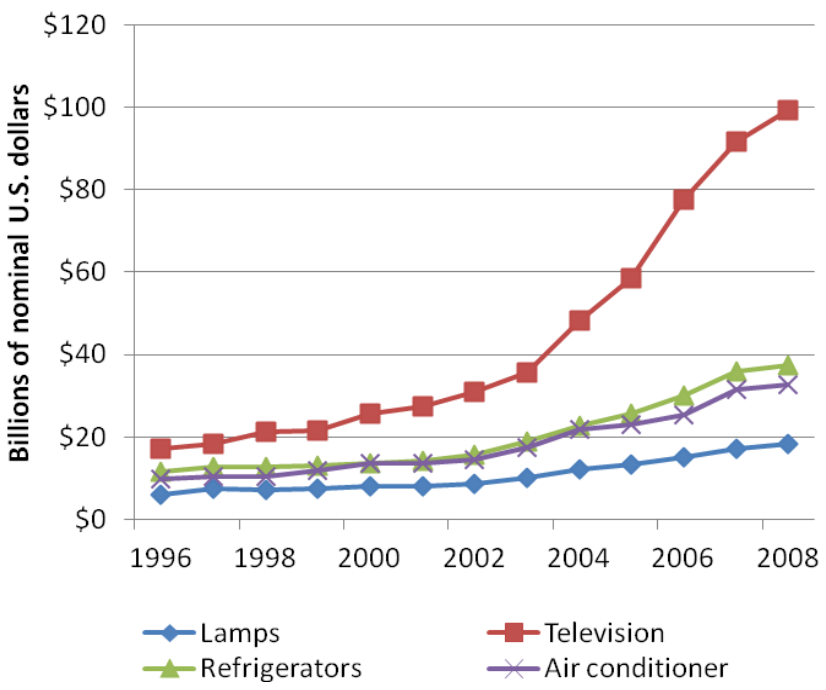
of those improvements are as a result of government policies such as minimum energy performance standards (MEPS) and labelling programmes, which have had a transformative effect on the market.

The global market for energy-efficient products

16. The products analysed in the next section are selected energy-efficient appliances purchased by households. The following examples give some indication of how trade in these appliances has expanded in recent years.

17. Every major residential appliance, including refrigerators, lighting, TV, and air-conditioners, now has a global market (Figure 2). Globalisation of the appliance industry has proceeded apace. World trade in refrigerators in 2008 totalled about USD 37 billion, which is more than triple from the trade volume in 1999. World trade in televisions grew more rapidly; totalling about USD 17 billion in 1996 and reaching USD 99 billion in 2008. This implies that the benefit from the deployment of energy-efficient appliances is more widely available, and that the role of trade in facilitating such dissemination is quite important.

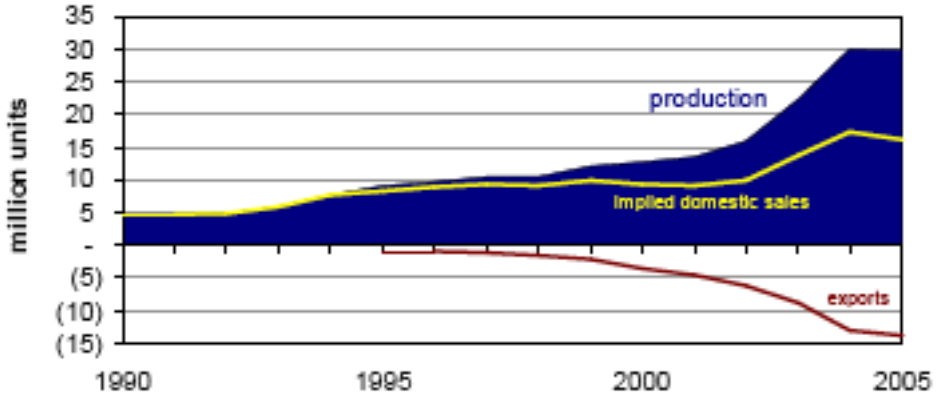
Figure 2. World imports of selected household appliances, 1996-2008



Source: UN Commodity Trade Statistics.

18. The centre of gravity of manufacture has shifted significantly over the past two decades, towards Asia, where labour costs are relatively low. One country that has benefited in particular is China: its exports of refrigerators reached 14 million units in 2005 (Figure 3), which represented 46% of its total production. Imports have not been more than 0.1 million units per year since 1996 (Fridley *et al.*, 2007).

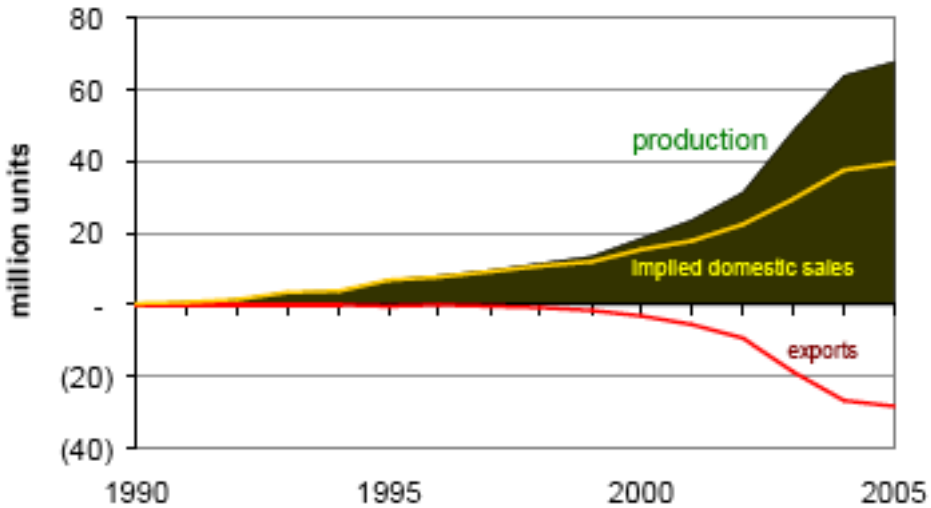
Figure 3. China's annual production, sales and trade of refrigerators, 1990-2005



Source: Fridley *et al.* (2007).

19. The trend is even more dramatic for air conditioners. China's production of air conditioners rose from 0.24 million units to 68 million units in just fifteen years (Figure 3). A Lawrence Berkeley National Laboratory study (Fridley *et al.*, 2007) shows that China's production of room air conditioners grew at an average annual rate of 26% between 1995 and 2005. In 2005, exports represented 42% of domestic production.

Figure 4. China's annual production, sales and trade of room air conditioners, 1990-2005



Source: Fridley *et al.* (2007).

The challenge for energy efficiency to deliver

20. Trade, however, is complicated because of how countries regulate the energy performance of goods. Two relatively similar products can have significantly different rates of energy consumption. This is as true within a country or region as between trading partners. Regions such as the European Union rank appliances from A to G, from the best to the worst.[5] There are other programmes, however, such as

[5] These categories are likely to changed in light of the adoption in 2010 of a revised labelling directive (European Union, 2010). Under Directive 2010/30/EU, three additional classes (A+, A++, and A+++ for

ENERGY STAR in the United States, that are endorsement labels, not comparing appliances but identifying goods that are among the best performers in their product category.

21. Expectations for energy efficiency to "deliver" reductions in GHG emissions are high, and necessarily so. There is a growing consensus that nuclear energy and Carbon Capture and Storage (CCS) facilities will have difficulty expanding sufficiently to enable countries to meet the 2020 targets because of the long lead times required to construct nuclear power plants and because CCS is still in the development stage, with strong promise but also with the normal technological deployment issues that affect any nascent technology. Assuming that current policies to promote renewable energy remain in place, it will have a major impact; but it is unlikely to make as much a difference to GHG emissions as improvements in energy efficiency, which is still the most cost-effective GHG-mitigation option in most countries.

22. There are, however, several challenges that must be overcome for energy efficiency to achieve its full potential. Improving energy efficiency does not necessarily generate energy savings: it may at the same time increase the use of the energy-using device, offsetting to some extent the efficiency gains. As costs fall, thanks to improved energy efficiency, consumers may use more illumination; cool (heat) more spaces or to a lower (higher) temperature; and buy more electrical appliances or use them more intensively. They may also choose devices with higher performance, larger size, and greater amenity and functionality — all of which can erode some of the gains made through improvements in energy efficiency (Calwell, 2010, p. 1). The magnitude of the rebound effect varies greatly by energy-using device, socio-economic factors, and policy environment, and can be small where consumption is constrained by, for example, by the size of people's homes. Second, while the markets for many consumer appliances are saturated in high-income economies, they are not yet saturated in the large, emerging economies. This means that energy consumption will grow globally, even with strong energy-efficiency improvements. It is all the more important to ensure that the best available technologies are used in these new markets, to avoid "locking in" less-efficient technologies for the generation or more of the life of the technologies (which varies according to technology).

23. Even in mature markets, however, the stock of existing appliances typically takes a decade or more to turn over. For example, the average refrigerator in Europe lasts for 13 years.[6] New appliances are significantly more efficient than the ones they are replacing, but a high percentage of refrigerators currently in use will still be in use in 2020. Whether public policy should be used to accelerate the early replacement (and scrapping) of household appliances is another question. A recent analysis of the impacts of automobile scrapping schemes on CO_2 emissions undertaken for the OECD (Fraga, 2011), for example, showed that the biggest reductions are achieved the newer the car that is replaced — i.e. the more years it would have been used otherwise. On other hand, the newer the car scrapped, the higher the costs. Analogous considerations would apply in the case of large appliances. There would also be implications for waste streams from the premature disposal of appliances.

24. The other challenge is to ensure that the most-efficient products available are bought and used. For governments this means steering customers to such products, ensuring that the least efficient products — including imported products — are kept out of the market, or both. There is also a need to ensure there are no "unintentional" trade barriers that restrict goods that bring important energy and climate benefits (as well as other co-benefits).

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the most efficient appliances) may be added to the classification if required by technological progress. In principle, the total number of classes will be limited to seven, unless more classes are still populated.

6 Personal communication with Luigi Meli, Secretary General, CECED, the European Committee of Domestic Equipment Manufacturers. ENERGY STAR states that the average lifetime of a new refrigerator is 14 years. www.energystar.gov/ia/partners/manuf_res/downloads/2007Refrigerator_prg.pdf

25. The following two chapters provide a quantitative analysis on the potential and the impact of deploying energy-efficient technologies in the residential sector. It starts with a general discussion of the modelling activity and then in Chapter 3 provides detail on particular technologies.

2. MODELLING THE POTENTIAL FOR CO_2 EMISSIONS REDUCTION

26. A CO_2-mitigation assessment modelling framework was developed by the Japanese institute, RITE, in order to assess in a consistent manner the six greenhouse gases covered by the Kyoto Protocol.[7] The framework consists of three modules: (1) the DNE21+ Model for energy-related CO_2 emissions; (2) a Non-Energy CO_2 Emission Scenario for non-energy CO_2 emissions estimation independently of energy-related CO_2 emissions, and (3) a Non-CO_2 GHG Assessment Model for emissions of CH_4, N_2O, HFCs, PFC, and SF_6.

27. In this study, the DNE21+ model was used to identify abatement opportunities with technology details and to get an understanding of how efficiency improvements can impact on CO_2 emission reduction. DNE21+ is a bottom-up, technology-oriented model used for assessing energy systems at the global scale. It is an inter-temporal (forward-looking) linear programming model, in which the total system cost of energy is minimized for the period of 2000-50 under various constraints, such as an economy-wide CO_2 emissions cap and a carbon price imposed on some specific sectors.

28. Box 2 explains the differences between bottom-up, top-down and hybrid models. Bottom-up models, like the DNE21+ model, produce marginal-abatement-cost (MAC) curves that allow many negative-cost options to exist, especially in the field of energy efficiency. Modelling work undertaken by top-down models assumes such negative-cost options do not exist, on the argument that the negative costs are apparent only because certain costs are hidden. The lack of feedbacks between different sectors and regions arising from a partial-equilibrium framework can also explain differences in the results.

29. Figure 5 provides an overview of the energy and CO_2 flows in DNE21+. Eight types of primary energy sources are explicitly modelled: natural gas, oil, coal, biomass, hydroelectric and geothermal power, solar photovoltaics, wind, and nuclear power. Sectors not incorporated into the bottom-up modelling fell into four categories; solid energy demand, liquid energy (gasoline, light oil and heavy oil) demand, gaseous fuel demand and electrical energy demand. Their demands are estimated in a top-down manner. Electricity demand is modelled to balance demand and supply consistent with a power load-duration curve. In the energy transformation sector, technological costs and efficient energy-supply technologies for oil refineries and various types of power generation, and carbon capture and storage (CCS), are taken into account.

[7] The six gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Box 2. Model Types: Bottom-Up, Top-Down and Hybrid

A key distinction between model types is how they characterize technology, emissions, energy and the economy. Many models fall into the two general categories of "bottom-up" or "top-down", although some models contain elements of both approaches and are referred to as "hybrid" models. Bottom-up models are best suited to answer questions about specific low-carbon technology deployment, whereas top-down models are best suited to answer questions about economic impacts of carbon policies.

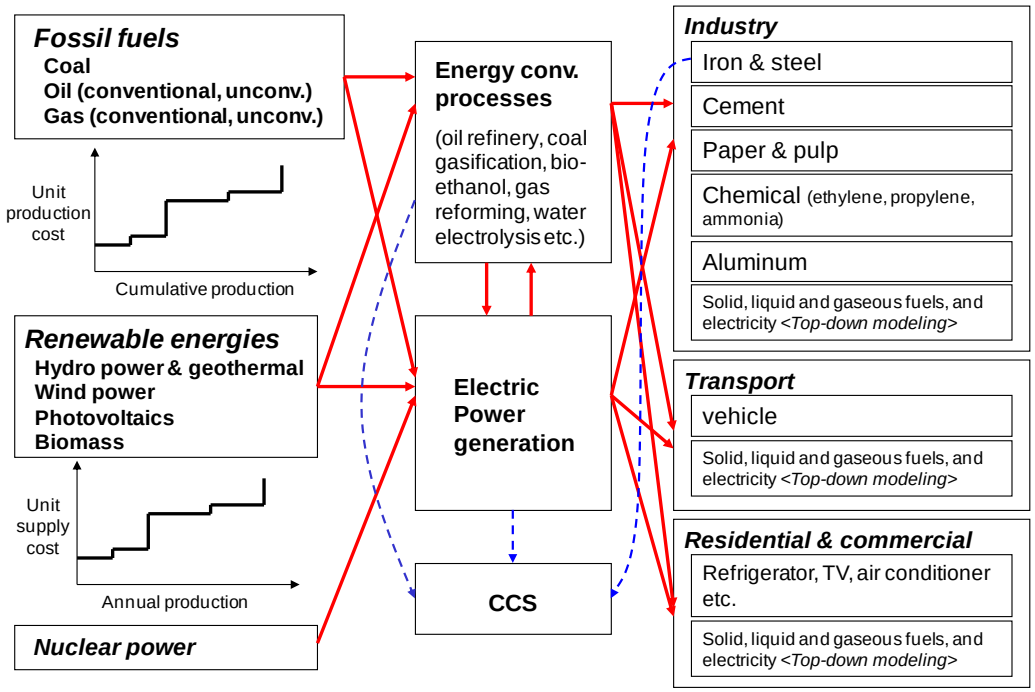
Bottom-up models typically assess distinct mitigation technologies or practices, including their costs and emission reduction capabilities, as well as their substitutability with other technologies. A combination of mitigation technologies is then used to meet energy demands under an environmental constraint. Bottom-up models tend to focus on the interactions within the energy system, rather than its relationship with the overall economy.

Top-down models usually view the economy as an integrated whole, reaching economic equilibrium under an environmental constraint through substituting capital, energy, and labour. Top-down models tend to focus on economic processes rather than technology detail or market products. ***Computable general equilibrium (CGE) models*** are a subset of top-down models that quantitatively simulate the economy. Demand and supply of each commodity and factor across a specified set of markets in the economy are balanced through a price mechanism.

Hybrid models combine elements of both bottom-up technology detail, usually focused on the electricity sector, and top-down economic integration.

Source : Clapp *et al.* (2009); see van Vuuren *et. al.* (2009) for more detail.

Figure 5. Energy flows in the DNE21+ model



Source: Research Institute of Innovative Technology for the Earth.

30. Regarding the end-use sectors, various technological options to improve energy efficiency are modelled explicitly. Focus is put on the technological costs and energy efficiency of energy-intensive industries, including steel, cement, pulp and paper, alumina, some sections of the chemical industry

(ethylene, propylene production and ammonia production in the petrochemical industry), transportation (automobiles). Technological changes are included exogenously, and the costs of technologies are generally assumed to decline over time and their performance to improve. The vintages of these technological facilities are also included in the model. Overall, around 300 individual technological changes that are either already applied today or will become commercially viable in the near future were identified.

31. In the reference case, the cost of various technologies and energy systems, such as energy flow and capacity of energy-related facilities, are examined without any CO_2 emission controls. In the event that some sort of climate-change policy or measure is implemented, minimum system cost is re-optimized to meet the constraints; usually it leads to an overall decrease in final energy demand or emission reductions due to the energy-price increase.

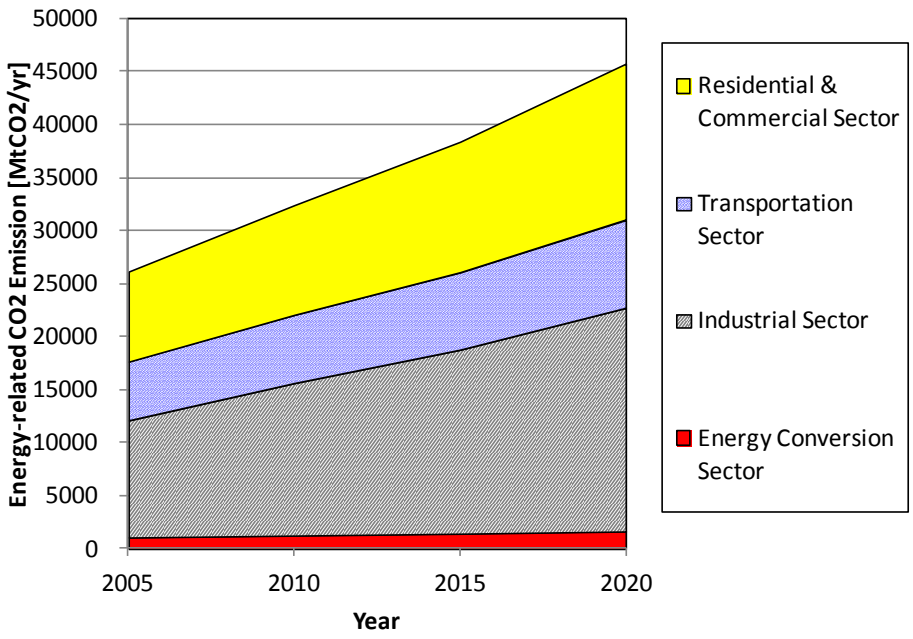
32. DNE21+ is similar to the IEA ETP MARKAL model (see Gielen and Taylor, 2007) in that both models provide an explicit explanation of energy-supply technologies as well as energy end-use technologies in detail. The DNE21+ model is, however, more regionally disaggregated. For the purposes of this study, the countries and regions were re-aggregated to show the overall tendency of 11 major world regions: Canada and the United States; the European Union; the Commonwealth of Independent States (CIS) and non-OECD Europe; Japan; Australia and New Zealand; China; India; the rest of Asia; the Middle East; South & Central America and Africa.

33. The historical emissions of six GHGs from Annex I and non-Annex I countries under the Kyoto Protocol are based on GHG inventories of UNFCCC (2009) and IEA Statistics (IEA, 2007), respectively. Energy-related CO_2 emissions are based on IEA Statistics for all countries. Since there are slight differences between IEA data and UNFCCC data, minor modifications were made to ensure consistency between the total GHG emissions and the UNFCCC inventory.

Scenarios on key drivers

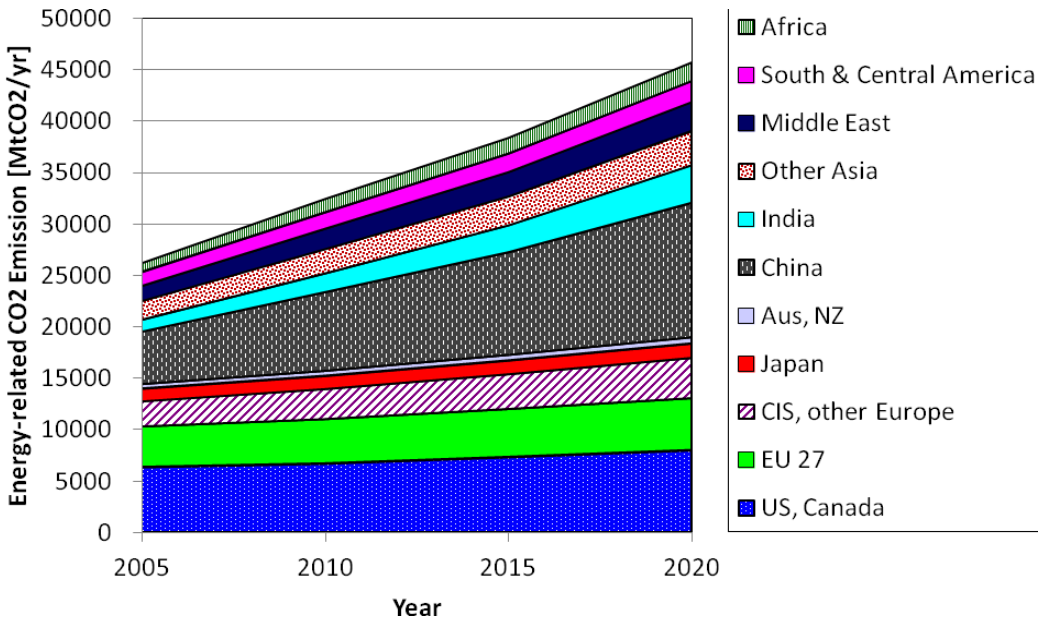
34. Figure 6 and Figure 7 present the baseline scenario of sectoral and regional energy-related CO_2 emissions. In this study the baseline emissions correspond to the technology frozen (TF) case, in which the CO_2 intensity is fixed at a constant level (that of 2005), with the assumption that the growth in emissions comes from other drivers, such as population and economic growth.

Figure 6. Global direct and indirect CO_2 emissions, by end-use sector (Indirect)



Source: Research Institute of Innovative Technology for the Earth.

Figure 7. Projected CO_2 emissions, by region



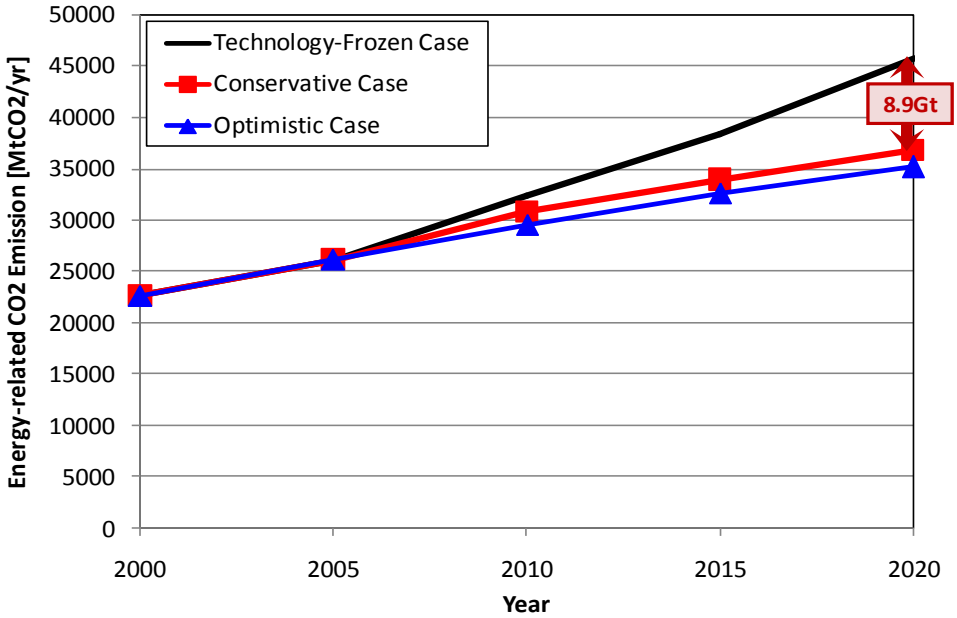
Source: Research Institute of Innovative Technology for the Earth.

35. Energy-related CO_2 emissions in the baseline scenario rise from 26.2 Gt in 2005 to 45.7 Gt in 2020, under the assumption that CO_2 emission intensity remains unchanged. From a sectoral perspective, the indirect emissions[8] in 2005 were 8.5 Gt from the residential sector, 5.6 Gt from the transport sector, and 11.0 Gt from the industrial sector. Between 2005 and 2020, the share of industry's direct and indirect emissions increases from 42% to 46%. During the same period, emissions from transport drop from 21% to 18%, and the residential sector's emissions remain essentially unchanged, at 32%. Clearly, the residential sector will play an important role in the future.

Potential for energy-efficiency improvements

36. Figure 8 illustrates future global emission trajectories of the TF case and of the cases with a zero price on carbon emissions through 2020. The CO_2 emission-mitigation potential from improvements in energy efficiency is defined here to be the vertical difference from the projected emission level of the TF case. A zero carbon price scenario conceptually means capturing the full abatement opportunities that produce a positive net return.

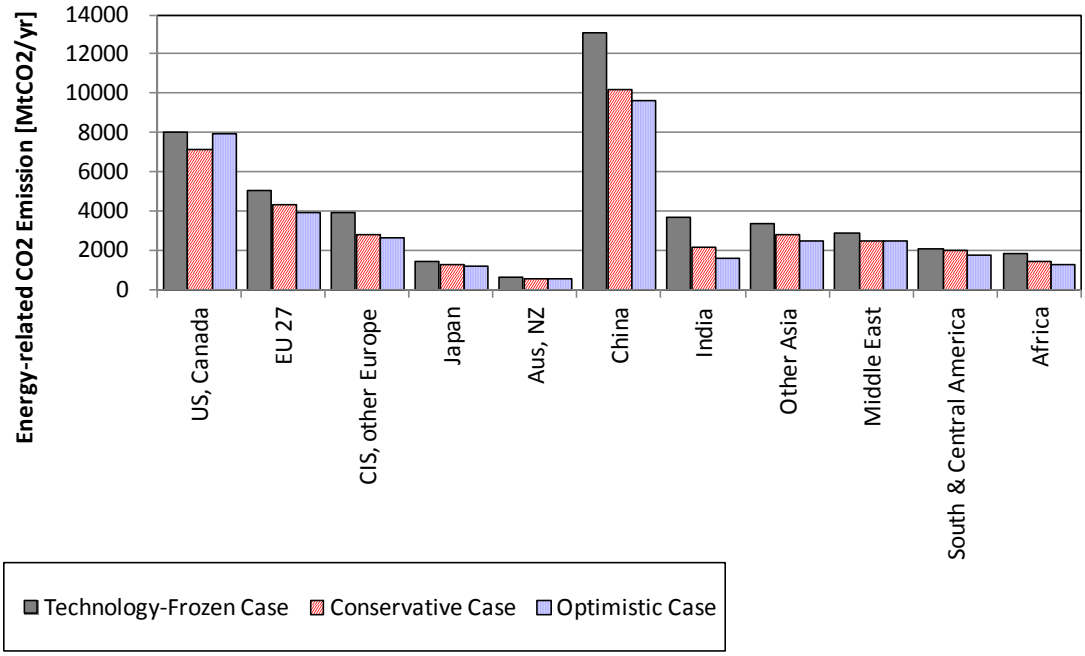
Figure 8. Global CO2 Emission Trajectory



Source: Research Institute of Innovative Technology for the Earth.

8 Indirect emissions (of carbon dioxide) cover both direct emissions from any fuel use and indirect emissions arising from the electricity consumption.

Figure 9. CO_2 Emissions by Region in 2020



Source: Research Institute of Innovative Technology for the Earth.

37. Future population and economic growth drive increases in the demand for energy. At the same time, however, efficiency improvements offer substantial potential to mitigate CO_2 emissions (Figure 8). Without efficiency improvements (as in the technology frozen scenario), global CO_2 emissions would almost double, from 22.7 Gt in 2000 to 45.7 Gt in 2020. The graph shows that 8.9 Gt of CO_2 abatement potential is available at negative or zero cost in 2020. If a longer payback period is allowed, a further 1.7 Gt of opportunities could be gained at below zero cost in 2020.

38. Figures 7 and 9 present CO_2 emissions by region in 2020. The biggest emitter is expected to be China, reaching almost 13 Gt, 2.5 times larger than that of 2005 emission, in the TF case, followed by 8 Gt from the United States and 5 Gt from the European Union. Inevitably China has the largest (3 Gt) opportunities for mitigation mitigating CO_2 emissions, equivalent to almost 2.5 times of Japan's expected emissions in 2020 under the zero carbon price scenarios.

39. In 2005, Canada and the United States were responsible for 24% of global emissions, at 6.4 Gt, compared with 5.1 Gt from China, 4.0 Gt from the European Union and 1.1 Gt from India. Under the FT scenario, however, the regional shares of CO_2 emissions would undergo a drastic change over the next 15 years. In 2020, China's emissions would reach 13.1 Gt, or 29% of global emissions. The share of Canada and the United States would decline to 18%, and that of the European Union would drop to 11%.

Global marginal abatement cost curve

40. Marginal abatement cost (MAC) curves have been widely quoted in the international climate change arena, especially after McKinsey and Company published its report in 2007 (Creyts *et al.*, 2007). The basic idea of the cost curve is that it displays the abatement potential and corresponding cost for abatement technologies relative to a reference scenario in a given year. A MAC curve can be interpreted as the carbon price that would be set in an idealized global emissions-trading system. A MAC curve can

change over time because remaining opportunities for mitigation generally becomes more expensive, as low-cost options are exhausted and diminishing returns to scale are encountered.

41. The curves provide a least-cost ranking of options across technologies and sectors. From a policy-design perspective, the curve helps to understand which technologies entail the lowest unit abatement costs for society, as well as which ones offer the largest abatement potential. The width of each bar represents the potential of that opportunity to reduce CO_2 emissions in a specific year compared with the reference case. The height of each bar represents the cost of avoiding one metric tonne of CO_2 in the year of the analysis.

42. The MAC curves presented here were constructed as follows;

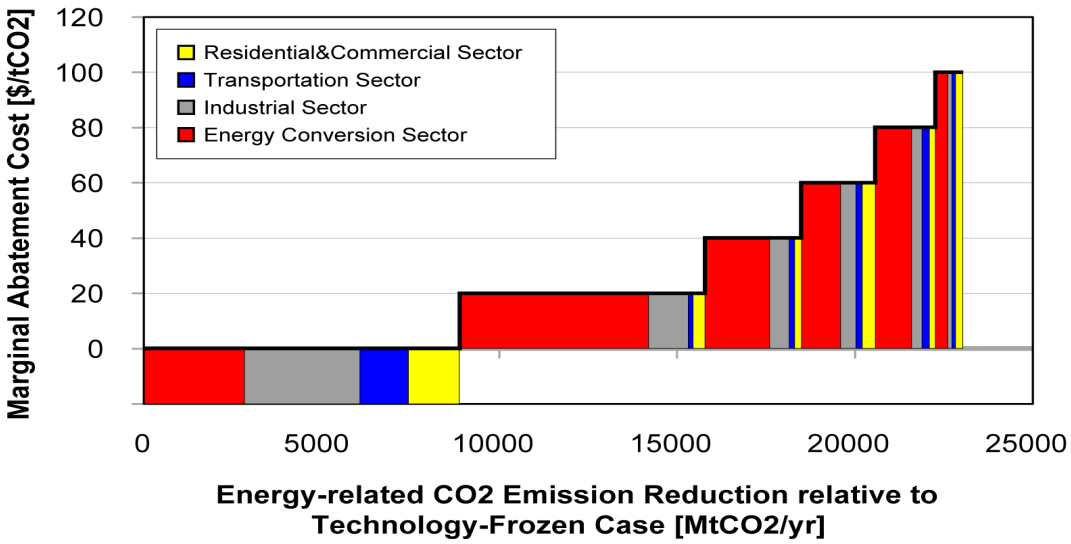
1. As described in the methodology section in the Annex, the abatement potentials are derived on the basis of considerations of availability, reduction efficiency and technical and economic applicability of the different abatement options. Abatement potentials per CO_2 price step and region are specified for a reference time frame, here chosen as 2020.

2. The optimal system, and likewise mitigation potential, may change if the carbon prices change, so it is necessary to run the model for every carbon price.

3. Taking the X axis as absolute potentials, e.g. in tonnes of CO_2, or in relative terms (e.g. percentage) of a given baseline, and the Y axis as the costs of that measure or technology, plot the results gained by the procedures above. Consequently, the MAC curve will be a stepwise function with a discrete choice set of carbon prices.

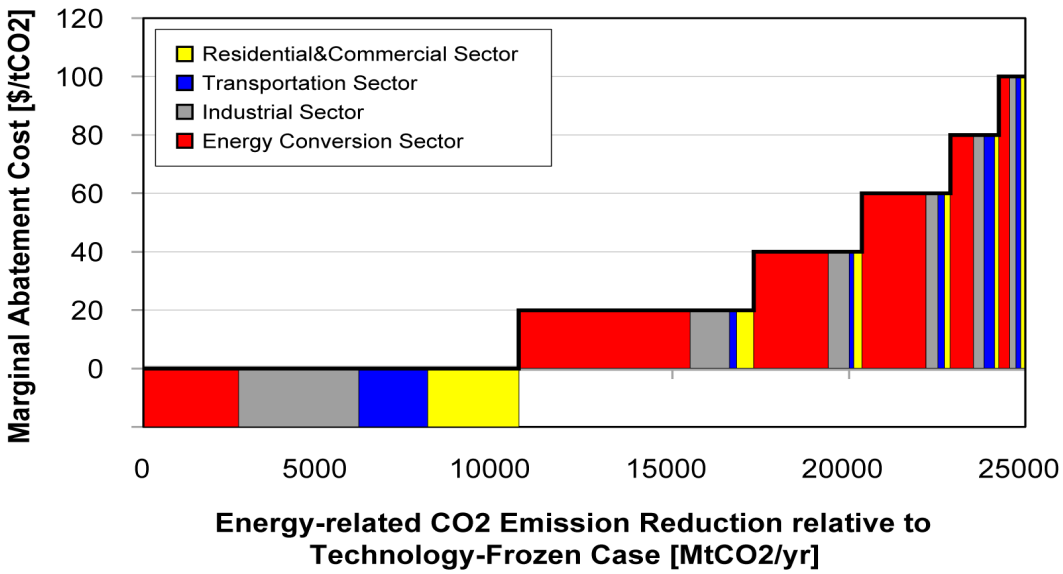
43. The priority in this study was to look at the global emission reduction opportunities with one consistent methodology, rather than to delve deeply into any individual emission-reduction opportunity. So, as in Figures 10 and 11, the MAC curves were constructed to show the breakdown for each sector of abatement costs in 2010 in increments of USD 20 per step.

Figure 10. Global MAC curve in 2020 under the conservative case



Source: Research Institute of Innovative Technology for the Earth.

Figure 11. Global MAC curve in 2020 under the optimistic case



Source: Research Institute of Innovative Technology for the Earth.

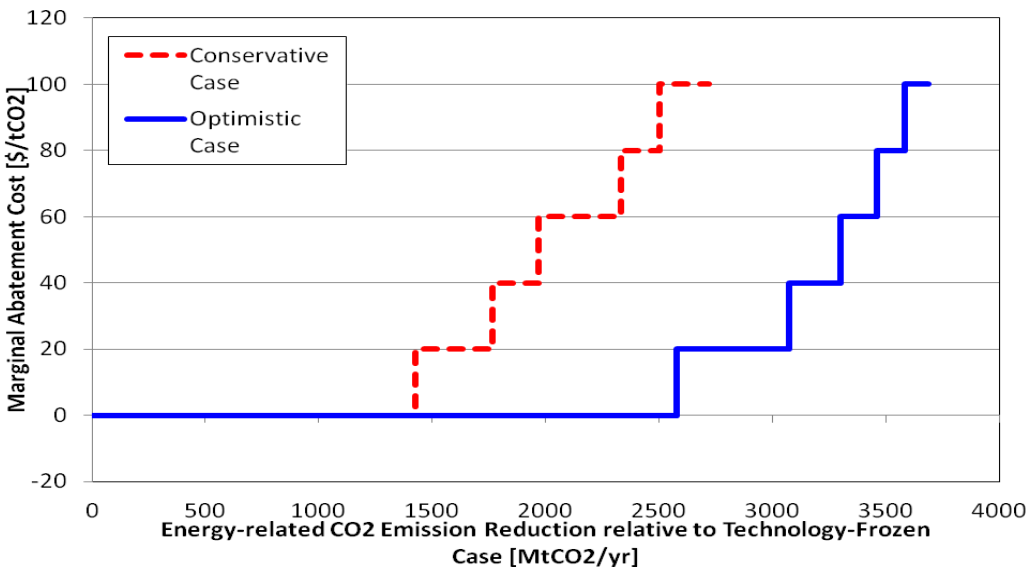
44. The cost curves for 2020 identify a potential of 8.9 Gt net gain opportunities under conservative assumptions, and 10.6 Gt for the optimistic case in 2020, relative to the Technology Frozen case. These graphs illustrate that the abatement potential in the residential and commercial sectors significantly increase, compared with other sectors, if the payback period on investments is extended.

45. Theoretically, abatement opportunities with negative cost occur when, over the lifetime of technologies, energy efficiency gains are bigger than the initial investment costs. In reality, however, capturing the full abatement potential is virtually impossible. The rate of uptake of efficiency measures is often slow, largely because of the existence of market barriers and failures. These include hidden and transaction costs such as the tariff barriers on cross border trade and the cost of the time needed to plan new investments, capital constraints, a lack of information about the available options, misaligned incentives, together with behavioural and organisational factors affecting economic rationality in decision-making. Therefore, one of the biggest challenges for policy maker is how to realize these potentials fully, including through the removal of market and regulatory barriers.

Marginal abatement cost curve for the residential sector

46. The shape of the MAC curves differ by country and sector, according to the constraints faced locally. Figure 12 shows the MAC curves of the residential and commercial sector in aggregate in 2020. The gap between the two curves comes from the difference in the payback period to recover the cost of an investment. Even under the conservative case, 1.4 Gt of CO_2 emissions abatement potential is identified with the technically maximum deployment below USD 0/t CO_2.

Figure 12. Global MAC Curves of the Residential and Commercial Sector

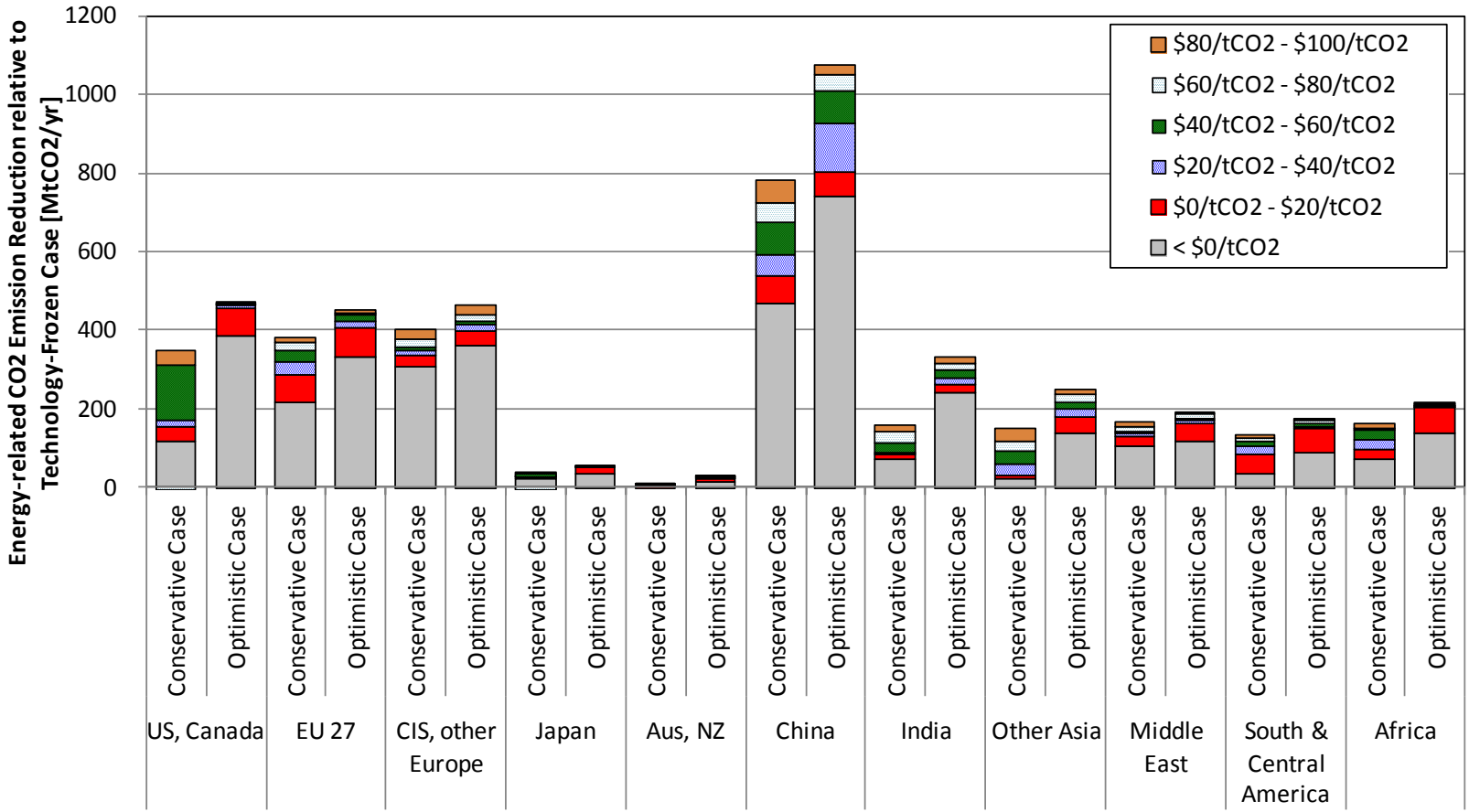


Source: Research Institute of Innovative Technology for the Earth.

47. Once again, China has the largest abatement potential in the residential and commercial sector in 2020, followed by the United States and the European Union (Figure 13). In other words, the full deployment of low-carbon technologies in these regions is one of the key issues in order to ensure the effectiveness of climate change policy. This is consistent with analysis from many other organisations, including the IEA.

Figure 13. Emission-reduction potentials in the residential and commercial sector, by region, in 2020

(Relative to the TF case in 2020)



Source: Research Institute of Innovative Technology for the Earth.

3. BENEFITS OF GREATER DEPLOYMENT OF ENERGY-EFFICIENT PRODUCTS IN THE RESIDENTIAL SECTOR

Features of the residential sector

48. Appliances, office and consumer electronics, and lighting represent a significant share of energy use in most countries, and are a rapidly growing source of electricity demand and associated GHG emissions as rising incomes allow people to use and purchase more energy-using devices for comfort, convenience, time-saving, and entertainment and because new products are constantly coming onto the market.

49. Energy demand in the residential sector is driven by various factors, including population, income level, local climate, tradition and lifestyle. Energy demand and potential to improve efficiency in households in different countries can vary widely. According to the McKinsey and Company (2009) report, globally, the greatest opportunities for is in the residential sector, which is also the world's largest consumer of energy with 25% of global end-use demand. By implementing currently available technologies, the sector's energy demand growth would more than halve, from 2.4% a year to only 1.0% a year. There is a large gap, however, between actual and best practice in terms of the implementation of cost-effective energy-efficiency measures in the residential sector.

50. This chapter estimates energy savings potential from improvements in the performance of representative electric appliances in the residential sector: refrigerators, lighting, televisions and air-conditioners. A more in-depth assessment of these products allows for a better understanding of the overall energy consumption in the residential sector and potential opportunities for energy savings.

51. Energy use in the residential sectors differs from energy use in industry in several important ways. For example, the scale of use per unit is totally different; the energy use of an individual usually takes place on a small scale, while industrial facilities are very large. A relatively small number of large point sources in the industrial sector are easy to identify, but it is quite difficult to track the profiles of individual appliances scattered across millions of homes, and the status of their use. In addition, energy use in industry is much more related to operational practices than in the residential sector. In the residential sector, once energy-efficient lighting or appliances are installed, their efficiency remains fairly constant throughout their lifetime.

52. As stated in Chapter 1, every major residential appliance, including refrigerators, lighting, televisions and air-conditioners are globally traded and this provides the opportunity for efficiency improvements to have a worldwide impact.

CO_2-reduction potential of replacement by efficient products

Approach

53. It is important to estimate the CO_2-reduction potential of replacing all products and technologies with specific products and technologies that are already known to be cost-effective and energy-efficient through existing investigations. The key to realize this potential is the full deployment of best available

low-carbon technologies in each cycle of renewal of technologies. The additional costs to society can usually be offset by benefits brought about with energy savings over the lifetime of technologies.

54. The product lifetime needs to be taken into consideration when determining the replacement cycle. Industrial facilities, such as power plants or steel works, have a long lifetime and it takes significant time to replace them. However, electric appliances have a relatively short lifetime, so it is a realistic assumption to estimate theoretical potentials for replacing all products with the most energy-efficient products within the timeframe of this study (to 2020). In addition, the residential sector was responsible for about one third of world total final energy demand, which implies this sector has a huge impact on CO_2 mitigation in the near term.

55. As previously stated, the focus is on refrigerators, lighting, televisions, and air conditioners in the residential sector. These products are chosen because of their significant energy impact due to a very high rate of penetration, and their large volume of cross-border trade. It is difficult to obtain a good profile of the stock, size, average age and efficiency of these products in every corner of world. Instead, estimates of the energy savings potential was estimated from data collected by RITE on the energy efficiency of selected products, country level energy demand and estimations of the stock of appliances in each economy.

56. The methodology is general in nature and can be applied to a number of appliance and equipment types. Here the mitigation potential was defined as the gap between the reference-case CO_2 emission and CO_2 emissions resulting from the replacement of the currently penetrated electric appliances by the highest efficiency products in all countries. In order to estimate the potential, the following steps were undertaken:

1. *Categorise the product type:* For each appliance there is a huge variation in size, type, usage and efficiency. The energy consumption depends highly on the average consumer usage patterns and climate zone for some products like refrigerators and air conditioners. Data on the total stock, usage patterns and other aspects of user behaviour for each product are usually not available, so the first step involved setting up several categories for each appliance, and determining product-level energy demand, lifetime, and costs, using characteristics of representative appliances as shown below. Cost data used for the analysis are described in Table 1.

2. *Estimate the total stock of appliances in the year 2000:* The number of products in use will impact on the total energy consumption. Data were collected on the stock of appliances in service mainly from the statistics of the IEA, World Bank (2006), JEITA (2007), Nishio and Iwafune (2009), and Burmert (2003), tracking data at the regional level.

3. *Assess total energy demand for the appliance in 2000:* For energy-services demand, the key components are the penetration of energy-consuming products and their efficiency level. Data were collected from available surveys.[9] If data were not available, demand was estimated based on GDP per capita or other indicators.

[9] For lighting, for example, RITE first plotted data on energy demand for lighting obtained from *Light's Labour's Lost* (IEA, 2006). Because the IEA data did not cover all country or regions, RITE then conducted a regression analysis, and interpolated for lacking data, on the assumption that energy consumption for lighting can be expressed as a function of GDP per capita. Similar but not identical extrapolation and interpolation methods were used to estimate energy consumption for refrigerators, televisions and air conditioners.

Table 1. Product categorisation

Appliance		Product Category	Energy Consumption (kWh/unit/yr)	Lifetime (years)	Price (USD/unit)
Refrigerator		Low-Efficiency	1318	15	443
		Middle Efficiency	842	15	758
		High Efficiency	408	15	1525
Televisions [in 2020]	Small	Low-Efficiency	259	15	258
		High Efficiency	138	15	308
	Large	Low-Efficiency	412	15	2603
		High Efficiency	276	15	2696
		Advanced	170	15	2875
Lighting* [in 2020]	Small	Incandescent	21.9	2.74	0.8
		CFL, fluorescent	5.8	11.0	8
		Advanced	1.6	47.9	18
	Middle	Mid-Eff. fluorescent	134.8	3.1	4.0
		High-Eff. fluorescent	97.3	4.1	10
		Advanced	62.6	3.4	40
	Large	Mid-Eff. HID	821.3	3.7	40
		High-Eff. HID	657.0	3.7	90
Air Conditioner		Low-Eff. (COP 2.1)	1.412**	15	960
		Mid-Eff. (COP 3.9)	0.798**	15	1020
		High-Eff. (COP 6.5)	0.498**	15	1080

* Lighting usage pattern is differentiated by size: 1 hr for small, 8 hr for middle, and 9 hr for large, measured on a daily basis.

**Energy consumption of air conditioners is shown hourly.

Source: Research Institute of Innovative Technology for the Earth, based on various sources, including national statistics of retail prices, the web pages of manufactures, and the catalog of energy-efficient products published by the Agency for Natural Resources and Energy of Japan (www.enecho.meti.go.jp/policy/saveenergy/seinoucatalog_2009winter.pdf). RITE plotted all these data, categorized them into several groups, and took their average performance.

4. *Estimate the average energy efficiency of the appliance in 2000:* At the individual product level, energy efficiency can be thought of as one of several product characteristics as shown in Table 1. Due to the different penetration rate of energy-efficient products, regional efficiency varies at a more aggregate level. Drawing on data on the average efficiency of appliences by country or region, compiled by Tanaka *et al.* (2005), the regional efficiency of the appliances in aggregate was identified from the results of steps 3 and 4 above (Table 2).

5. *Determine the distribution of the appliance by category in 2000:* From the data of efficiency at product level, efficiency at regionally aggregated level, and stock of products, the total number of a particular product type for each category and for each region were estimated by back calculation. Annex 2 and 3 show the results and were used for establishing the number of products to be potentially replaced by more-efficient products.

6. *Develop future scenarios of energy demand by product up to 2020:* Future energy demand was projected by two key drivers: GDP and population. For air conditioners, “cooling degree das” was also added as a variable. Appliance lifetime and associated retirements were taken into account to estimate the stock of each appliance type over time. Saturation levels, in which further penetration was therefore not likely to drive energy demand, were also considered. See Annex 1 for more detail.

Table 2. Estimated current efficiency of electric appliances (estimated national or regional average)

Products	Refrigerator	Television			Lighting	Air Conditioner
Unit	(kWh/d.u./y)	(kWh/d.u./y)			(lm/W)	(kWh/d.u./150h)
Region		Small	Large	Ave.		
US, Canada	1081	208	344	258	49.7	202
EU 27	1211	208	385	218	51.0	196
CIS, other Europe	1211	244	385	246	44.8	199
Japan	746	211	398	234	63.9	167
Aus, NZ	1007	205	385	231	49.5	198
China	1318	245	364	245	54.2	189
India	1318	243	385	243	43.3	196
Other Asia	1011	232	389	232	47.7	197
Middle East	1318	213	385	213	42.7	199
South & Central America	1318	245	367	245	42.5	199
Africa	1318	232	385	232	43.0	199
World average	***1177***	***230***	***356***	***239***	***48.4***	***197***

Source: Research Institute of Innovative Technology for the Earth.

7. *Set up two cases:* One case is the reference case, where the penetration rate of energy-efficient products in each regional does not change in the future, a similar concept to the Technology Frozen case. The other case is an idealized case, wherein all products with low efficiency are replaced by products with higher efficiency by 2020. Theoretically, this can happen by 2020 because the lifetime (replacement period) of all the products is within 15 years. By multiplying the efficiency per product and the stock of each appliance, we obtained an estimate of total energy use, which was easily converted into CO_2 equivalents.

8. *Calculate the potential of the substitution effect:* In this framework, the potential was defined as the difference in CO_2 emissions between the reference case and the ideal case.

57. Note that the stock and efficiency estimation embody a large set of assumptions. Nonetheless, the authors believe that the estimates are reasonable given the information available. Given the uncertainty in technological progress, a certain estimation error is inherent. In what follows, the results through the steps above are described with some features for each product.

Refrigerators

58. Refrigerators are one of the electrical appliances most commonly found in homes, providing convenience for safe food preservation. They are produced in very large numbers and there is a significant and growing inter-regional trade in finished products. This pattern has been reinforced as manufacturers are increasingly moving beyond their traditional market boundaries.

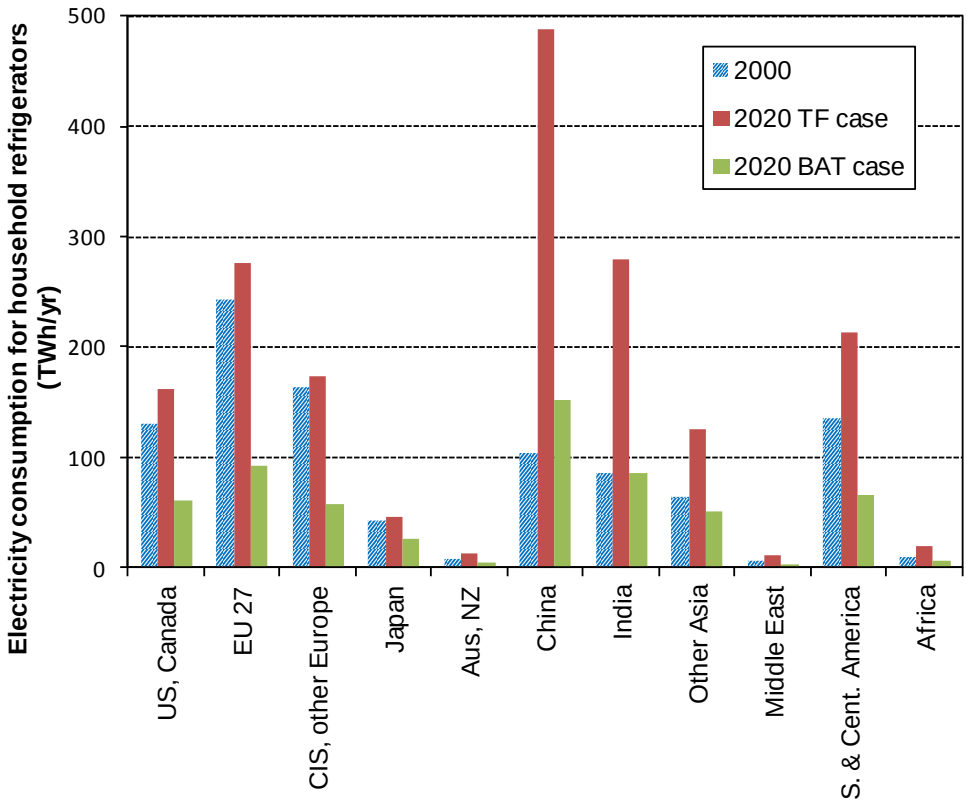
59. The key components of refrigerators — the refrigerant and thermal insulation — are widely traded. The refrigerant absorbs heat from the refrigerator cabinet space and transfers it to the ambient

environment.[10] Thermal insulation requires highly energy efficient foam-blowing agents to limit heat transfer to refrigerated cold spaces and reduce energy consumption.

60. There are, however, large variations in the size and unit electricity consumption of refrigerators across regions. According to the IEA (2006a), the average refrigerator in use in its member countries used 626 kWh per year in 2000. This ranged from 872 kWh per year per unit in the OECD Pacific region to 850 kWh per year in North America to 432 kWh in OECD Europe.

61. Improvement in the energy efficiency of refrigerators continues. The average new appliance uses about 60% of the energy of the equivalent 1992 model, which implies that there is substantial room for improvement in the existing stock of refrigerating appliances. Modelling by RITE suggests that under an optimistic scenario, electricity consumption for household refrigerators in 2020 could be much less or no higher than in 2000 in most regions of the world (Figure 14). This suggests a significant CO_2 emissions-mitigation potential (Figure 15).

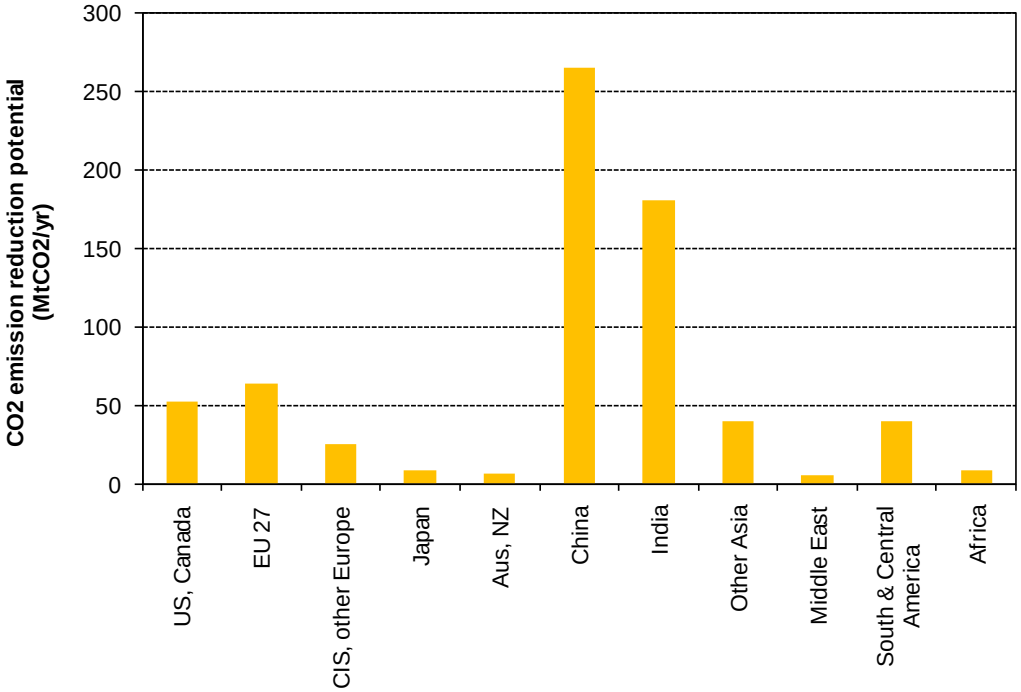
Figure 14. Electricity consumption of refrigerators



Source: Research Institute of Innovative Technology for the Earth.

[10] For environmental reasons, since the mid-1980s manufacturers of refrigerators have transitioned from refrigerants based on chlorofluorocarbons (CFCs), to low or non-ozone depleting compounds such as hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs) and hydrocarbons (HCs).

Figure 15. CO_2 emissions mitigation potential of refrigerators



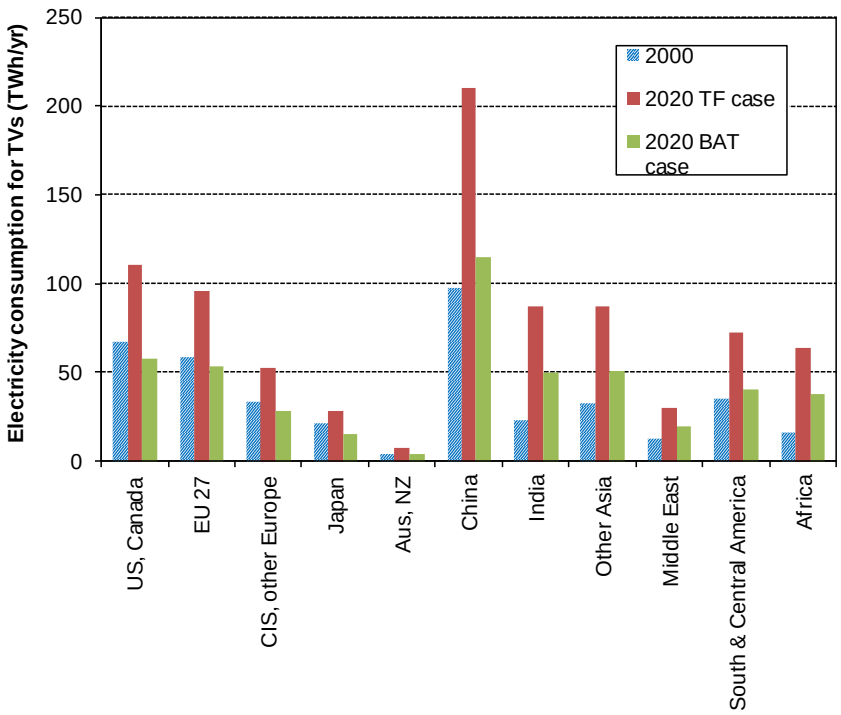
Source: Research Institute of Innovative Technology for the Earth.

Televisions

62. Worldwide, energy consumption by televisions has doubled over the last decade, from some 150 TWhrs in 2000 to around 300 TWhrs in 2009 (IEA, 2010). The electric power used by an operating television is mainly related to three factors: screen size; technology type, such as plasma or Liquid crystal display (LCD); and picture brightness, which nearly always depends on user-selected picture settings. Old, cathode-ray televisions (CRTs) are starting to disappear, especially in developed countries, and are being replaced by much larger plasma and LCD-based High-Definition Television (HDTVs). Although LCD screens usually use less energy to provide the same display function as other technologies, more and more electricity is being spent on TV-related activity with the increasing popularity of TV-based entertainment options, such as video game consoles, digital video recorders, and streaming or on-demand video devices. The IEA (2010) forecasts that by 2020 the television energy consumption could exceed 1 500 TWhrs and almost double again 10 years later.

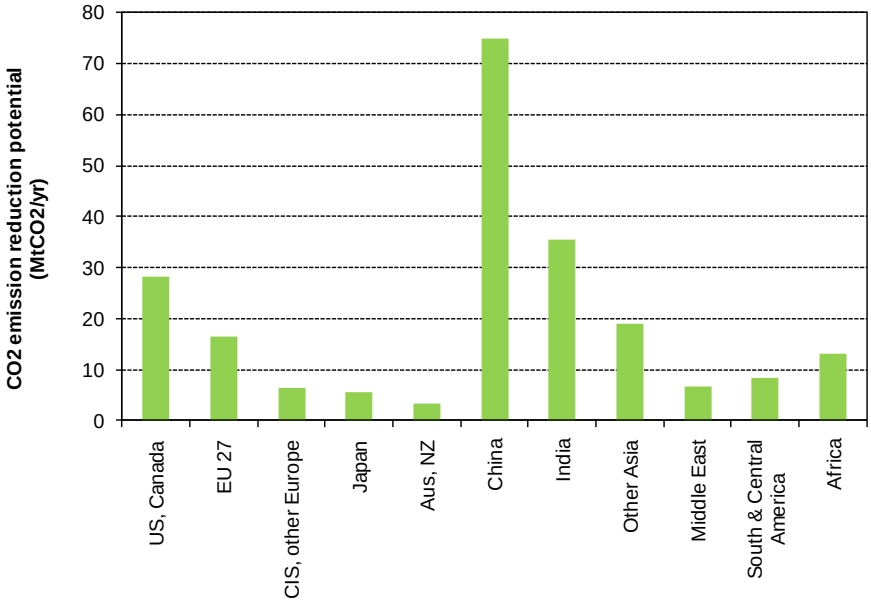
63. According to IEA analysis, plasma TVs use more power than LCD TVs, consuming, on average, roughly two to three times more electricity to produce an image of the same brightness as LCDs. In the last couple of years, plasma TV makers have made some progress, but they still cannot compete with LCDs for energy efficiency. Even among CRTs, energy efficiency can vary by more than 40%, so there are substantial technical savings potentials even using the traditional CRT technology. As for refrigerators, modelling by RITE suggests that, under an optimistic scenario, electricity consumption for televisions in 2020 could be much less than in 2000 for many world regions, though consumption in non-OECD countries can still be expected to rise (Figure 16). The CO_2 mitigation potentials by region are hence about one-third that of refrigerators (Figure 17).

Figure 16. Electricity consumption of televisions, by region



Source: Research Institute of Innovative Technology for the Earth.

Figure 17. CO_2 emissions mitigation potential of televisions



Source: Research Institute of Innovative Technology for the Earth.

Lighting

64. The efficiency of electric lighting devices has over the last three decades has improved tremendously. While the technology of incandescent and fluorescent lamps is mature, with little room for increased luminous efficiency, Light Emitting Diodes (LEDs) and Organic Light Emitting Diodes (OLEDs) can be expected to continue improving very rapidly. Such advances in lamps should be accompanied by reductions in cost as well.

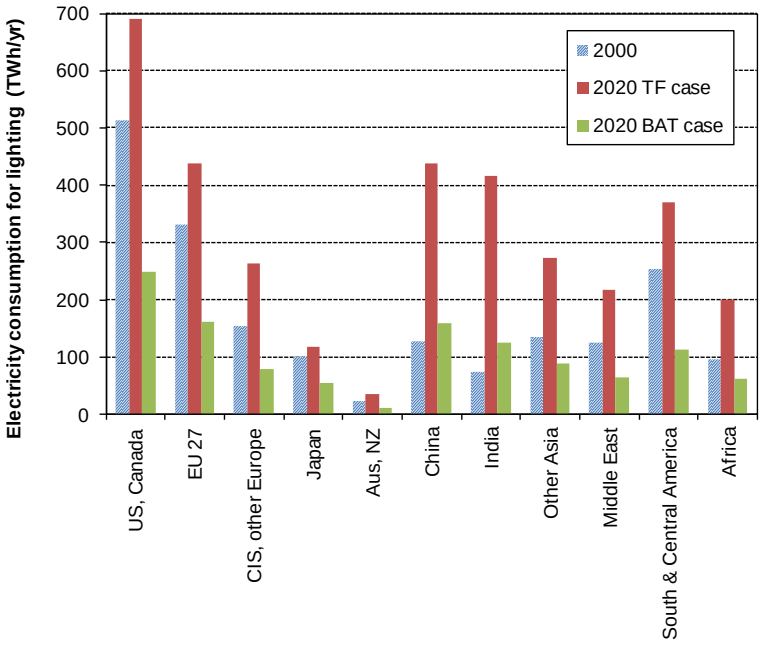
65. Incandescent bulbs create light through exothermic Joule heating. They are inexpensive and have excellent colour-rendering properties; but their lifetime is generally short and their energy efficiency is low. A fluorescent lamp is an arc-discharge lamp that uses electricity to excite mercury vapour atoms. A fluorescent lamp converts electrical power into visible light more efficiently and has a longer lifetime than an incandescent lamp.

66. LEDs have many advantages: they are compact and lightweight, they have good visibility, they can be switched on and off quickly, they can withstand shocks and they have long service lives. But they have a low luminescence intensity and are relatively expensive. An OLED is a LED with an emissive electroluminescent layer composed of a film of organic compounds. OLEDs can also be used in light sources for general space illumination, and large-area light-emitting elements. Due to their younger stage of development, OLEDs typically emit less light per unit area than inorganic solid-state based LEDs that are usually designed for use as point-light sources.

67. According to the IPCC, energy use for lighting can be reduced by 75% to 90% compared with conventional practice through: *(i)* the use of day-lighting with occupancy and daylight sensors to dim and switch off electric lighting when not needed; *(ii)* the use of the most efficient lighting devices available; and *(iii)* the use of such measures as ambient or task lighting. The IEA has pointed out that a market shift from inefficient incandescent lamps to compact fluorescent lamps (CFLs) would cut world electricity demand for lighting by 18%. This implies that large energy savings can be achieved by selecting lamps with higher efficiency.

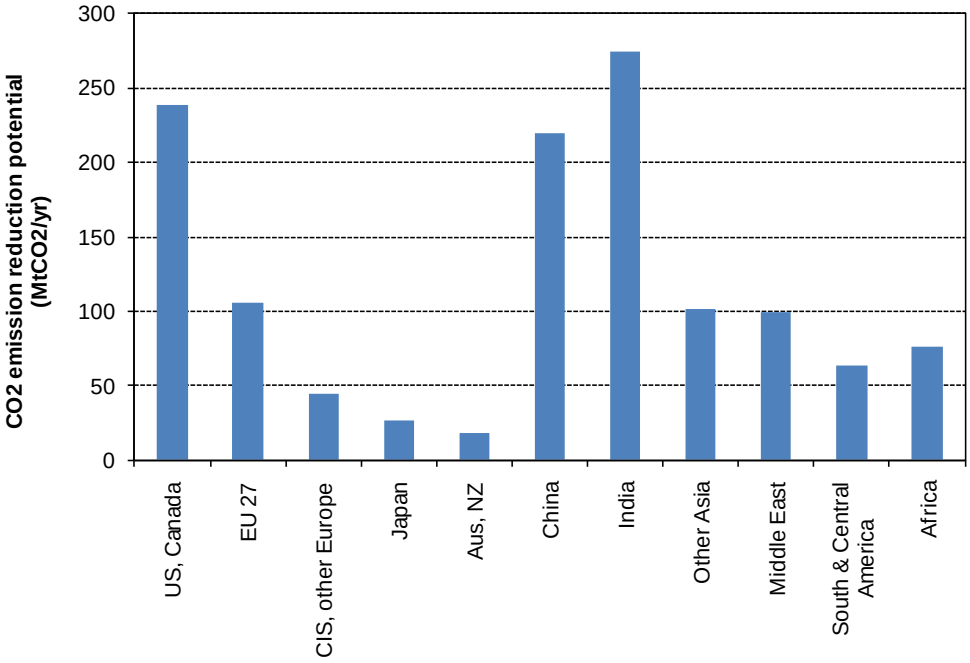
68. Despite the availability of a whole array of energy-efficient lighting technologies, however, incandescent lamps are still the dominant technology in use for domestic lighting in most countries, though fluorescent lighting and halogen lamps also make significant contributions. The very low purchase cost of incandescent bulbs is a disincentive for consumers to choose more efficient bulbs, such as CFLs, which are more expensive. Modelling by RITE shows that, under an optimistic scenario, electricity consumption for lighting could be less in 2020 than in 2000 in almost all world regions, and only slightly higher in China and India (Figure 18). Of the four electrical appliances studied, the CO_2 emissions-mitigation potential is hence greatest for lighting (Figure 19).

Figure 18. Electricity consumption for lighting, by region



Source: Research Institute of Innovative Technology for the Earth.

Figure 19. CO_2 emissions mitigation potential of lighting



Source: Research Institute of Innovative Technology for the Earth.

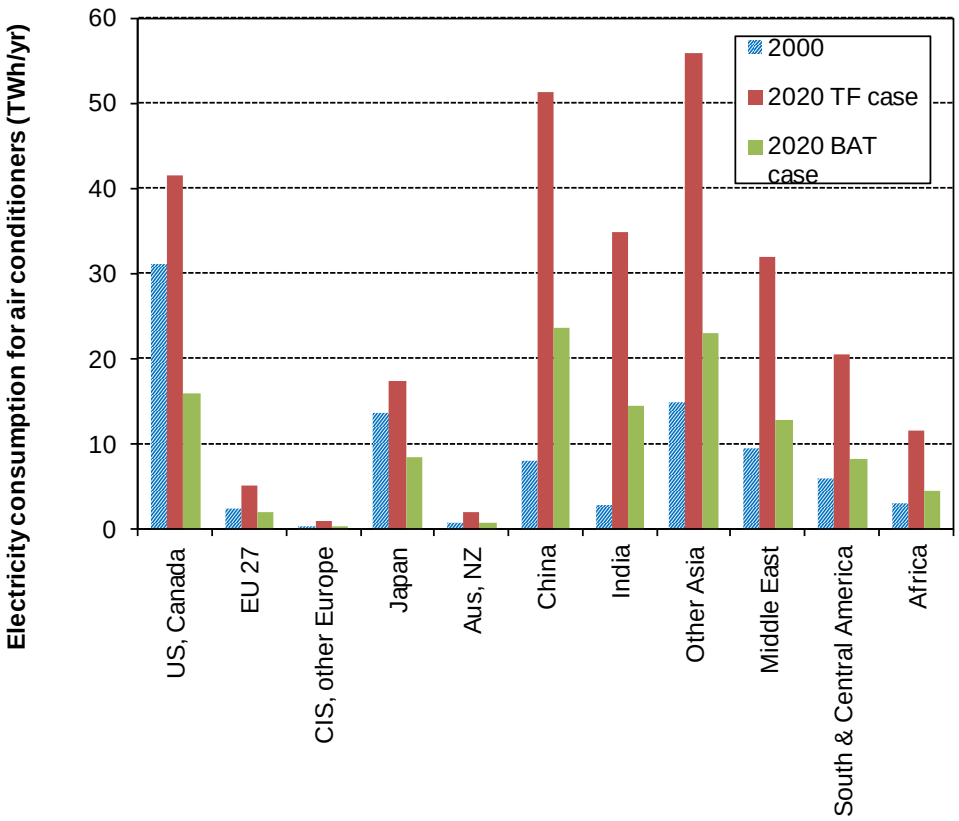
Air Conditioners

69. Most air conditioners are driven by heat pumps, but the efficiency of the air conditioners available on the market varies substantially. The main types of air conditioners are single-package room air conditioners, split-system room air conditioners and packaged central air conditioners. Room air conditioners include window-mounted appliances, wall-mounted units with a sleeve to allow through-the-wall mounting, and freestanding portable units that can easily be moved on wheels. The least-efficient portable air conditioner might have an energy efficiency ratio of less than 1.5 W/W (watts of cooling output per watts of power input), whereas the most efficient split-room air conditioners can achieve more than 6.5 W/W.

70. The efficiency of these systems depends both on the coefficient of performance (COP) of the unit, and the building and the integration of the system into it. The efficiency of this technology has improved significantly in recent years. The IEA has estimated that the COP of heat-pump air conditioners increased from around 4.3 in 1997 to around 6.6 in 2006, while some COPs now reach 9.0.

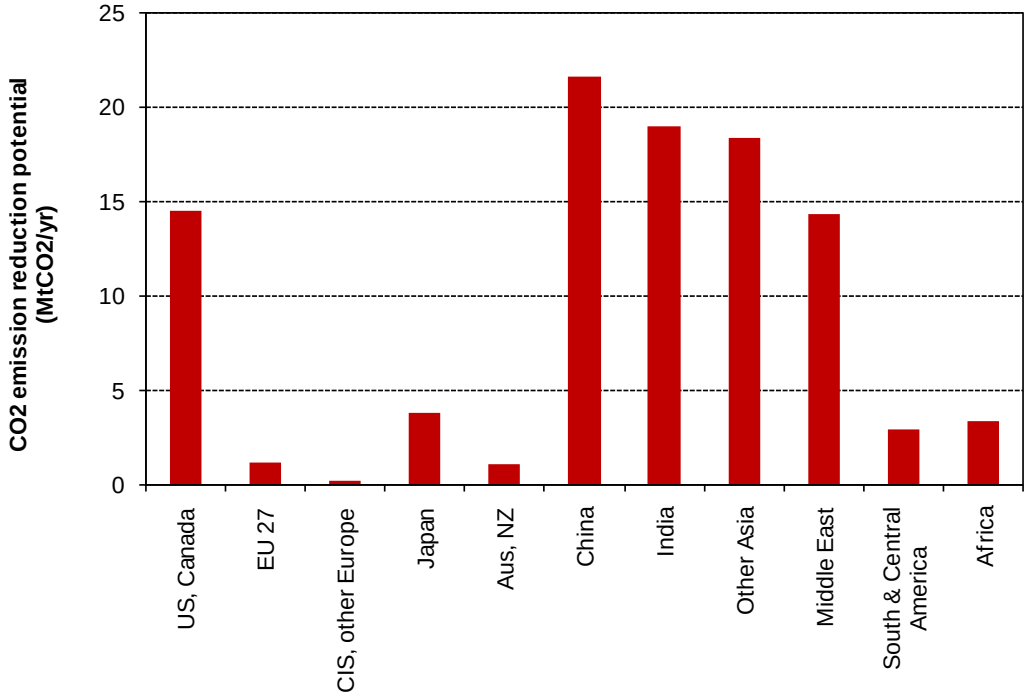
71. The number of air conditioners in use is growing rapidly. This rapid growth offers opportunities to roll-out more efficient appliances (Figure 20), but the installation of more advanced systems can be difficult because more efficient systems are initially expensive, even though they may be cheaper on a lifetime basis. The CO2 mitigation potential under an optimistic scenario would still be significant, however (Figure 21).

Figure 20. Electricity consumption for air containers, by region



Source: Research Institute of Innovative Technology for the Earth.

Figure 21. CO_2 emissions mitigation potential of air conditioners



Source: Research Institute of Innovative Technology for the Earth.

Carbon abatement cost of replacement

72. Electric appliances typically remain in use for at least a decade, until they are retired at the end of their life, so their design energy performance is crucial. However, people often have rather short-term perspectives when they invest in energy-using products. The upfront investment itself can be a significant barrier; many consumers require savings in electricity bills to pay back in only one to two years for them to pay more for an energy-efficiency appliance. As a result, appliance makers often compete more on shelf price than on life-time costs, and hence may choose not to include additional energy-saving features in their products even if these would pay for themselves over the lifetime of the appliance. Here we study the impact of such short-sighted behaviour.

73. From an investment perspective, energy-efficiency choices fundamentally involve investment decisions that trade off higher initial capital costs. Consumers have often been resistant to even small upfront costs, such as those required for energy-efficient appliances, if the payback period exceeds two years. From an economic perspective, however, the energy savings usually outweigh the upfront investment, so that these opportunities carry a net economic benefit over their lifetime, even without any additional CO_2 incentive.

74. We assessed the gap between these perspectives through the change of the abatement costs, taking different payback periods, as follows. First, the annual total costs (TC) of products were calculated according to the formula below:

TC per year = (Initial investment/ Payback period) + annual O&M + annual energy cost

75. Then, the abatement cost, which reflects the annualized cost of different abatement technologies (substitute technologies with higher efficiency) in a given year per tonne of carbon saved compared with the business-as-usual technology (substituted technology with lower efficiency), was obtained as follows:

Abatement costs = (TC of substitute tech - TC of substituted tech) / (CO_2 emissions of substituted tech - CO_2 of substitute tech)

76. In terms of payback period, five cases, ranging from 1 year to 12.8 years, were examined. The length of 12.8 years corresponds to the payback time in which 15 years product lifetime is discounted at a deemed real interest rate of 2% per year. The length of 10.4 years corresponds to a discount rate of 5% for products with 15 years lifetime, and 7.6 years to a 10% discount rate. Table 3 provides summary results. Details are shown in Annex 3. This table suggests that most of the technologies that offer significant energy-efficiency opportunities are currently cost competitive if a longer payback period is taken.

77. Electricity prices also vary by region, sector, time, and season, so a sensitivity analysis was performed on these variables. An underlying assumption for Table 3 was USD 0.15/kWh and 0.50 kg of CO_2/kWh. Figure 22 illustrates the results of the sensitivity analysis for electricity price in the case of refrigerators substitution from mid- to high-efficiency. It implies that the levelised electricity price is a key for economic efficiency; however, the assumed payback period could be more important factor.

Table 3. Abatement cost of replacement, assuming USD 0.15/kWh and 0.50kgCO_2/kWh

Product	Replacement		Payback Period (years)				
	From	To	1	3	7.6	10.4	12.8
Refrigerator	Low-Eff.	Middle-Eff.	+	+	–	–	–
	Middle-Eff.	High-Eff.	+	+	+	+	–
Television [in 2020]	Small Low-Eff.	Small High-Eff.	+	–	–	–	–
	Large Low-Eff.	Large High-Eff.	+	+	-	–	–
	Large High-Eff.	Large Advanced	+	+	+	+	–
Lighting* [in 2020]	Small Incandescent	Small CFL	+	–	–	–	–
	Small CFL	Small advanced	+	+	+	+	+
	Mid-Eff. fluorescent	High-Eff. fluorescent	+	–	–	–	–
	High-Eff. fluorescent	Advanced	+	+	+	+	+
	Mid-Eff. HID	High-Eff. HID	+	+	–	–	–
Air Conditioner**	Low-Eff.	Middle-Eff.	+	+	–	–	–
	Middle-Eff.	High-Eff.	+	+	+	–	–

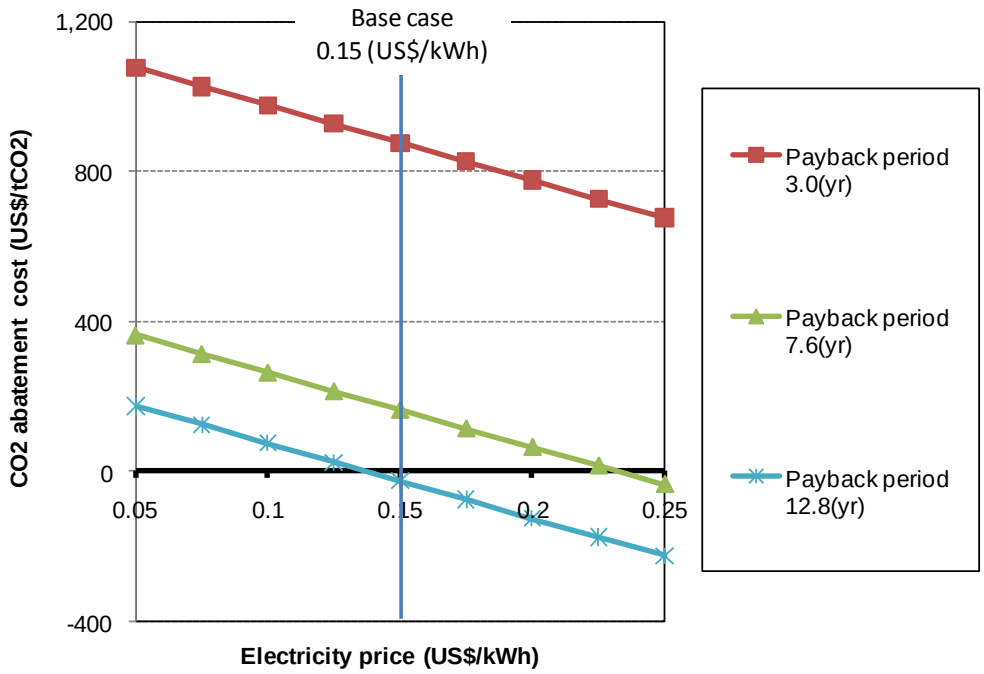
* Payback period for Lighting is adjusted in accordance with lifetime of each product.

** In this table air conditioner is assumed that usage ratio is 157 hours per year.

–: Negative abatement cost, +: Positive abatement cost

Source: Research Institute of Innovative Technology for the Earth.

Figure 22. Sensitivity analysis of CO_2 abatement cost for refrigerators[1] to different assumptions about electricity-prices and investment pay-back period



1. From mid-efficiency to high-efficiency.

Source: Research Institute of Innovative Technology for the Earth.

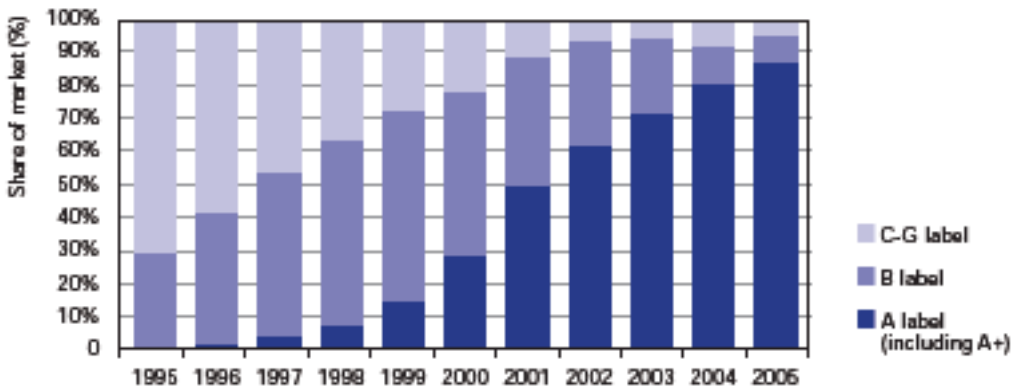
4. OVERCOMING BARRIERS TO THE ACHIEVEMENT OF THE POTENTIAL FOR ENERGY EFFICIENCY

78. The previous section underscores the impact that replacing technologies currently in use with ones that are much more energy-efficient would have on energy use and GHG emissions. It also alludes to the barriers that hinder the full potential from being achieved. Policymakers and programme implementers, however, know that, because of various financial and policy barriers, not all of that potential is certain to be achieved.

79. There are, of course, factors that will help. First, for the technologies under discussion, indications are that further improvements can be achieved. Technological breakthroughs are unpredictable, but likely. Technology is not the limiting factor.

80. Second, the market for electrical appliances is working reasonably well with the policy instruments currently available, at least in OECD countries. The increasing use of appliance labels at the point of sale has been an important factor in transforming the market for electrical appliances. Figure 23 shows how the market share of "A" and "A+" labels, used throughout the European Union, increased in Denmark between 1995 and 2005 for cold appliances (refrigerators and freezers). Cold appliances conforming to these ratings now represent over 80% of the market (IEA, 2009).

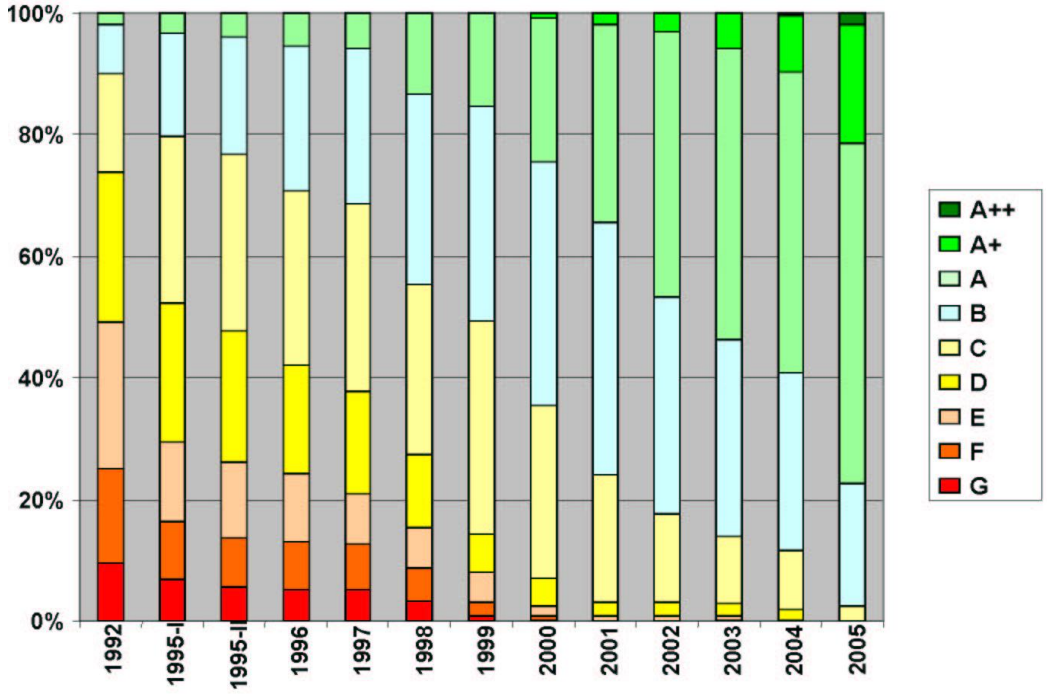
Figure 23. Sales of cold appliances in Denmark, 1995-2005 by energy rating



Source: Danish Energy Agency.

81. Figure 24 shows the evolution of energy classes in Europe between 1992 and 2005. The move to the top classes accelerated after 2000. The last two examples show that there are important advances being made today to deploy more efficient technologies.

Figure 24. Evolution of sales of household appliances by energy class in Europe, 1992-2005



Source: European Committee of Domestic Equipment Manufacturers (www.ceced.org).

82. There are, however, numerous factors that are keeping the full economic potential of energy efficiency from being achieved. Among the many market barriers that affect consumer choice and behaviour are:[11]

Lack of information: When consumers do not have adequate information, they miss out on cost-effective opportunities.

Lack of confidence: Traditionally there has been scepticism about predictions of the benefits of any new technology, and this holds equally true for energy-efficient appliances.

Financial barriers: This can be an issue especially for large household appliances, which households purchase infrequently, or the retrofitting of multi-pane windows or other energy-efficient investments. Many consumers must borrow money to undertake such purchases, which can drive up their costs. While this may be less of an issue in OECD countries, it may be very important in developing countries, where markets for consumer finance are less well developed. There may also be costs associated with the disposal of large household appliances.

Inertia: Consumers normally opt to avoid changing habits or actions, especially when conditions such as energy prices are stable.

Separation of capital expenditure and operating expenditure: Often, those using energy or making capital decisions about appliances are not the ones who pay directly for the system's

11. The IEA has written extensively on this topic over the years. The IEA first discussed barriers in detail in *Energy Conservation in IEA Countries*, OECD, Paris, 1987; its most recent study on this topic is *Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency*, OECD/IEA, Paris, 2007.

energy use and hence lack an incentive to minimise operating costs. This is particularly true in rental markets.

Incremental capital-equipment costs: Energy-efficient appliances are often (but not always) more expensive at the point of purchase than their less efficient counterparts. This has been especially true for lighting. Import tariffs on products raise domestic prices above what they would otherwise be.

Energy subsidies: Many countries, especially in non-OECD countries, subsidise electricity prices for domestic consumers for reasons of wealth redistribution and social welfare. Subsidies to energy services are as a rule ineffective, economically inefficient and contrary to good environmental practice.[12]

83. Most domestic energy-efficiency policies are designed to address the first five of the above barriers, such as through appliance labelling programmes, minimum energy-performance standards (MEPS), and financial incentives to help sway consumers to purchase relatively energy-efficient goods (Annex 2). OECD countries were the first to establish such programmes, but a number of emerging economies — e.g., Brazil, China, Chinese Taipei, India, Iran, the Philippines, Russia, Singapore, and Thailand —- are also developing their own MEPS and supporting policy frameworks. A recent study of Demand-side management policies in the buildings sector of countries that are members of the Asia Pacific Partnership documents a major initiative in China in 2008 to subsidize the wholesale and retail prices of CFLs (de la Rue du Can *et al.*, 2011). In India, several electric utilities are starting to implement demand-side management programmes.

84. However, many countries, especially developing countries, do not yet have well-established energy-efficiency policies. Moreover, the effects of their trade and energy policies may actually be discouraging the penetration of more energy-efficient products.

85. Several factors in these countries may be creating barriers to trade in the most energy-efficient products.[13] These include:

- high tariffs on goods, especially electrical household appliances;
- low internal prices for energy;
- a lack of minimum energy-performance standards;
- a lack of agreed international standards, or the use of national standards that diverge from international norms.

General non-tariff measures — that is, other than those specifically related to the products in question — may also be creating barriers to trade in these products, but the extent to which this may be the case is beyond the scope of this paper to assess.

12. Generally, economists counsel providing assistance more targeted at the poor, such as through conditional cash transfers, rather than universal energy subsidies. See IEA *et al.* (2010).

13. When consumers purchase an electric appliance they are buying entertainment or comfort or other services: they are not buying a television to save energy or reduce GHG emissions. Motivating consumers to choose the more energy-efficient option is tricky. The important point about analysing the full range of barriers is to determine if and what policy instruments can be used to help achieve more of the cost-effective potential of energy-efficiency improvements.

High import tariffs and low electricity prices

86. Although most OECD countries, and many developing countries, apply low (i.e. 5% or less) tariffs on electrical appliances, many apply tariffs that are 10% or greater, with some applying tariffs as high as 35% (Annex 6, Tables A6.1-A6.5). Among the populous countries applying tariffs of 20% or more on window or wall air-conditioning units (HS 8415.10) are Bangladesh, Egypt, Kenya, Malaysia, Nigeria, Pakistan, Thailand, and Viet Nam. These eight countries, along with South Africa, also feature among the larger countries applying tariffs of 20% or more on household refrigerators (HS 8418.21). And among the countries levying import tariffs of 20% or greater on colour televisions (HS 8528.72) are Bangladesh, Brazil, China, Egypt, Ethiopia, Malaysia, Pakistan, the Russian Federation, Thailand, and Viet Nam. With respect to lighting, a fewer number of populous countries apply tariffs of 20% or higher. For tungsten-halogen filament lamps (HS 853921) these are Ethiopia, Kenya, Nigeria Pakistan, and the Russian Federation; and for fluorescent lamps (HS 853931) the high-tariff countries include the same group (except for the Russian Federation), plus Viet Nam (34% tariff).

87. The effects of these tariffs on the diffusion of newer, more energy-efficient goods is likely to depend on a number of factors, including whether there are domestic manufacturers of like products in the countries applying the tariffs. If the appliance is not produced domestically, a high import tariff will increase its internal price, and overall demand for that good may be reduced. But consumers will also likely keep older appliances in operation longer than would be the case in the absence of the tariff. Given that technological change generally results in improvements in energy efficiency over time, the net effect on energy consumption associated with the appliance's use in the country could be positive or negative as a combined result of lower overall demand but greater proportional ownership of older-vintage models.

88. The existence of one or more major manufacturers of the product in the country can change the situation. If the manufacturer produces appliances that are as energy-efficient as the choice of appliances available from the world market, the effect of border protection will be as described above. But it is possible that the domestic manufacturer produces a less energy-efficient version of the appliance. Thus the effect of the import tariff may be to favour sales of the locally manufactured appliance. The likelihood that the domestic manufacturer will produce a version of the appliance — e.g. a refrigerator — that is relatively inexpensive to buy but relatively energy-inefficient, increases the lower are the domestic prices for energy, especially for electricity, in the country compared with international reference prices.

89. Table 4 shows that average electricity prices paid by residential consumers in China, Egypt, India, Indonesia, Kazakhstan, Nigeria, Pakistan, the Russian Federation, Thailand, Saudi Arabia, South Africa, and Vietnam are all less than half the price paid in Japan, and in the case of several of the countries the prices are less than one-third those paid in Japan.[14] High import tariffs on appliances, combined with low electricity prices in these countries, likely combine to steer consumers towards appliances that are the cheapest to buy, but consume more energy over the long run.

14. Japan has been used for this comparison as a reference because its electricity prices are near the average for the OECD region, and the country applies a 0% import tariff on the four electrical goods discussed in this report.

Table 4. Average electricity prices in Japan and in selected developing and emerging economies, latest year

(US cents[1] per kilowatt-hour)

Country	Residential consumers		Industrial consumers	
	Data year	Price per kWh[2]	Data year	Industrial
Japan	2010	21-29	2010	12.2
China	2010	7-9	..	..
Egypt	2010	1-8	..	..
India	2010	3-8	..	..
Indonesia	2010	2-6	2009	6.2
Kazakhstan	2010	6	2010	4.6
Nigeria	2010	1-6	..	..
Pakistan	2010	2-15	..	..
Russian Federation	2010	8	2010	5
Thailand	2009	10	2009	7.6
Saudi Arabia	2010	1	July 2010	3.7
South Africa	2010	8-13	June 2011	8.6
Viet Nam	2010	3-9	..	..

1. One U.S. cent = USD 0.01.

2. The low end of the range represents the price for the first 50 kWh consumed in a month and the high end of the range the price for the 1001st kWh consumed in a month. Prices are converted at the market exchange rate in September 2010.

Sources: • **Residential (Japan, Kazakhstan, and Thailand):** IEA (2011b) ; • **Residential (all other countries):** Miramontes and Ahmed (2010); • **Industrial (Saudi Arabia):** Karam (2010); • **Industrial (South Africa):** NUS Consulting Group (2011); • **Industrial (all other countries):**.

90. Even in countries that apply low import tariffs on appliances, of course, low electricity prices may dampen any incentives consumers may have to opt for the (generally more expensive) energy-efficient models. Residential electricity tariffs in India, which levies a 10% import tariff on household appliances, are well below those of most OECD countries.

91. There are also a number of small, net-energy-importing countries that apply high tariffs on goods and also charge consumers relatively high electricity prices. The issue in those countries is often that investing in improving energy efficiency might lead to greater imports of foreign-manufactured goods in the short term, but reduced imports of energy products (e.g. fuel oil for electric power plants) in the longer term. Part of the case for reducing tariffs on energy-efficient goods, and goods that help to improve energy efficiency, is thus the longer-term trade benefits of reducing the need to import fuels.

Differences in standards and conformity-assessment procedures

92. Among developed countries, and among a growing number of developing countries (Annex 6, Table A6.6), minimum energy-performance standards (MEPS) are helping to drive industries and household consumers to purchase the most energy-efficient goods. Generally, the stricter the standards the larger the potential market for relatively energy-efficient goods. Differences in MEPS, and in particular in testing protocols and other aspects of conformity-assessment procedures, however, can add to trade costs and make exporting to foreign markets more difficult. The main obstacles for trade in goods subject to

these standards are thus those relating to differences in the ways that the standards are specified and, in some cases, to the additional costs imposed on international trade by the need to prove conformity with differing standards across multiple jurisdictions.

International co-operation on harmonization

93. Energy-efficiency policies are increasingly global in their effects, as the manufacture of and trade in technologies expand. This has put more emphasis on the need for international co-operation. There is a recognized need at the international level to "either standardise or harmonise product descriptions and energy-performance metrics or to develop algorithms that would allow simple conversion from one set of requirements to another without necessitating retesting." (Steenblik *et al.*, 2006) As the IEA (2010, p. 15) has observed:

> International trade considerations and the existence of global markets create new market barriers when each country independently implements its own energy-efficient product policies and standards. Mass-manufactured products often do not differ much across countries, irrespective of national efficiency schemes. … New national efficiency schemes should therefore take account of existing efforts so the market transformation strategy works effectively within an increasingly global market for energy-efficient products.

94. Fortunately, there are now many initiatives at the national and regional levels, as well as globally, to encourage standards development and to encourage the harmonization or alignment of standards. The IEA (Waide, 2008, p. 3) observes that "Harmonisation of … energy-performance standards helps:

- minimise product energy performance testing and verification costs for increasingly globalized energy-using equipment markets;
- enable energy performance to be compared on a common basis across broad economic and political groupings;
- facilitate adoption of more efficient product manufacturing; and
- accelerate transfer of best practice in policy settings."

The following sections provide examples of some of the progress that has been made in harmonising standards at the regional level and, in some cases, globally.

IEA programmes

95. The IEA is involved in policy development for its member countries and increasingly focussing beyond its member countries. Besides publishing major studies on lighting and appliances, the IEA has also established several **implementing agreements** related to technology development and deployment. Those that are particularly relevant to energy efficiency include:

- The 4E Implementing Agreement,[15] which focuses on electrical end-use equipment from the residential, commercial and industrial sectors. 4E focuses on equipment that contributes most to the total end-use electricity consumption, such as electric motors and lighting, and will include technologies with fast-growing markets shares such as set-top boxes.

15. www.iea-4e.org

- The IEA Demand Side Management Agreement,[16] which promotes energy efficiency and demand-side management for global sustainable development and for business opportunities. This includes a wide range of actions to reduce demand for electricity (or gas) or to shift demand from peak to off-peak times. One of the current projects is on co-operation in the development of standards.

96. In 1999, the IEA proposed that all countries harmonise energy policies to reduce standby electric-power demand to no more than one watt per device. Standby power is the electricity consumed by appliances while switched off or not performing their primary functions. The proposal contained three elements:

- Participating countries would seek to lower standby power demand to below 1 watt in all products by 2010;

- Each country would use measures and policies appropriate to its own circumstances; and

- All countries would adopt the same definition and test procedure.

97. An internationally sanctioned definition and test procedure for Standby Power was adopted by the International Electrotechnical Commission (IEC 62301) in 2005, and this is now widely specified and used. Many countries have adopted standby requirements into their regulations.

APEC Programmes

98. The Asia-Pacific Economic Cooperation (APEC) Forum has also recently embarked on a number of activities to promote energy efficiency. Among the groups assisting APEC's Energy Working Group is the Expert Group on Energy Efficiency and Conservation (EGEE&C). The EGEE&C was formed in the early 1990s and has since organized a large number of desk studies, workshops and demonstration projects to promote energy-efficient practices and technologies, including through reductions in trade barriers. Recent work has included, for example:

- Developing a common protocol for measuring the seasonal energy efficiency (SEER) of air conditioners in order to reduce barriers to trade in these appliances.

- Assisting APEC member economies in the development of common protocols for measuring standby power in appliances and electronics, in order to facilitate the global alignment of standards relating to standby-power consumption.

- Developing lighting standards and testing technology for lighting modules and fixtures that incorporate light-emitting diodes (LEDs). APEC economies are responsible for most of the world's production of LEDs.

Other international and regional co-operation on harmonisation of standards

99. Numerous efforts to harmonise standards for energy efficiency are underway across the world. These include initiatives by both governmental and non-governmental bodies (Janssen, 2010). Some examples of these international-harmonisation efforts include:

16. www.ieadsm.org

International CFL Harmonisation Initiative (CFLI)[17] **—** This initiative was launched at a conference in Shanghai in 2005, supported by Australia, China, the European Union, the United States, the Efficient Lighting Initiative (ELI), and several manufacturers. Its objective is to harmonise standards across the major markets in order to improve quality, lower compliance costs, reduce manufacturer costs and lower consumer prices. In 2008 the CFLI identified 32 different schemes around the world that address the efficiency of CFLs, even though 80% of the world's CFLs are produced in mainland China and 10% in Chinese Taipei (CFLI, 2008).

Efficient Lighting Initiative (ELI)[18] **—** ELI started in seven countries (in Argentina, the Czech Republic, Hungary, Latvia, Peru, the Philippines and South Africa) to help in the market transformation of efficient lighting. The original programme tested the quality certification and labelling concept. ELI was operated by the International Finance Corporation (IFC) and was funded by the Global Environment Facility (GEF). In 2005, the China Standard Certification Centre (CSC) was commissioned by the IFC to develop and expand the ELI certification and branding system globally. Now a new body, the ELI Quality Certification Institute, operates the expanded ELI programme.

100. Equally important have been efforts at the international level to establish common, or at least comparable, test procedures for energy-using appliances. The International Electrotechnical Commission (IEC), for example, has formed a working group comprised of representatives from the Australia, China Japan, the Netherlands, the United Kingdom, and the United States, tasked with developing a test procedure that would provide an energy-consumption measurement that would represent real-world television use and would be fair for all display technologies (Box 2). As the IEA (2010) describes this effort, it "shows how experts (tasked and funded by a small number of motivated major economies) can deliver a test method suitable for global alignment. The governments involved were able to avoid multiple regulatory debates that result in different stringency levels in the three regional markets discussed. They were also able to preserve their sovereign right to determine the best set of cost-effective activities for their own national jurisdiction."

17. www.apec-esis.org/www/cfl/

18. www.efficientlighting.net

Box 3. The IEC's initiative on television test procedures

What was done?

The need to address television energy consumption was recognised by some regulators and industry experts by 2005. They identified the need for an internationally recognised energy-use test procedure, covering all available television display technologies fairly and accurately. At that time, the IEC standard 62087 only covered CRT technology. By 2006, an IEC working group with representation from the United States, United Kingdom, Netherlands, Japan and Australia (and later also China) was tasked to develop a test procedure that would provide an energy consumption measurement that represented real world television use and was fair for all display technologies.

The experts were funded by governments and industry associations to model real world television viewing, particularly in regards to average picture brightness levels (APL), which, together with screen size, are the main contributing factors to television energy consumption. In a public review process taking several years, the group produced a 10-minute video loop that consisted of material not subject to copyright from all corners of the globe that matched the APL histogram. They also settled issues within the test method to the satisfaction of the global industry and regulatory agencies publishing the method as IEC 62087 Edition 2. A globally applicable test method appeared for the first time in late 2008.

What resulted?

As of 2010, three regulated schemes and one voluntary scheme had adopted the test protocol to measure energy efficiency (Australia, California and Europe) as well as Energy Star. The performance requirements of the three regulatory schemes were settled in national debates (following established legal frameworks) and some dialogue between the parties negotiating performance requirements did occur.

The alignment that characterised the development of the test method, however, did not flow through to the suite of performance regulations adopted in the three jurisdictions. Regulators adopted a similar approach to defining energy performance metrics, consisting of the energy demand per square cm (or inch) of screen surface plus an fixed amount of energy per television, and followed a common format by establishing two performance levels to help phase in mandatory minimum performance levels. The regulations in the three locations, however, commenced at differing times, were set at differing stringencies and involved some different interpretations of the IEC test procedure.

Lessons learned

The main lesson is that an internationally accepted test procedures for energy use is essential. Without the IEC test procedure for televisions, harmonisation of energy efficiency metrics in various economies, and to some extent requirements, as is starting to occur, would most likely have not emerged. Secondly, for products with challenging and complex energy consumption characteristics, a well-coordinated and focused international group can overcome the challenges involved in developing a unified test procedure that can be applied globally.

Earlier involvement of Chinese government and industry experts could have avoided the larger differences between the test procedure used in China and those in other economies. Although the procedures are somewhat [similar] everywhere, differences between the Chinese procedure and those in the United States, the European Union and Australia are more significant. Availability of better market and sales data could have reduced the time needed to start work on the IEC test procedure. This, consequently, might have led to an earlier availability of a harmonised test procedure, allowing for the application of the procedure in advance of the development of performance requirements and full adoption in all MEPS developments.

The success of the television test procedure has led a group of experts to successfully petition the IEC to commence work on a new measurement method for set-top boxes, which was published in April 2011 as Edition 3 of IEC 62087 (IEC, 2011). In parallel to this work, the IEC has also established a working group investigating what other product energy test procedures are still deficient. It is now possible to map television test results from various national and sub-national programmes which facilitate benchmarking of programme results. The benchmarking may encourage closer co-operation between regulatory agencies in setting future performance requirements for globally traded products.

Source: Adapted from IEA (2010), pp. 49-51.

Capacity-building

101. Many non-OECD countries, particularly developing countries, have limited capacity to develop and implement policies to promote the deployment of energy-efficient technologies. This is particularly true for standards development. Accordingly, a several national governments and non-governmental organizations have established programmes to help these countries.

102. In January 2008 the Swedish Ministry for Foreign Affairs initiated a project on climate standards in co-operation with the Swedish Standards Institute (SIS), the Swedish National Board of Trade, the Swedish Aid Agency (SIDA) and the International Standards Organisation (ISO). The prime objective of the Swedish Climate Standards Project is to strengthen developing countries' opportunities for increasing trade in goods and services that help reduce greenhouse-gas emissions. One important activity involves supporting developing countries becoming more involved in international standardisation relating to climate-policy objectives, including standards for energy-efficient goods – thereby influencing the content of such right from the beginning, instead of applying standards designed by developed countries in accordance with their needs and production conditions. By active participation in such standardisation work, the Project hopes to enable developing countries to expand their production of and trade in "climate-friendly" goods and services.

103. Separately, the CEECAP — Implementing EU Appliance Policy in Central and Eastern Europe project — supported Central and Eastern European (CEE) countries in creating suitable conditions for implementing appliance labelling and efficiency policies in accordance with the EU's Appliance efficiency legislation and programmes. The project started in early 2006 and lasted for 30 months. It was carried out in six CEE countries of (Czech Republic, Bulgaria, Lithuania, Poland, Romania and Slovakia). These countries now participate fully in EU-related programmes.

104. The Asia-Pacific Energy Research Centre (APERC) has been helping APEC members build capacity in the area of energy efficiency through peer reviews on energy efficiency (PREEs). In 2009 it conducted PREEs for New Zealand, Chile, Viet Nam and Thailand, and in 2010 it conducted ones for Chinese Taipei, Peru and Malaysia (Kobayashi, 2011). The PREE reports make a number of recommendations, including indentifying barriers — political, financial, and technical barriers (e.g. relating to end-use data, experts, standards, monitoring and evaluation, product testing) to energy efficiency.

105. In recent years, non-governmental bodies also have become involved in efforts to ensure more energy-efficient products are available on the market. In some cases, these efforts reinforce or attempt to accelerate government efforts; in other cases, they act in the absence of effective government initiatives. The following are two examples:

- **CLASP, the Collaborative Labelling and Appliance Standards Programme,**[19] provides technical assistance related to standards and in over 50 countries, monitors the full extent of standards and labelling globally. Since 1999, CLASP has assisted with the implementation of 24 efficiency standards or labels. CLASP is a not-for-profit organisation based in Washington, D.C., with offices in Europe, China, India and Latin America, through support from the US-based foundation, ClimateWorks.[20]

19. www.clasponline.org

20. www.climateworks.org

- **ECOS, the European Environmental Citizens Organisation for Standardisation,**[21] is a consortium of European environmental NGOs created to enhance the voice of environmental protection in the standardisation processes. ECOS aims at increasing the environmental performance of products, ensuring sound measurement methods for pollutants, greening management systems in businesses and improving consumer information towards sustainable consumption. ECOS is mainly involved in monitoring the activities of the international standardisation bodies and product policies at the European Union level (such as the Directive on the "Eco-design of Energy-Using Products").

106. Another example is the Steel Task Force of the Asia Pacific Partnership. Among its activities to promote various energy-efficient technologies in the steel sector are identifying concrete quantitative indicators related to energy efficiency and environmental improvement, and activities to diffuse technology (Table 5).

21. www.ecostandard.org

Table 5. The expansion and development of the sectoral approach in the steel industry

Activity	Japan-China partnership	APP	World Steel Partnership	Notes
Starting date	July 2005	April 2006	April 2007	—
Number of countries (Share of world steel production)	2 (approx.50%)	7 (approx. 60%)	55 (approx.85%)	'Sectoral Approach' has been expanded gradually from bilateral to multi-lateral
1. Publication of a State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook	○Furnished core date for APP-SOACT (April 2006)	◎Published the first version of SOACT (January 2008)	○Looking to develop a worldwide version of the Handbook	A common world-wide Handbook is difficult to publish because the APP and the EU have different approaches to sharing information.
2.Method to calculate an efficiency index	○Capacity building for statistical calculation is taking place in China.	◎Approved by all APP countries.	◎Approved and shared world widely.	This method was submitted to the ISO by the Japanese steel industry and is expected to be approved.
Designing of a database to support the index		○Designing database for seven counties	◎Designing a world-wide data base	There is a need to secure the duty to protect data, the data coverage and the data quality.
3.Method to set up the target		◎Approved by all seven member countries	○Method discussed (resolves the dis-tortion of international competition)	Concrete target is determined by negotiation with each country.
4.Technology transfer (by exchanging experts)	◎Periodical meetings of experts (incl. visits of steel-works)	◎Site visits and exchange of technology	○Meetings will be held	Realization of CO_2 reduction by technology transfer
5.Future vision			◎Designing 2050 Vision (Reference for IEA, RITE)	Public announcement to society will be made.
6.The development of innovative technology (drastic low-carbon technology is necessary)			◎Innovative tech-nology development is under discussion. Example: CO_2Breakthrough Programme (2003.10-)	Innovative technology is the essential solution.

◎ extremely important for diffusing technology;

○ important for diffusing technology

5. CONCLUSIONS

107. Policymakers responsible for climate-change have long appreciated the potential impact of improving energy efficiency, and in many countries policy initiatives to promote energy-efficient products have been integrated into climate-change strategies. Appliance labelling and minimum energy performance standards have evolved significantly in the past two decades. The primary motivator has been to meet the goals of energy-efficiency policy, while climate change was largely seen as a co-benefit, at least at the beginning. Over time, energy efficiency became totally integrated into climate-change policies in many countries and regions. In Europe, completing the single market was an important driver to ensure that goods could be traded fairly throughout the European Union. This also happened in many other countries with federal systems.

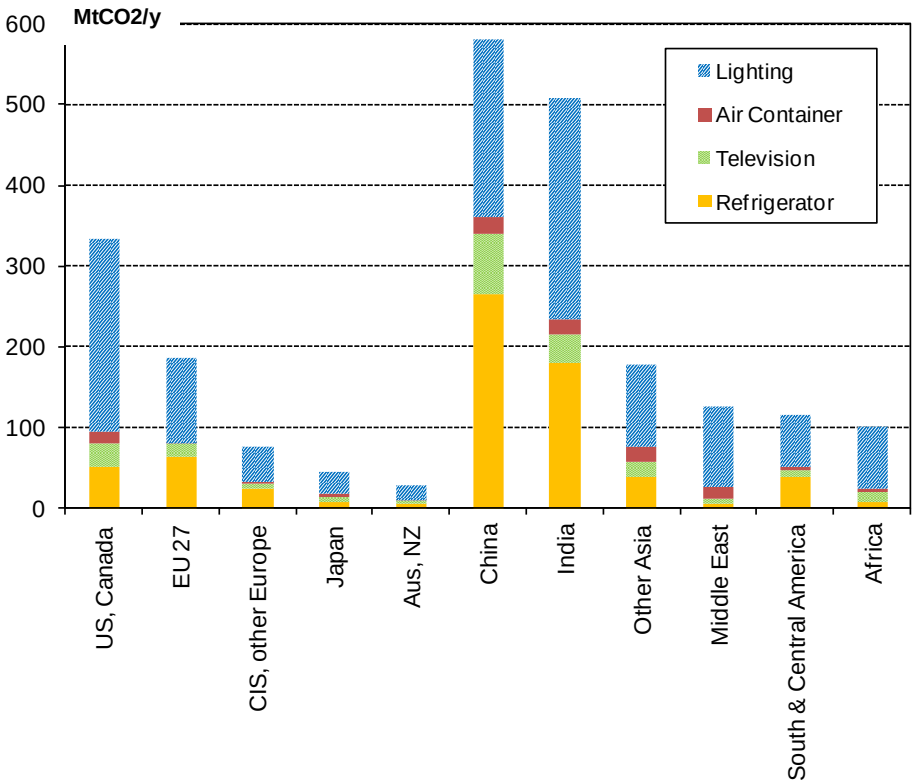
108. Deploying the most energy-efficient technologies, even for the few products analysed for this report, could make a significant contribution to meeting climate-change targets in 2020 and beyond (IEA, 2010).

109. Increasing the availability of appliances with high efficiency will be particularly important because countries like India and China are expected to experience strong growth in residential energy demand in the coming decades. These countries, as well as a large number of smaller countries whose per-capita income is increasing, offer great opportunities to reduce CO_2 emissions (compared with a business-as-usual scenario) through deployment of highly efficient energy-using technologies. Among the steps that need to be taken is the removal of trade barriers. Bilateral and multi-lateral programmes can also play an important role.

110. One of the main conclusions from this report is that if the world were to successfully implement every cost-effective measure (as listed in the cost curve developed in the modelling), in strict order from low-cost to higher-cost in sequence, the theoretical potential of negative-cost measures would be 8.9 Gt of CO_2-equivalent in 2020. This implies that the amount of GHG emissions that can be avoided at costs below USD 0 per tonne of CO_2-equivalent could play a key role in climate policy. These opportunities with a net economic benefit largely consist of measures to improve energy efficiency.

111. The extent to which this potential will be realized will be critically influenced by policies. Policies to promote energy efficiency have been largely helpful. OECD countries have been very active in the last 10-15 years in establishing minimum energy performance standards (MEPS) and labelling schemes, which cover an ever-expanding range of traded goods such as household appliances, heating and cooling equipment, home entertainment, ICT equipment for home or office, lighting, buildings materials, and electric motors. There is, in addition, a strong policy framework supporting these standards and labelling schemes, particularly in OECD countries, but also increasingly in others, notably Brazil, China, Chinese Taipei, India, Iran, the Philippines, Russia, Singapore, and Thailand. These frameworks include combinations of demand-side management (DSM) programmes, information campaigns, and reforms of electricity pricing.

Figure 25. CO_2 emissions mitigation potential



Source: Research Institute of Innovative Technology for the Earth.

112. Many of the MEPS and labelling schemes emerged at a time when international trade in electrical appliances accounted for a small share of the global market. That situation has since changed. Electrical appliances and their components are produced in a number of countries, thus encouraging globalized supply trains. Under such circumstances, trade can help increase competition and innovation, thus increasing the range of relatively energy-efficient appliances available. But trade can be slowed by the existence of multiple standards that segment the market, and by differences in conformity-assessment procedures, or lack of mutual recognition of testing results. Until recently, however, the concern has mainly been with intra-regional trade (e.g. within Europe or North America). In recognition of these changes, numerous initiatives are underway at the regional and global level to harmonise testing procedures, to establish international norms, and to make national MEPS more comparable.

113. The situation is starkly different for the many developing countries that have not yet established MEPS. The reasons for this situation are many, but can include: a lack of demand because of low per-capita income; limited capacity and resources to develop standards; and lack of awareness of the benefits of encouraging energy efficiency. There is some support bilaterally and internationally to help developing countries develop their capacity and understanding of the role that improved energy efficiency can play, but in many countries these efforts are still at an early stage.

114. What has perhaps been inadequately recognized, however, is the dual problem of high import tariffs on electrical appliances — especially those that account for a large portion of household electricity consumption — and low internal energy prices. Numerous countries in the developing world have both, including several ones with populations of 50 million or more. This study notes that such border protection, combined with low energy prices, could be sending the wrong signals to customers,

encouraging them to minimize their up-front expenditure on appliances and opting for ones that are relatively inefficient over the life-time of their operation.

115. Trade is fundamental for the deployment of energy-efficient products, and economies need to be open to benefit from such trade. The energy performance of traded energy-using products and products that affect energy consumption (e.g. efficient windows, insulation, tires) will have an enormous impact on energy use in developing countries, whose populations are growing and whose markets for energy-using household products are far from saturated. Reducing tariffs on energy-consuming goods would not be a sufficient step to ensure maximum penetration rates of relatively energy-efficient products, but it is a necessary step, especially in countries that are currently inadvertently encouraging the purchase of relatively inefficient energy-using goods through maintaining energy prices that are kept artificially low.

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ANNEX 1. THE COPENHAGEN ACCORD

116. The Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), at its fifteenth session, took note of the Copenhagen Accord of 18 December 2009 by way of decision 2/CP.15. The text of the Copenhagen Accord can be found at http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf. The chapeau of the Copenhagen Accord lists the following 114 Parties agreeing to the Accord:

> Albania, Algeria, Armenia, Australia, Austria, Bahamas, Bangladesh, Belarus, Belgium, Benin, Bhutan, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Burkina Faso, Cambodia, Canada, Central African Republic, Chile, China, Colombia, Congo, Costa Rica, Côte d'Ivoire, Croatia, Cyprus[22,23], Czech Republic, Democratic Republic of Congo, Denmark, Djibouti, Eritrea, Estonia, Ethiopia, European Union, Fiji, Finland, France, Gabon, Georgia, Germany, Ghana, Greece, Guatemala, Guinea, Guyana, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kiribati, Lao People's Democratic Republic, Latvia, Lesotho, Liechtenstein, Lithuania, Luxemburg, Madagascar, Malawi, Maldives, Mali, Malta, Marshall Islands, Mauritania, Mexico, Monaco, Mongolia, Montenegro, Morocco, Namibia, Nepal, Netherlands, New Zealand, Norway, Palau, Panama, Papua New Guinea, Peru, Poland, Portugal, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Rwanda, Samoa, San Marino, Senegal, Serbia, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Spain, Sweden, Swaziland, Switzerland, The Former Yugoslav Republic of Macedonia, Tonga, Trinidad and Tobago, Tunisia, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, United States of America, Uruguay, Zambia.

117. Since the issuance of the report of the COP on its fifteenth session, the UNFCCC Secretariat has received communications from the following Parties expressing their intention to be listed as agreeing to the Accord:

> Afghanistan, Angola, Antigua and Barbuda, Barbados, Belize, Brunei Darussalam, Burundi, Cameroon, Cape Verde, Chad, Comores, Gambia, Guinea-Bissau, Honduras, Jamaica, Kenya, Liberia, Mauritius, Mozambique, Nigeria, Saint Lucia, Tajikistan, Timor-Leste, Togo, Uganda, Ukraine, Viet Nam.

118. As a result, as of November 2011, the total number of Parties that have expressed their intention to be listed as agreeing to the Accord stood at 141.

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22. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

23. Footnote by all the European Union Member States of the OECD and the European Commission: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

ANNEX 2. AN OVERVIEW OF DNE 21+ MODEL

Economic Models of Climate Change

119. This annex provides more information on the DNE21+ model used in this study. In general, many economic models used to analyse aspects of climate change fall into the two general categories: "bottom-up" or "top-down." A key distinction between model types is how they characterise the economy, technology and emissions.

120. Bottom-up models typically assess distinct mitigation technologies or practices, including their costs, CO_2 emission-reduction potentials and their substitutability with other technologies. This approach allows evaluating a wider range of policy options and provides deeper insights into specific low-carbon technology development and deployment, while paying relatively little attention to macro-economic feedbacks between production and consumption through the market.

121. Top-down models, on the other hand, focus on the processes within the economy as a whole and the associated interactions through the price mechanism, rather than technology detail or market products. Therefore, top-down models are well suited to assess the economy-wide impacts of environmental policy. Disadvantages of this approach are that they have less detail on the specific abatement technologies, and that historic behaviour is assumed to be relevant for future systems. This implies model calibration factors are determined on the basis of historic evidence.

122. The IPCC fourth assessment report (IPCC, 2007) assessed the reduction potential reported by both top-down and bottom-up approaches. The results of the two approaches were found comparable at the global level, although the results could not be compared at a regional and sectoral level due to different data formats.

DNE21+ Model

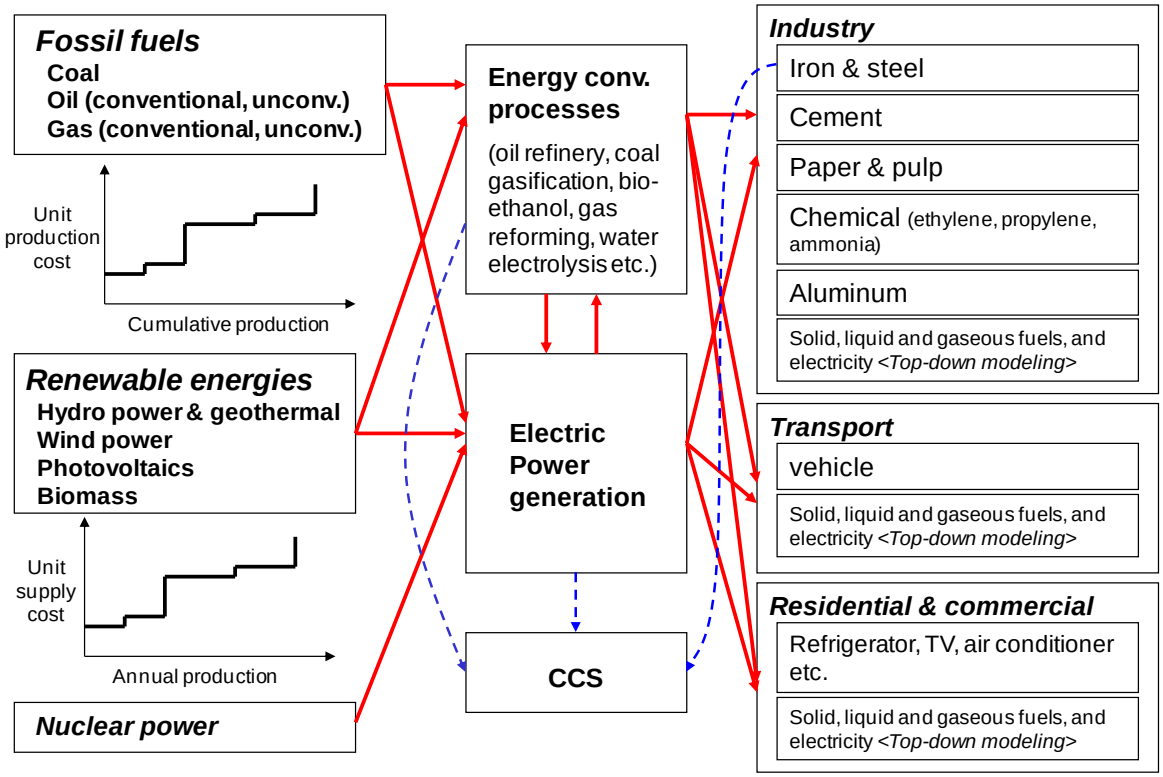
123. RITE developed its CO_2-mitigation assessment modelling framework in order to assess in a consistent manner the six GHGs covered by the Kyoto Protocol. The framework consists of three modules: (1) DNE21+ Model for energy-related CO_2 emissions; (2) a Non-Energy CO_2 Emission Scenario for non-energy CO_2 emissions estimation independently of energy-related CO2 emissions, and 3) a Non-CO2 GHG Assessment Model for emissions of CH_4, N_2O, HFCs, PFC, and SF_6.

124. In this study, the DNE21+ model was used to identify abatement opportunities with technology details and to get an understanding of how efficiency improvements can impact on CO_2 emission reduction. DNE21+ is a technology-oriented, bottom-up model for global energy system assessment. It is an inter-temporal linear programming model, in which the total system cost of energy is minimised for the period of 2000–2050 under various constraints, such as an economy-wide CO_2 emission cap and a carbon price imposed on some specific sectors.

125. DNE21+ provides projections until the mid-21st century, with nine representative points for the years 2000, 2005, 2010, 2015, 2020, 2025, 2030, 2040 and 2050 (2005 represents the period from 2003 to 2007, 2010 represents the period from 2008 to 2012, and so on).

126. Figure A1.2 provides an overview of the energy and CO_2 flows in DNE21+. Nine types of primary energy sources are explicitly modelled: natural gas, oil, coal, biomass, hydro, geothermal, solar photovoltaics, wind and nuclear. Sectors not incorporated into the bottom-up modelling fall into four categories: solid energy demand, liquid energy (gasoline, light oil and heavy oil) demand, gaseous fuel demand and electrical energy demand. Their demands are estimated in a top-down manner. Electricity demand is modelled to balance demand and supply consistent with a power load-duration curve. In the energy transformation sector, technological costs and efficient energy-supply technologies for oil refineries and various types of power generation, and carbon-dioxide capture and storage (CCS), are taken into account.

Figure A1.1. Energy flows of the DNE21+ model



Source: Research Institute of Innovative Technology for the Earth.

127. With regard to end-use sectors, various technological options to improve energy efficiency are explicitly modelled. Focus is put on the technological costs and energy efficiency of energy-intensive industries, including steel, cement, pulp and paper, alumina, some sections of the chemical industry (ethylene, propylene production and ammonia production in the petrochemical industry) and transportation (automobiles). Technological changes are included exogenously, and the costs of technologies are generally assumed to decline over time and their performance to improve. The vintages of these technological facilities are also included in the model. Overall, RITE has identified around 300 individual technological changes that are either already applied today or will become commercially viable in the near future. Illustrative measures by sector are listed in Table A1.1.

Table A1.1 Technology list of the DNE21+ model

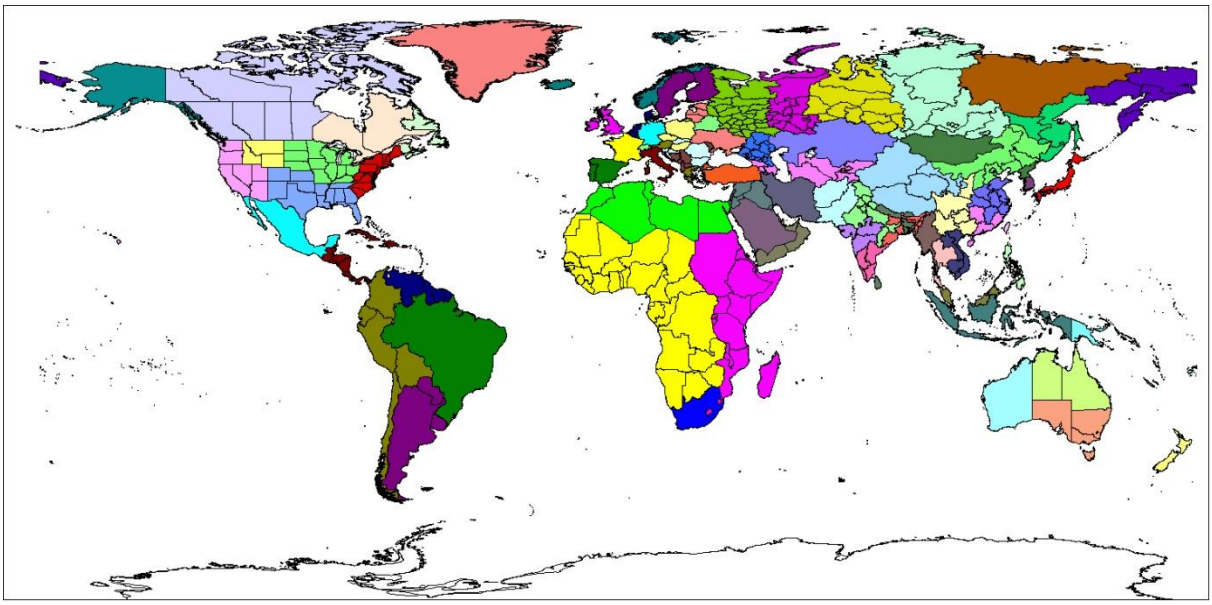
Sector	Technologies
Electricity	Coal power {low efficiency (subcriticality), mid-efficiency (supercriticality), high efficiency (extra supercriticality–Integrated coal Gasification Combined Cycle (IGCC)/Integrated coal gasification Fuel Cell Combined Cycle (IGFC)), IGCC with precombustion CO_2 capture}, Oil power {low efficiency (diesel generator, etc.), mid-efficiency (subcriticality), high efficiency (supercriticality), Combined Heat and Power (CHP)}, Synthetic oil power {mid-efficiency, high efficiency}, Natural gas power {low efficiency (steam turbine), mid-efficiency (conventional Natural Gas Combined Cycle (NGCC)), high efficiency (high-temperature NGCC), CHP, oxy-fuel combustion}, Biomass power {low efficiency, high efficiency}, Nuclear power {conventional, next-generation (Generation IV, etc.)}, Hydro/geothermal power, Wind power, Photovoltaics, Power storage system for wind/PV, Hydrogen power, Electrical cable {conventional, superconducting high efficiency}, Carbon dioxide Capture and Storage (CCS) {post-combustion capture; applicable for coal, oil, synthetic oil, natural gas, biomass power}
Other energy supply	Oil refinery, Gas reforming, Gas liquefaction, Coal liquefaction, Coal gasification, Biomass fermentation, Biomass liquefaction, Biomass gasification, Water electrolysis
Industry	
Iron and steel	Blast Furnace & Basic Oxygen Furnace (BF-BOF) {low efficiency (small scale), mid-efficiency (large scale), high efficiency (large scale, equipped with Coke Dry Quenching (CDQ), Top-pressure Recovery Turbine (TRT), recovery of by-product gases), next-generation (super coke oven (e.g. SCOPE 21), utilizing plastic wastes and tire wastes, as well as highly efficient equipment), iron production by hydrogen reduction}, Coke Oven Gas (COG) recovery {externally attachable to low/mid-efficient BF-BOF}, Linz-Donawitz converter Gas (LDG) recovery, CDQ/TRT {externally attachable to mid-efficient BF-BOF}, Direct reduction {natural gas base (mid/high efficiency), hydrogen gasification base}, Scrap-used Electric Arc Furnace (Scrap-EAF) {low efficiency (small scale), mid-efficiency (tri-phase electric arc furnace), high efficiency (DC water-cooled walls arc furnace equipped with scrap preheating)}, CCS {applicable to BF-BOF}
Cement	Small-scale facilities: Vertical kiln, Wet rotary kiln, Dry rotary kiln, Suspension Preheater /New Sspension Preheater (SP/NSP) dry rotary kiln, Advanced fluidized bed shaft furnace {equipped with SP/NSP, efficient clinker coolers} Large-scale facilities (more efficient than small-scale ones): Wet rotary kiln, Dry rotary kiln, SP/NSP dry rotary kiln, SP/NSP dry rotary kiln (high efficiency) {equipped with efficient clinker coolers, SP with 5 or 6 levels, efficient waste heat recovery}
Pulp and paper	Chemical pulp {low efficiency, mid-efficiency, high efficiency, next generation}, Paper recycling {low efficiency, mid-efficiency, high efficiency}, Milling paper {low efficiency, mid-efficiency, high efficiency, next-generation}, Black liquid recovery and use {low efficiency, high efficiency}, Paper sludge boilers, Steam turbine power systems
Aluminum	Söderberg aluminum production, Prebake aluminum production
Chemical	Ethylene/propylene: Naphtha cracking {low efficiency, mid-efficiency, high efficiency, next-generation}, Other production {ethane cracker, etc.; low efficiency, mid-efficiency, high efficiency} Ammonia: from Coal {low efficiency, mid-efficiency, high efficiency}, from Oil {low efficiency, mid-efficiency, high efficiency}, from Natural gas {low efficiency, mid-efficiency, high efficiency}
Transportation	Types: Small passenger car, Large passenger car, Bus, Small truck, Large truck Internal combustion engines (gasoline/diesel) {conventional internal combustion cars (low/high efficiency), hybrid cars, plug-in hybrid cars}, Electric cars, Fuel-cell cars, Alternative fuels {bioethanol mixed with gasoline, biodiesel mixed with diesel, Compressed Natural Gas (CNG)}
Residential and commercial	Refrigerator {low efficiency, mid-efficiency, high efficiency}, Lighting {small bulb, small fluorescent light, small next generation (Light-Emitting Diode (LED), etc.), medium-size mid-efficiency fluorescent light, medium-size high-efficiency fluorescent light, medium-size next-generation (LED, Organic Light-Emitting Diode (OLED), etc.), large-size mid-efficiency High Intensity Discharge (HID), large-size high-efficiency HID, large-size next-generation (LED, etc.)}, Television {small-size low-efficiency, small-size high-efficiency, large-size low-efficiency, large-size high-efficiency, large-size next-generation (high-efficiency liquid crystal television, plasma, rear projection, OLED)}, Air conditioner {low efficiency, mid-efficiency, high efficiency}, Gas cooking stove {low efficiency, mid-efficiency, high efficiency}

Source: Research Institute of Innovative Technology for the Earth.

128. In the reference case, the cost of various technologies and energy systems, such as energy flow and capacity of energy related facilities, are examined without any CO_2 emission controls. In the event that some sort of climate-change policy or measure is implemented, minimum system cost is re-optimised to meet the constraints. Usually it leads to an overall decrease in final energy demand or emission reductions due to the energy-price increase.

129. DNE21+ is similar to the IEA ETP model (IEA, 2006) in that both models provide an explicit explanation of energy-supply technologies as well as energy end-use technologies in detail. The DNE21+ model is, however, more regionally disaggregated (so as to present a more realistic picture), dividing the world into 77 countries and regions. As shown in Figure A1.2, countries with large geographical areas, such as the USA, Canada, Australia, China, India, Brazil and Russia, are disaggregated into 3–8 regions in order to reflect the transportation costs of energy and CO_2 in greater detail. For the purposes of this study, however, the countries and regions were re-aggregated to show the overall tendency of 11 major: (1) Canada and the United States; (2) the EU 27; (3) the CIS and other Europe; (4) Japan; (5) Australia and New Zealand; (6) China; (7) India; (8) Other Asia; (9) the Middle East; (10) South & Central America; and (11) Africa.

Figure A1.2. The DNE21+ model's geographical coverage



Source: Research Institute of Innovative Technology for the Earth.

130. The historical emissions of six GHGs by Annex I and non-Annex I countries under the Kyoto Protocol are based on GHG inventories of UNFCCC (2009) and IEA Statistics (IEA, 2007), respectively. Energy-related CO2 emissions are based on IEA Statistics for all countries. Since there are slight differences between IEA data and UNFCCC data, minor modifications were made to ensure consistency between the total GHG emissions and the UNFCCC inventory.

Key model assumptions

131. The population estimates of the United Nations (UN, 2006) – 7.7 billion people in 2020 – are used to predict the population scenario. The GDP growth rates of the GDPs of major countries and the world were estimated by the Japan Economics Research Center for the Mid-term Target Exploratory Council of the Japanese Government in December 2008. The average annual rates of GDP growth from

2005 to 2020 are: 1.9% for the United States, 1.9% for the EU27, 1.3% for Japan, 5.0% for Russia, 8.2% for China, 7.2% for India and 3.0% for the whole world. Population and GDP were used for assumptions on the amount of production level or extent of service activity in each sector, consistent with the optimal combination of various bottom-up technologies for each sector.

132. The assumption for the payback period for investment is one of the key factors for estimations of marginal abatement costs. The payback period was calculated on the basis of numerous socio-economic factors such as the interest rate, income and financial leeway, risk preference, and expected profit rate of stock holders. The general return on investment (ROI) is 10%-20%, corresponding to a payback period of 5-10 years.

133. As for energy prices, referring to the IEA's *World Energy Outlook* 2008 and 2009, the crude oil price, a proxy for international prices, was assumed to be around USD 90 per barrel in 2020.

CO_2 mitigation potential

Approach and assumptions

134. The main purpose of this task was to sketch out an assessment of the level of emissions reduction that a range of measures could deliver. MAC curves, which show the relationship between tonnes of emissions abated and the CO_2 or GHG price, allows RITE to know how much CO_2 each measure could save (the level of abatement potential) and the associated cost per tonne of abated CO_2. The construction of MACs involves multiple runs of a model in RITE's approach.

135. In order to identify the gaps between theoretical potential and the actual situation, the model was run with different carbon prices to obtain different MAC curves under respective constraints. RITE regarded a short payback period as the actual situation because the modellers assumed rather high annual expense rates, in which the discount rate was taken into account, for various kinds of investments. In order to gain theoretical potential, the conditions were eased and the model was run with a longer payback period. Comparing these two results, the gaps between theoretical potential and the actual situation could be identified.

Concepts of mitigation potentials

136. The amount of CO_2 emissions that can be reduced by the deployment of a technology is often referred to as its emission-reduction potential, but it includes various concepts, such as technical potential, economic potential and market potential.

137. According to the IPCC (2007), the term technical potential refers to the total amount of avoided CO2 emissions as a result of implementation of reduction measures while still providing a similar level of service. The technical reduction potential has constraints of practical and physical limits, such as the number of available technologies and the rate at which these technologies may be employed.

138. The term economic potential is defined as the quantity of CO_2 emissions that can be reduced at given costs compared to a reference. The economic potential takes into account costs as well as technical limits. Economic potential is typically defined from a macro-economic perspective, taking into account social costs and benefits and social discount rates based on the assumption that market efficiency is improved by policies and measures and that the barriers are removed.

139. Market potential is usually calculated using private costs and private discount rates. A privately optimal decision would entail choosing the level of energy efficiency to minimise the present value of

private costs, which might be expected to occur under forecast market conditions, including policies and measures currently in place, noting that barriers limit actual uptake of abatement.

140. The technical potential is greater than the economic potential, and the economic potential is greater than the market potential. Here the economic potentials were studied because they showed what might be achieved if appropriate new and additional policies were put into place to remove barriers, while studies of market potential could be used to inform policy makers about mitigation potential with existing policies and barriers.

Methodology

141. As a first step, the mitigation potential was explored to provide a comparative assessment across various scenarios through DNE21+ in which the maximum deployment of around 300 individual low-carbon technologies in different sectors of the economy was assessed. Based on the results, some sensitivity analysis was performed, comparing several scenarios, and the MAC curves are derived for identifying areas to be prioritised.

142. The abatement potential was defined as the volume difference between the reference emissions and the emissions after some policy or measure has been applied. The reference case was defined as the Technology-Frozen (TF) case, where the CO_2 intensity is fixed at 2005 levels until 2020. The variables are global carbon prices and payback period. In terms of carbon prices, their impacts were estimated on the change of potentials after 2010 with every increments of USD 20, ranging from USD 0 to USD 100. With regard to payback periods two cases shown in Table A1.2, conservative one and optimistic one, were set up, so as to estimate how much consumers are resilient to or sensitive to the upfront costs of energy-efficient appliances.

Table A1.2. Assumption of payback periods (Years)

	Conservative Case		Optimistic Case	
	Upper Limit	Lower Limit	Upper Limit	Lower Limit
Electricity Generation Sector	10.0	6.7	15.0	11.7
Other Energy Conversion Sector	7.0	4.7	12.0	9.7
Industrial Sector	10.0	6.7	15.0	11.7
Transportation Sector	5.0	3.3	10.0	8.3
(Niche market for eco-friendly consumers)	(10)			
Residential & Commercial Sector	3.0	2.0	8.0	7.0

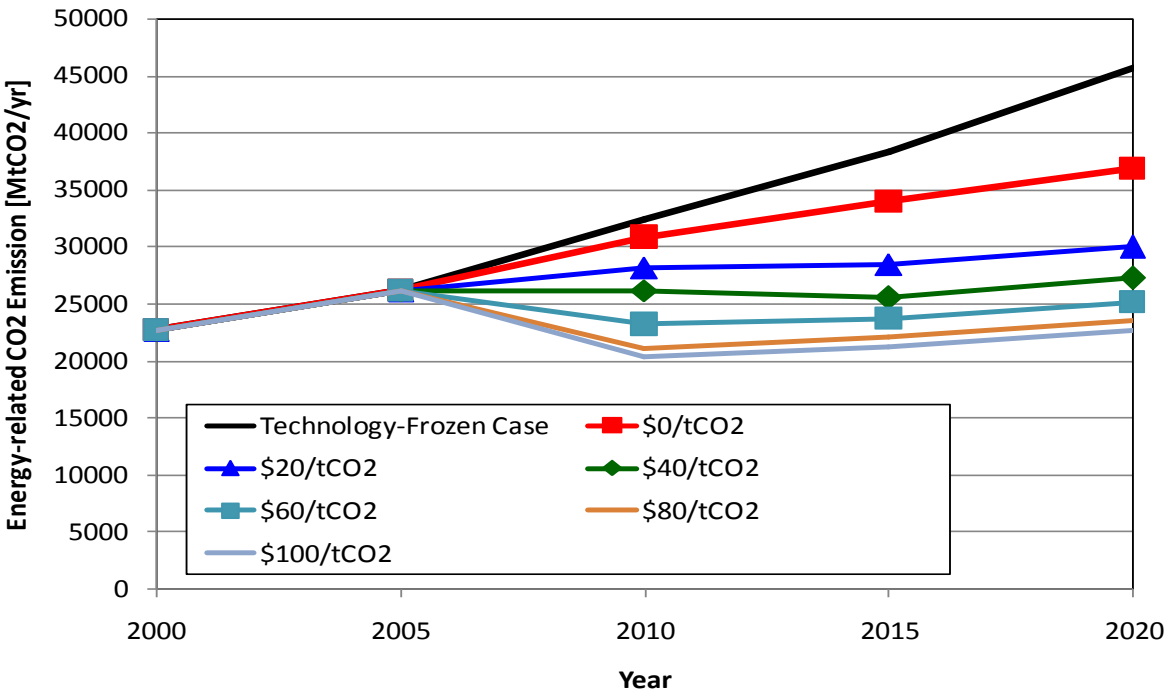
Source: Research Institute of Innovative Technology for the Earth.

143. Payback periods were differentiated within the above ranges, depending on the regions' per-capita GDP as an indicator of wealth and generosity. The duration of the payback period gets longer as the per-capita GDP increases. The volume of people who purchase environment friendly cars, such as Hybrids and EVs, with longer payback periods was taken into consideration under the category of "Niche market for eco-friendly consumers", so that their payback period could be larger as the per-capita GDP increase.

The impacts of carbon prices

144. Figure A1.3 suggests that setting a price on carbon emissions will mitigate CO_2 emission more. The higher the carbon price, the more it will reduce carbon emissions. If a carbon price at USD 100/tCO_2 should be imposed globally, the level of CO_2 emissions could be about 22.7 Gt in 2020, a similar level of the emissions in 2000. It should be also noted that incremental volume of reduction potential is getting smaller as the carbon price increase. About 70% of the reduction potential of the USD100/t CO_2 scenario will be captured under the USD 20/t CO_2 scenario. This implies that many of the measures can be realised at a relatively low cost and many would even produce a positive net return.

Figure A1.3. Global CO_2 emissions with carbon prices

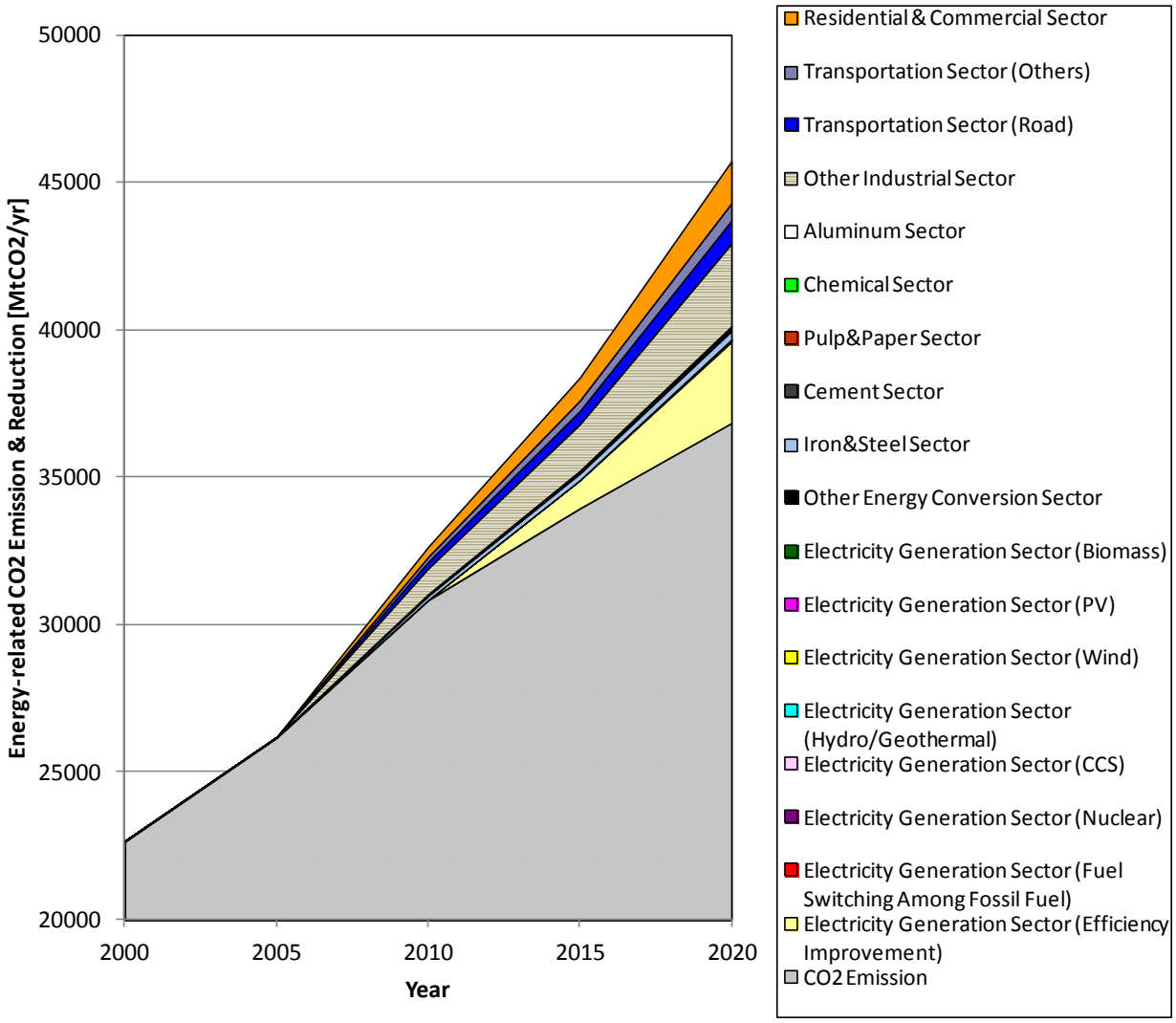


Source: Research Institute of Innovative Technology for the Earth.

145. Abatement opportunities typically consist of energy efficiency, shifting fuels, or shifting to low-carbon alternatives. Figure A1.4 shows abatement potential across sectors under USD 0/t-CO2 scenario, relative to the Technology Frozen case. The technical potential for efficiency improvements to reduce emissions is substantial, particularly in the power sector. There are also impressive gains in the efficiency of the residential sector, including air conditioner, lighting and refrigerator. Emerging technologies such as solar and CCS do not yet contribute substantial abatement volumes in 2020 because they are still expensive given their early stage of development.

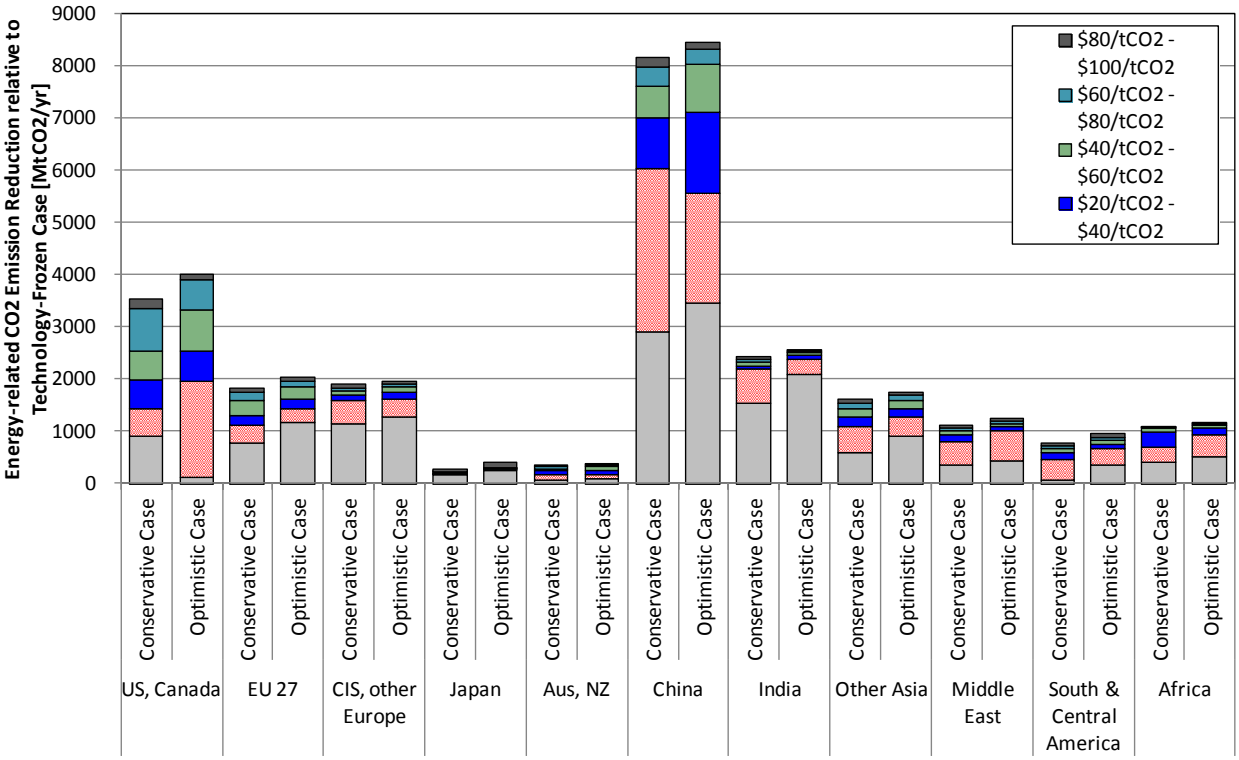
146. As shown in Figure A1.5, regional abatement potential or cost-effective emission mitigation measures differ across religions due to differences in current energy efficiency levels, industrial structures, potentials of renewable energy resources, and expected future economic growth.

Figure A1.4. Global abatement potential by sector under the USD 0 per tonne of CO_2 abatement cost scenario



Source: Research Institute of Innovative Technology for the Earth.

Figure A1.5. Emission-reduction potentials in 2020, by world region (relative to the technology frozen case)



Source: Research Institute of Innovative Technology for the Earth.

ANNEX 2. ESTIMATED STOCK BY TECHNOLOGY TYPE IN 2000

Figure A2.1. Refrigerators

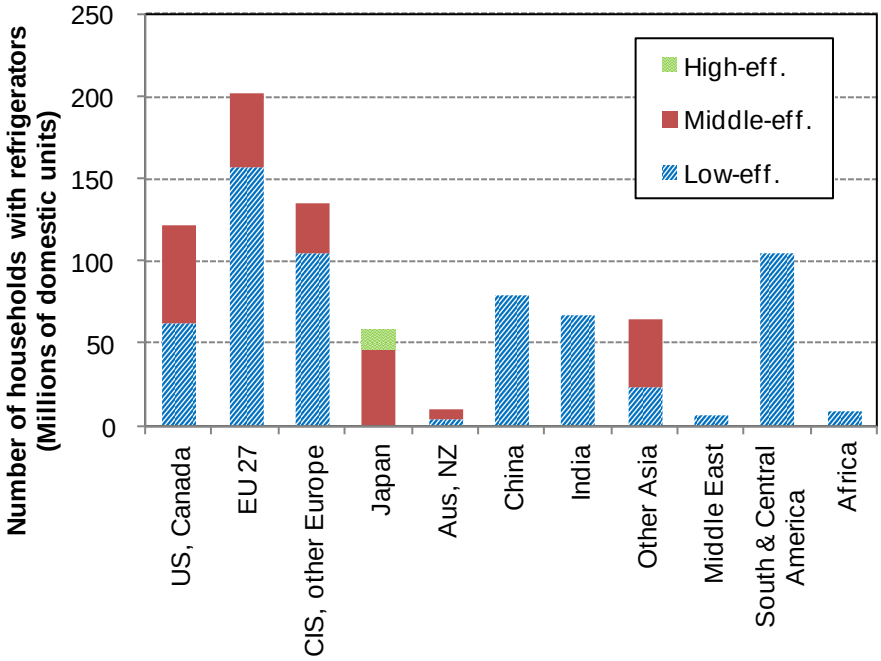


Figure A2.2. Televisions

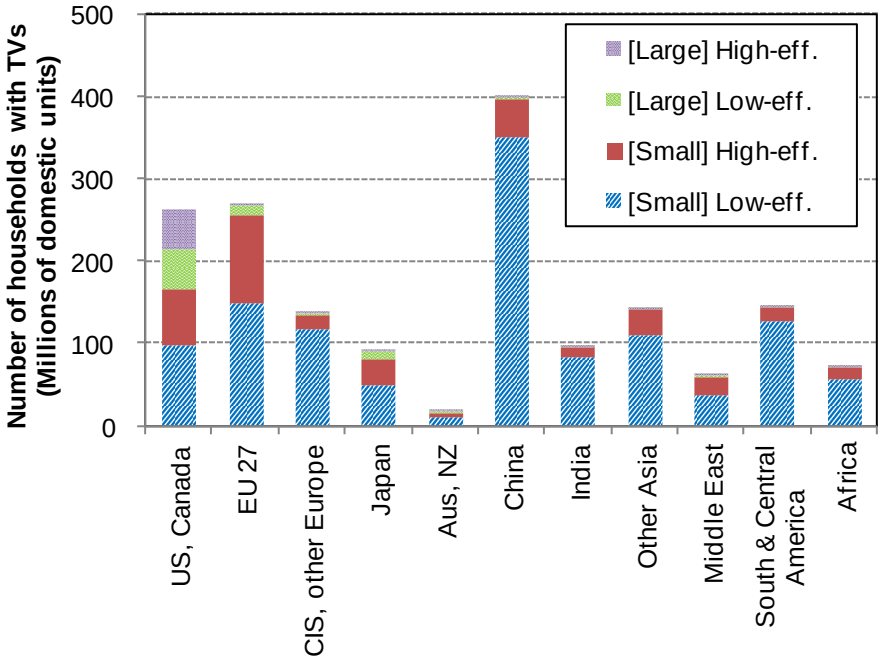


Figure A2.3. Lighting products

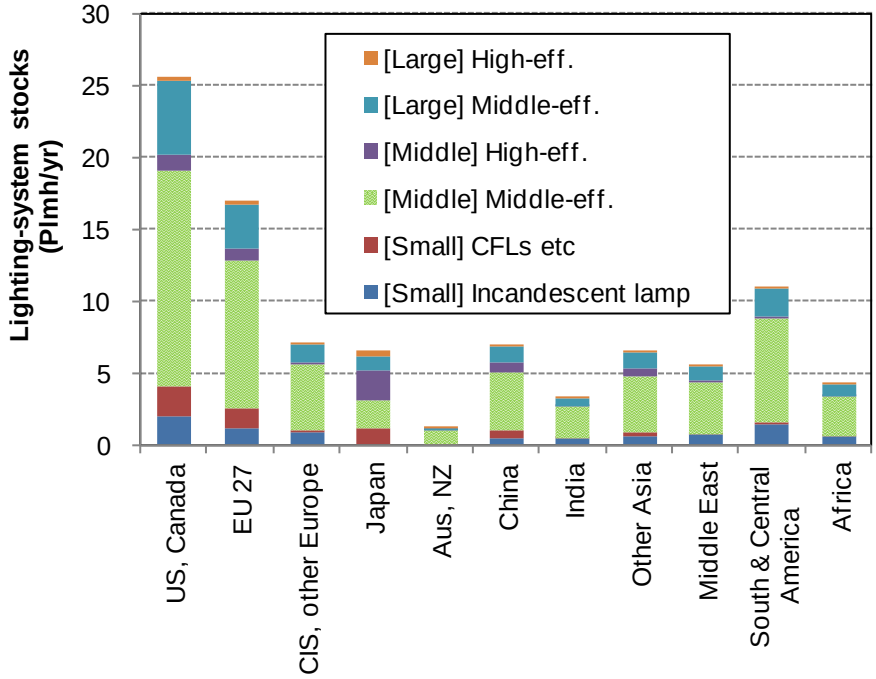
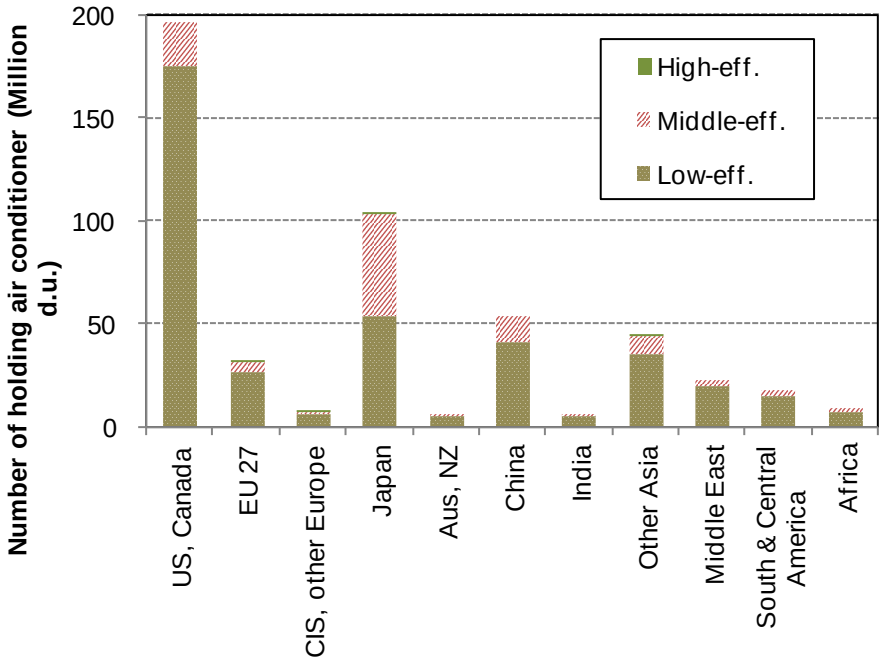


Figure A2.4. Air conditioners



ANNEX 3. ESTIMATED STOCK OF APPLIANCE BY REGION, 2000-2020

Figure A3.1. Refrigerators

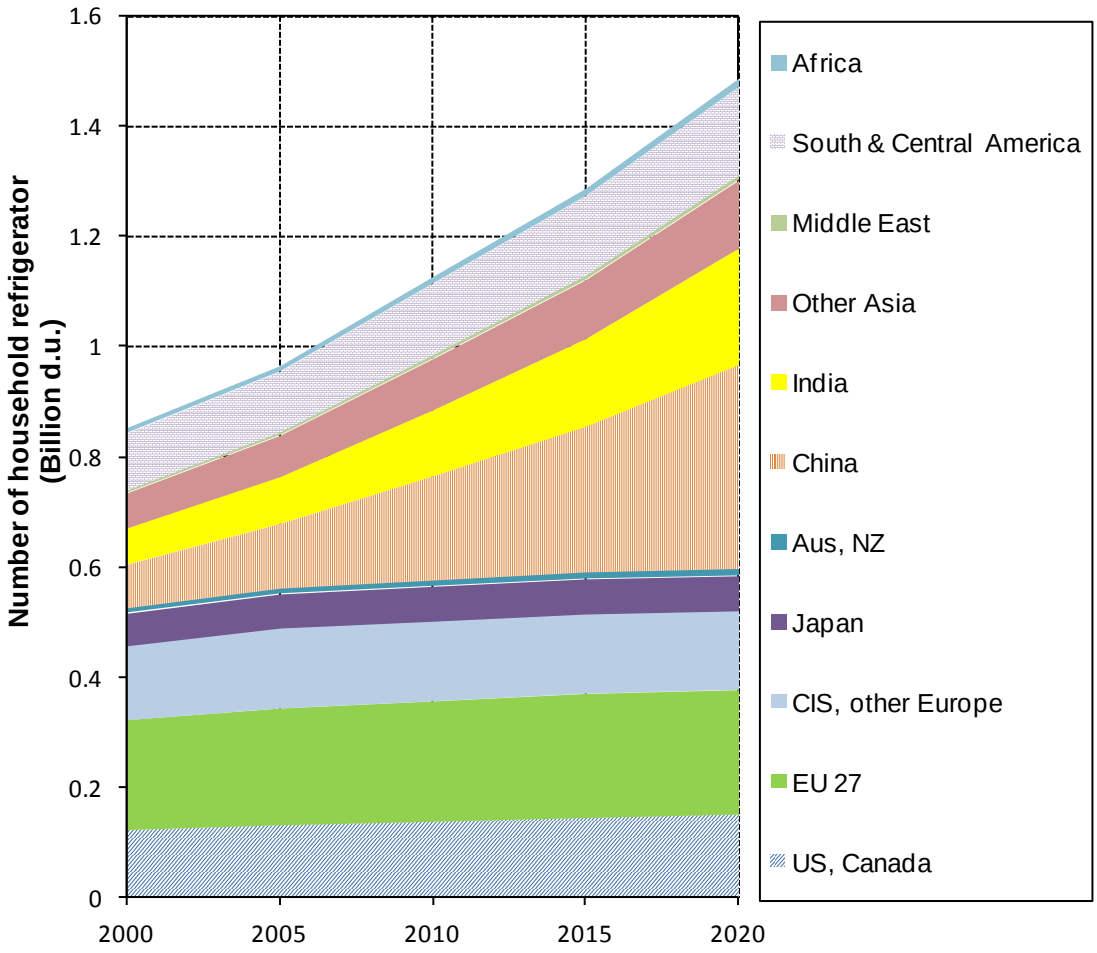


Figure A3.2. Televisions

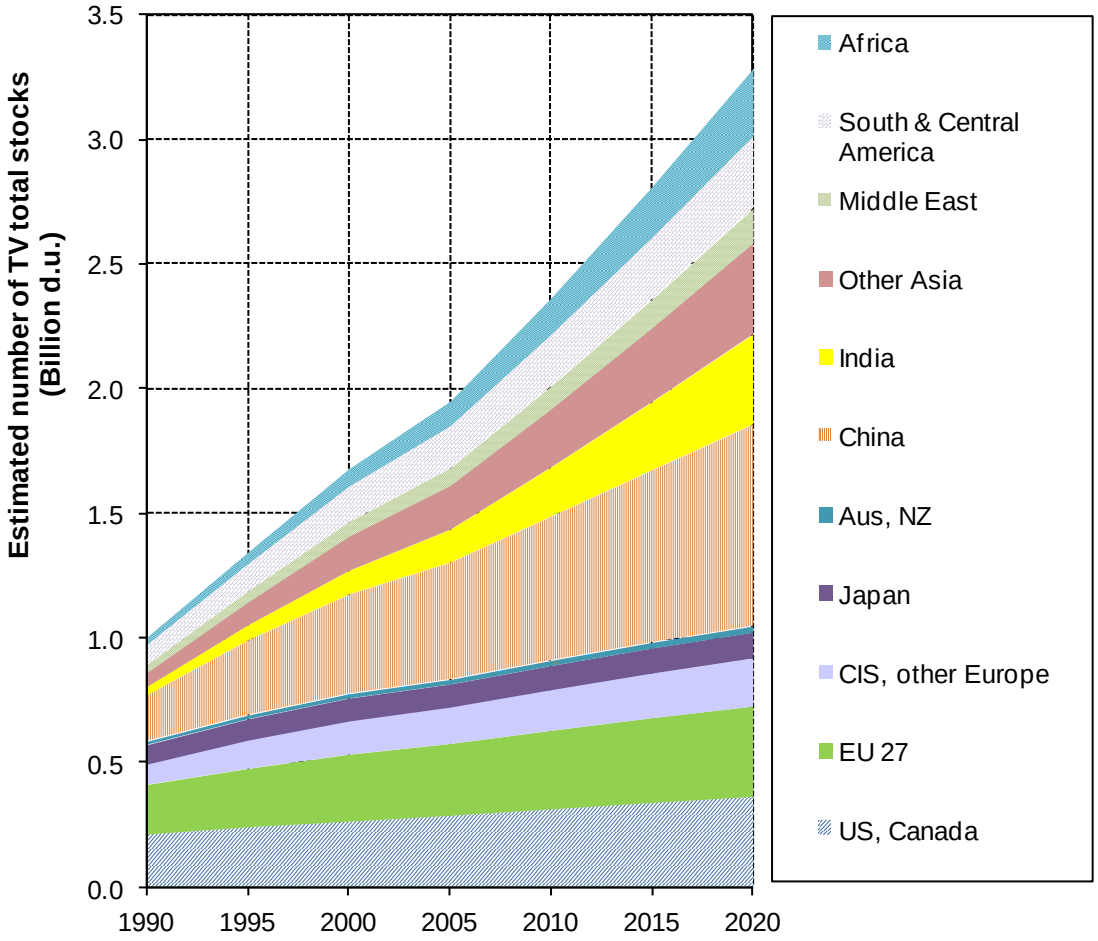


Figure A3.3. Lighting demand

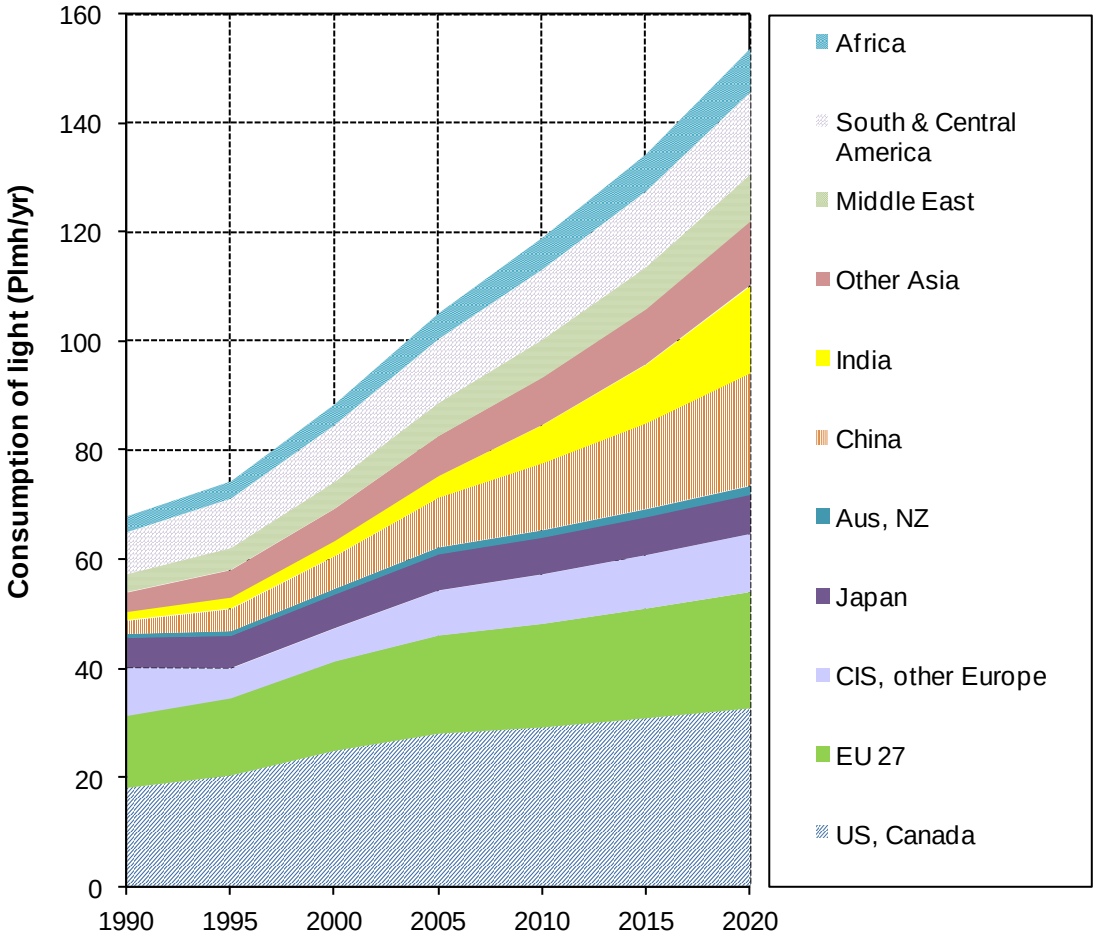
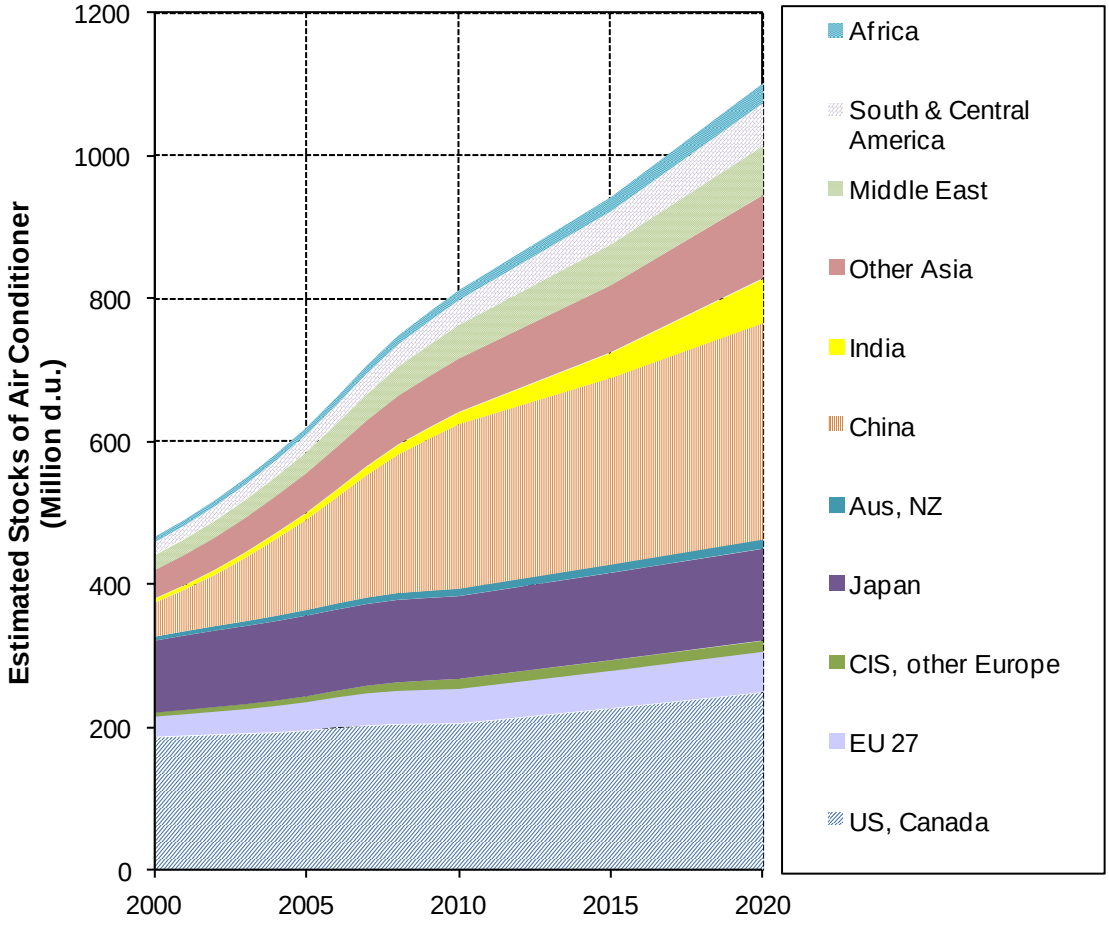


Figure A3.4. Air conditioners



ANNEX 4. ABATEMENT COST OF REPLACEMENT (USD/TCO$_2$)

	Replacement		Payback Period (year)				
	From	**To**	**1**	**3**	**7.6**	**10.4**	**12.8**
Refrigerator	Low Efficiency	Middle Efficiency	1 021	141	-26	-172	-197
	Middle Efficiency	High Efficiency	3 228	876	164	40	-25
Television (in 2020)	Small Low Eff.	Small High Eff.	525	-24	-191	-220	-235
	Large Low Eff.	Large High Eff.	1 066	156	-120	-168	-193
	Large High Eff.	Large Advanced	3 071	824	144	25	-37
Lighting (in 2020)	Small Incandescent	Small CFL	296	-101	-221	-242	-253
	Small CFL	Small advanced	4 453	1 285	325	158	70
	Mid-Eff. fluorescent	High-Eff. fluorescent	446	-51	-201	-228	-241
	High-Eff. fluorescent	Advanced	6 258	1 886	563	332	211
	Mid-Eff. HID	High-Eff. HID	1 523	308	-60	-124	-158
Air Conditioner[1]	Low Efficiency	Middle Efficiency	943	115	-136	-180	-203
	Middle Efficiency	High Efficiency	2 243	548	35	-54	-102

1. In this table, air conditioners are assumed to be used 157 hours per year, which corresponds to the average number of cooling degree days (1 046) in China (Burmert, 2003).

ANNEX 5. DOMESTIC POLICIES TO PROMOTE ENERGY-EFFICIENCY

147. Promoting energy efficiency effectively requires a range of policy instruments, from information programmes to financial incentives to appropriate price signals. One category of instruments relates to regulations and standards that provide long-term signals and can be used in all end-use sectors. Regulations and standards can apply not only to specific technologies or systems but also to the availability and quality of information (e.g. for labelling of energy using equipment or vehicles for use at the point of sale).

148. Regulations and standards are used globally in all end-use sectors, and they have been used increasingly since the oil crisis of the 1970s. Some of the earliest included fuel-efficiency standards in the United States, combined with labelling at the point of sale. Some countries also developed appliance-labelling programmes in the 1970s.

149. The following briefly describes some of the existing energy-efficiency standards and labelling policies currently in use:

Appliance-labelling programmes

These can be *comparative labels or endorsement labels*. Comparative labels show the energy efficiency of a particular model relative to similar models on the market. Endorsement labels identify the best-performing models within an appliance category, to make it easier for consumers to differentiate one from the other through the label.

Canada has had a comparison-labelling programme since 1978. Other countries with comparison labels include Australia, China, the European Union and EFTA countries (Box 1), Japan, New Zealand and several others.[24] In 2005 China launched a mandatory comparative label, similar to the one used in Europe that covers refrigerators, washing machines, air conditioners and unitary air conditioners. Japan introduced a new comparison label, known as the *Uniform Energy-Saving Label* in October 2006, which is currently applied to air-conditioners, seven types of refrigerators and three types of televisions (CRT, LCD, and plasma). Examples of these labels are shown in Figures 25 and 26.

24. These include: Chinese Taipei, Russia, other countries of the former Soviet Union, Brazil, Israel, India, Malaysia, South Korea, Jamaica, Singapore, Hong Kong, Philippines, Thailand, Mexico, Costa Rica, Colombia, Peru, Iran, Venezuela, Indonesia, South Africa, Argentina, Egypt, Sri Lanka and Tunisia. *Source*: www.clasponline.org.

Figure A5.1. Example of an energy-performance label for a refrigerator sold in Japan

Source: www.clasponline.org/clasp.online.worldwide.php?programinfo=1208

Figure A5.2. Energy Star logo

Source: U.S. Environmental Protection Agency.

Box 4. Energy labelling in the European Union

The EU regulatory framework regarding labelling of energy-using products is set in the Energy Labelling Directive (92/75/EEC) to which implementing Directives for the following household appliances have been adopted:

- Refrigerators, freezers and their combinations
- Washing machines, dryers and their combinations
- Dishwashers
- Ovens
- Water heaters and hot-water storage appliances
- Lighting sources
- Air-conditioning appliances

The requirements are mandatory and common for all Member States. Household appliances offered for sale, hire or hire-purchase shall be accompanied with information relating to their energy consumption or other features, such as energy use, noise and volume.

Under the Directive, the retail trade is obliged to provide all the appliances displayed in salesrooms with energy labels and to list technical data in table form in the sales records. The information necessary to do so has to be provided by the supplier of the individual appliance.

There is a new recast of the Directive that will be approved in 2010. This includes a new label format.

150. The leading endorsement label is the **ENERGY STAR** label, which is administered by the US Environment Protection Agency but is used also in Australia, Canada, the European Union, the European Free Trade Association, Japan, New Zealand, Switzerland and Taiwan. ENERGY STAR is to an increasing extent global, even though it started in the United States in 1992 as a voluntary labelling programme to promote energy-efficient products and to reduce GHG emissions. Products include a wide range of appliances, office equipment, lighting and home electronics. The label also covers new homes and commercial and industrial buildings. The European Union uses ENERGY STAR for office equipment. Australia uses it for copiers, computers and monitors, printers and fax machines, scanners, consumer audio and DVD, multifunctional devices in the home and televisions and VCRs. In Canada, the ENERGY STAR label is used together with its own Energuide Label, which is a comparison label, for several major appliances; residential heating, cooling and ventilation equipment; office equipment; consumer electronics;

windows and doors; lighting; and commercial equipment. More and more countries are participating in ENERGY STAR or recognising the label.

151. Products that display the ENERGY STAR symbol have been tested according to prescribed procedures and have been found to meet or exceed stringent energy-efficiency levels without compromising performance. Each of these countries and regions tailor ENERGY STAR to their needs. For example, in the European Union, the ENERGY STAR is used for nine different energy-consuming products.

Minimum energy performance standards (MEPS)

152. Numerous countries have adopted MEPS. These regulations stipulate the minimum efficiency levels or the maximum energy-use levels acceptable for products sold in a particular country. Normally, MEPS are mandatory.

153. Australia, Canada, the European Union, New Zealand and the United States all have MEPS for a wide range of energy-using equipment. Many of the countries and regions have been tightening their performance standards in recent years. The European Union is going through that exercise right now. In Canada, it was announced in 2006 that the government would have standards for 20 new products and increase the stringency of existing standards for 10 products by 2010; as of December 2011, energy-efficiency regulations apply to some 43 categories of energy-using products. In the European Union, the Eco-design Directive was adopted in 2005. It establishes a framework under which manufacturers of energy-using products will, at the design stage, be obliged to reduce the energy consumption and other negative environmental impacts occurring throughout the product's life cycle. A revised Directive, which entered into force in 20 November 2009, extends the scope of the existing Directive by covering in principle all energy-related products. Some of the products will be dealt with through voluntary agreements with industry.

154. China and India are among the leading developing countries in this field. China first adopted MEPS in 1989. A voluntary endorsement label was then introduced in 1998. China currently applies MEPS to 22 appliances and 50 products sold in the country use a voluntary endorsement label that is based on the **ENERGY STAR**. There are no mandatory MEPS in India, though the Energy Conservation Act authorises the government to introduce them. India, however, has no plans to introduce them any time soon.

Box 5. Selected experiences with energy-efficiency regulations

A 2007 report from the IEA included the following examples:

- Australia had experienced a 40% reduction in the average energy consumption of new refrigerators sold in the country since 1993.
- The United States experienced a 60% reduction in the average electricity consumption of refrigerators and freezers sold in the country between 1980 and 2001. After the introduction of MEPS in 1993 and 2001, the energy consumption of the newest models dropped 20 % each time.
- The United Kingdom experienced a 20-25% reduction in the energy consumption of new refrigerators and freezers sold between 1980 and 2001. Energy-performance labels were introduced in 1995 and MEPS in 1999.

Source: IEA, *Experience with Energy Efficiency Regulations for Electrical Equipment*, Information Paper, International Energy Agency, Paris, 2007, pp 50-51.

Performance standards based on sales

155. Sales-weighted performance standards were first used for vehicles in the United States in the 1970s, and are still in use there today. Japan uses them for its Top Runner Programme (Box 4).

Box 6. The Top Runner programme in Japan

The Top Runner programme, initiated in 1998 under the Rational Use of Energy Act, is the most significant policy measure in Japan for improving the efficiency of electrical appliances, although its coverage also extends to categories of non-residential equipment and vehicles.

The Top Runner programme works by setting energy efficiency performance targets for categories of products whether they are domestically manufactured or imported. These target levels are expressed as an average sales-weighted performance figure, which is generally based on the level of the most energy-efficient products on the market at the time when targets are set.

Manufacturers of a product category covered by the programme are deemed to have met the future energy efficiency performance standard if the sales-weighted average energy efficiency performance of their products meets or exceeds the target level in the target year. There are exemptions within most categories for suppliers that sell only small quantities of products annually.

Although the Top Runner programme shares the objective of raising the average efficiency of appliances sold with regulatory measures used in other countries, there are differences. For example, under Top Runner no appliances are excluded from the market unless the supplier chooses to withdraw a product voluntarily.

The process of establishing Top Runner targets for appliances is authorised and overseen by the Agency for Natural Resources and Energy (ANRE) within the Ministry of Economy, Trade and Industry (METI). Product categories are assessed and considered for inclusion if they:

- are used in large quantities in Japan;
- are responsible for substantial quantities of energy consumption;
- demonstrate potential for improved energy performance.

Source: IEA (2009), p. 112.

Other policy instruments

156. Several other policy instruments are used to promote energy-efficient technologies. The following is a brief review of the main instruments:

Information and awareness-raising programmes

157. General information programmes are designed to target consumers, or subgroups of consumers, with information relevant to their purchasing decisions. These targeted or mass-audience information programmes or campaigns have been proven useful in broadening awareness of energy-efficiency opportunities. They have been particularly useful for promoting energy-efficient lighting.

Financial incentives

158. A range of financial instruments is available for promoting the deployment of energy-efficient technologies. Most are targeted at the consumer, to provide a market pull; some are targeted at the supply chain in order to reduce retail prices.

159. The main types of financial instruments used are grants, purchase rebates, accelerated-depreciation allowances[25] and other forms of tax instruments, low-interest loans, and discounts on the retail price. Sometimes these financial incentives are linked to appliances that achieve a minimum level of performance. Some energy companies offer their own rebates or discounts on the purchase price, often through a regulatory obligation. For example, in the United Kingdom, the Carbon Emissions Reduction Target (CERT) obliges energy companies to take steps to ensure that the amount of CO_2 emissions from homes is reduced over time. CFLs have been a major beneficiary of these programmes, either by directly providing the lights to consumers or by reducing the retail price in selected retail outlets.[26]

Environmental and climate-change policies

160. Climate-change policy is quite important to the successful deployment of energy-efficient technologies. The new Communication from the European Commission ("International climate policy post-Copenhagen: Acting now to reinvigorate global action on climate change," COM(2010)86 final, 9 March 2010) gives priority to energy-efficiency improvements and thus sends an important signal to all stakeholders. While many agree that energy efficiency is one of the most important least-cost options for mitigating GHG emissions, it does not always receive the priority from policymakers, including adequate resources, that it needs to be effective. It is important for climate-change analysts to continually assess the role energy efficiency can play in meeting national, regional and global climate-change obligations. That is particularly important because energy ministers often focus only on the energy-policy benefits, which may not always be as compelling as those for climate change.

Eco-design policies

161. The European Union, under its EU Eco-Design Framework Directive and the EU Energy Labelling Directive, is beginning to specify minimum ecodesign requirements combined with energy labelling schemes for priority energy-using products. Setting minimum eco-design requirements is taking place in the context of the Ecodesign Framework Directive (2005/32/EC). The scope, which originally only covered energy-using products (e.g. washing machines, refrigerating appliances, consumer electronics) was recently extended to cover in principle all energy-related products. This means that in future, products such windows, insulation materials or certain water using products like shower heads can be covered as well. Overall the scope covers not only household products, but industrial ones as well.

162. An implementing measure (Commission Regulation) formulates binding ecodesign requirements to be met by producers and importers for the placing on the European market. Although energy consumption is the most significant parameter, in principle also other environmental aspects can be covered, thus this framework goes beyond minimum energy performance standards. Moreover, the measure also contains non-binding "benchmarks" of best technology available on the market.

163. So far, implementing measures for nine products have been adopted: a "horizontal measure" on stand-by and off-mode losses; simple-set top boxes; tertiary and domestic lighting; electric motors;

25. Accelerated appreciation allowances would not normally be used for the specific technologies analysed in this report and not for the residential sector.

26. For more information, see www.ofgem.gov.uk/Sustainability/Environment/EnergyEff/CU/Pages/CU.aspx

external power supplies; circulators; domestic refrigerating appliances; and televisions. The nine eco-design measures adopted to date are expected to lead to annual savings by 2020 of 341 TWh. This means savings equivalent to 12% of the electricity consumption of the European Union in 2007 (compared with "business as usual").

164. Measures for another important group of products such as boilers, water heaters and air-conditioning should be tabled by the Commission in the near future, and an additional 15 products proposed in the "Ecodesign Working Plan" are in a study phase (the overall the intention is to cover some 40 products).

Industrial policy

165. Industrial policy can have a big influence on accelerating the deployment of energy-efficient products. There are several areas that are important: R&D for new energy-efficient products is important, although it will probably have a less noticeable effect for 2020 objectives. Long-term policy signals for energy efficiency objectives and targets also give long-term signals for investment in new manufacturing facilities. Often industry has obligations for testing, compliance, providing the labels for retailers and so on. These are areas where government cannot act on its own, and having industry as partners is key to obtaining their co-operation.

ANNEX 6. STATISTICAL TABLES

Table A6.1. Applied import tariffs on window or wall air-conditioning machines, self-contained or "split system" (HS 841510), latest available year

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Vanuatu	2007	50	50	50	0
Burundi	2003	40	40	40	0
Tunisia	2010	36	36	36	0
Bahamas	2002	35	35	35	0
Pakistan	2010	35	35	35	0
Cameroon	2009	30	30	30	0
Cape Verde	2011	30	30	30	0
Central African Republic	2006	30	30	30	0
Chad	2009	30	30	30	0
Congo	2006	30	30	30	0
Egypt	2009	30	30	30	0
Gabon	2009	30	30	30	0
Malaysia	2010	30	30	30	0
Nepal	2010	30	30	30	0
Rwanda	2009	30	30	30	0
Sierra Leone	2006	30	30	30	0
Sri Lanka	2010	30	30	30	0
Thailand	2011	30	30	30	0
Viet Nam	2009	28	20	36	0
Kenya	2009	25	25	25	0
Malawi	2009	25	25	25	0
Saint Kitts and Nevis	2009	25	25	25	0
Tanzania	2005	25	25	25	0
Uganda	2009	25	25	25	0
Zambia	2010	25	25	25	0
Algeria	2010	21.7	5	30	0
Bangladesh	2008	20.6	3	25	0
Antigua and Barbuda	2009	20	20	20	0
Barbados	2007	20	20	20	0
Belize	2009	20	20	20	0
Benin	2011	20	20	20	0
Burkina Faso	2011	20	20	20	0
Côte d'Ivoire	2011	20	20	20	0
Democratic Republic of the Congo	2010	20	20	20	0
Dominica	2007	20	20	20	0
Dominican Republic	2008	20	20	20	0
Gambia	2010	20	20	20	0
Ghana	2010	20	20	20	0
Grenada	2008	20	20	20	0
Guinea	2009	20	20	20	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Guinea Bissau	2011	20	20	20	0
Guyana	2008	20	20	20	0
Jamaica	2007	20	20	20	0
Lao People's Democratic Republic	2008	20	20	20	0
Madagascar	2008	20	20	20	0
Maldives	2010	20	20	20	0
Mali	2011	20	20	20	0
Mozambique	2011	20	20	20	0
Niger	2011	20	20	20	0
Nigeria	2011	20	5	35	0
Saint Lucia	2002	20	20	20	0
Saint Vincent and the Grenadines	2007	20	20	20	0
Senegal	2011	20	20	20	0
Suriname	2010	20	20	20	0
Togo	2011	20	20	20	0
Trinidad and Tobago	2007	20	20	20	0
Brazil	2011	17.3	14	20	0
Belarus	2001	15	15	15	0
Bolivarian Republic of Venezuela	2010	15	15	15	0
Cambodia	2008	15	15	15	0
China	2008	15	15	15	0
Ecuador	2009	15	15	15	0
El Salvador	2011	15	15	15	0
Ethiopia	2011	15	10	20	0
Fiji	2011	15	15	15	0
Former Yugoslav Republic of Macedonia	2009	15	15	15	0
Guatemala	2009	15	15	15	0
Honduras	2009	15	15	15	0
Nicaragua	2009	15	15	15	0
Russian Federation	2001	15	15	15	0
Zimbabwe	2010	15	15	15	0
Costa Rica	2010	14	14	14	0
Uruguay	2010	14	0	20	25
Djibouti	2009	13	13	13	0
Mauritania	2010	13	13	13	0
Argentina	2009	12.7	0	20	33.3
Israel	2009	11.3	10.5	12	0
Paraguay	2010	11.3	2	16	0
Albania	2009	10	10	10	0
Armenia	2008	10	10	10	0
Cuba	2011	10	10	10	0
Haiti	2011	10	10	10	0
Iceland	2010	10	10	10	0
India	2008	10	10	10	0
Indonesia	2011	10	10	10	0
Jordan	2010	10	0	20	50

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Kyrgyz Republic	2008	10	10	10	0
Panama	2009	10	10	10	0
Philippines	2010	10	10	10	0
Solomon Islands	2008	10	10	10	0
Taipei, Chinese	2011	9	8	10	0
Kingdom of Saudi Arabia	2008	8.5	5	12	0
Korea, Republic of	2011	8	8	8	0
Bolivia, Plurinational State of	2009	7.5	5	10	0
Botswana	2011	7.5	0	15	50
Lesotho	2011	7.5	0	15	50
Namibia	2011	7.5	0	15	50
South Africa	2011	7.5	0	15	50
Swaziland	2011	7.5	0	15	50
Chile	2011	6	6	6	0
Angola	2009	5	5	5	0
Australia	2011	5	5	5	0
Bahrain, Kingdom of	2009	5	5	5	0
Brunei Darussalam	2010	5	5	5	0
Colombia	2011	5	5	5	0
Kuwait	2009	5	5	5	0
Mongolia	2010	5	5	5	0
New Zealand	2009	5	5	5	0
Oman	2009	5	5	5	0
Qatar	2010	5	5	5	0
Serbia	2005	5	5	5	0
United Arab Emirates	2008	5	5	5	0
European Union	2011	2.5	2.2	2.7	0
Switzerland	2011	CHF 0.20/kg	CHF 0.20/kg	CHF 0.20/kg	0
Morocco	2009	2.5	2.5	2.5	0
Turkey	2009	2.5	2.2	2.7	0
Myanmar	2008	1	1	1	0
United States	2011	0.6	0	2.2	60
Canada	2010	0	0	0	100
Croatia	2011	0	0	0	100
Georgia	2009	0	0	0	100
Hong Kong, China	2011	0	0	0	100
Japan	2010	0	0	0	100
Macao, China	2011	0	0	0	100
Mauritius	2010	0	0	0	100
Mexico	2010	0	0	0	100
Moldova	2007	0	0	0	100
Norway	2011	0	0	0	100
Papua New Guinea	2010	0	0	0	100
Peru	2009	0	0	0	100
Singapore	2009	0	0	0	100
Tonga	2011	0	0	0	100

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Ukraine	2011	0	0	0	100

Sources: • **Ethiopia:** Ethiopian Revenue and Customs Authority (www.erca.gov.et/hscode.jsp); • **Switzerland:** Federal Customs Administration (http://xtares.admin.ch); • **All other economies:** WTO, Tariff Download Facility (http://tariffdata.wto.org).

Table A6.2. Applied import tariffs on household refrigerators, compression-type (HS 841821), latest available year

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Zimbabwe	2010	60	60	60	0
Burundi	2003	40	40	40	0
Tunisia	2010	36	36	36	0
Morocco	2009	35	35	35	0
Pakistan	2010	35	35	35	0
Saint Vincent and the Grenadines	2007	35	35	35	0
Cameroon	2009	30	30	30	0
Central African Republic	2006	30	30	30	0
Chad	2009	30	30	30	0
Congo	2006	30	30	30	0
Egypt	2009	30	30	30	0
Gabon	2009	30	30	30	0
Malaysia	2010	30	30	30	0
Rwanda	2009	30	30	30	0
Saint Lucia	2002	30	30	30	0
Sierra Leone	2006	30	30	30	0
Sri Lanka	2010	30	30	30	0
Thailand	2011	30	30	30	0
Vanuatu	2007	30	30	30	0
Viet Nam	2009	30	30	30	0
Antigua and Barbuda	2009	25	25	25	0
Bangladesh	2008	25	25	25	0
Botswana	2011	25	25	25	0
Grenada	2008	25	25	25	0
Kenya	2009	25	25	25	0
Lesotho	2011	25	25	25	0
Malawi	2009	25	25	25	0
Namibia	2011	25	25	25	0
Saint Kitts and Nevis	2009	25	25	25	0
South Africa	2011	25	25	25	0
Swaziland	2011	25	25	25	0
Tanzania	2005	25	25	25	0
Uganda	2009	25	25	25	0
Zambia	2010	25	25	25	0
Algeria	2010	21.7	5	30	0
Argentina	2009	20	20	20	0
Barbados	2007	20	20	20	0
Belarus	2001	20	20	20	0
Benin	2011	20	20	20	0
Bolivarian Republic of Venezuela	2010	20	20	20	0
Brazil	2011	20	20	20	0
Burkina Faso	2011	20	20	20	0
Cape Verde	2011	20	20	20	0
Côte d'Ivoire	2011	20	20	20	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Democratic Republic of the Congo	2010	20	20	20	0
Dominica	2007	20	20	20	0
Dominican Republic	2008	20	20	20	0
Ecuador	2009	20	20	20	0
Gambia	2010	20	20	20	0
Guinea	2009	20	20	20	0
Guinea Bissau	2011	20	20	20	0
Guyana	2008	20	20	20	0
Jamaica	2007	20	20	20	0
Madagascar	2008	20	20	20	0
Mali	2011	20	20	20	0
Mexico	2010	20	20	20	0
Mozambique	2011	20	20	20	0
Niger	2011	20	20	20	0
Nigeria	2011	20	5	35	0
Paraguay	2010	20	20	20	0
Russian Federation	2001	20	20	20	0
Senegal	2011	20	20	20	0
Suriname	2010	20	20	20	0
Togo	2011	20	20	20	0
Trinidad and Tobago	2007	20	20	20	0
Uruguay	2010	20	20	20	0
Peru	2009	17	17	17	0
Bahamas	2002	15	15	15	0
Cambodia	2008	15	15	15	0
Colombia	2011	15	15	15	0
Cuba	2011	15	15	15	0
El Salvador	2011	15	15	15	0
Ethiopia	2011	15	10	20	0
Fiji	2011	15	15	15	0
Former Yugoslav Republic of Macedonia	2009	15	15	15	0
Guatemala	2009	15	15	15	0
Honduras	2009	15	15	15	0
Nepal	2010	15	15	15	0
Nicaragua	2009	15	15	15	0
Costa Rica	2010	14	14	14	0
Mauritania	2010	13	13	13	0
Israel	2009	12	12	12	0
Kingdom of Saudi Arabia	2008	12	12	12	0
Albania	2009	10	10	10	0
Angola	2009	10	10	10	0
Armenia	2008	10	10	10	0
Bolivia, Plurinational State of	2009	10	10	10	0
China	2008	10	10	10	0
Croatia	2011	10	10	10	0
Ghana	2010	10	10	10	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
India	2008	10	10	10	0
Indonesia	2011	10	10	10	0
Jordan	2010	10	0	20	50
Kyrgyz Republic	2008	10	10	10	0
Lao People's Democratic Republic	2008	10	10	10	0
Myanmar	2008	10	10	10	0
Philippines	2010	10	10	10	0
Solomon Islands	2008	10	10	10	0
Canada	2010	8	8	8	0
Korea, Republic of	2011	8	8	8	0
Moldova	2007	8	0	10	20
Panama	2009	7.7	3	10	0
Iceland	2010	7.5	7.5	7.5	0
Ukraine	2011	7.4	5	10	0
Serbia	2005	6.4	1	10	0
Chile	2011	6	6	6	0
Taipei, Chinese	2011	5.4	4	8	0
Australia	2011	5	5	5	0
Bahrain, Kingdom of	2009	5	5	5	0
Brunei Darussalam	2010	5	5	5	0
Haiti	2011	5	5	5	0
Kuwait	2009	5	5	5	0
Maldives	2010	5	5	5	0
Mongolia	2010	5	5	5	0
New Zealand	2009	5	5	5	0
Oman	2009	5	5	5	0
Qatar	2010	5	5	5	0
United Arab Emirates	2008	5	5	5	0
European Union	2011	2.1	1.5	2.5	0
Switzerland	2011	CHF 0.16/kg	CHF 0.16/kg	CHF 0.16/kg	0
Turkey	2009	2.1	1.5	2.5	0
Djibouti	2009	1	1	1	0
Belize	2009	0	0	0	100
Georgia	2009	0	0	0	100
Hong Kong, China	2011	0	0	0	100
Japan	2010	0	0	0	100
Macao, China	2011	0	0	0	100
Mauritius	2010	0	0	0	100
Norway	2011	0	0	0	100
Papua New Guinea	2010	0	0	0	100
Singapore	2009	0	0	0	100
Tonga	2011	0	0	0	100
United States	2011	0	0	0	100

Sources: • **Ethiopia:** Ethiopian Revenue and Customs Authority (www.erca.gov.et/hscode.jsp); • **Switzerland:** Federal Customs Administration (http://xtares.admin.ch); • **All other economies:** WTO, Tariff Download Facility (http://tariffdata.wto.org).

Table A6.3. Applied import tariffs on reception apparatus for television, colour, whether or not incorporating radio-broadcast receivers (HS 852872), latest available year

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Zimbabwe	2010	40	40	40	0
Viet Nam	2009	38	38	38	0
Tunisia	2010	36	36	36	0
Pakistan	2010	33.8	30	35	0
Cameroon	2009	30	30	30	0
Central African Republic	2006	30	30	30	0
Chad	2009	30	30	30	0
China	2008	30	30	30	0
Congo	2006	30	30	30	0
Ethiopia	2011	30	30	30	0
Gabon	2009	30	30	30	0
Nepal	2010	30	30	30	0
Rwanda	2009	30	30	30	0
Sierra Leone	2006	30	30	30	0
Bahamas	2002	25	25	25	0
Bangladesh	2008	25	25	25	0
Malawi	2009	25	25	25	0
Saint Kitts and Nevis	2009	25	25	25	0
Vanuatu	2007	25	25	25	0
Zambia	2010	25	25	25	0
Algeria	2010	21.7	5	30	0
Egypt	2009	21.7	5	30	0
Antigua and Barbuda	2009	20	20	20	0
Argentina	2009	20	20	20	0
Barbados	2007	20	20	20	0
Belarus	2001	20	20	20	0
Belize	2009	20	20	20	0
Bolivarian Republic of Venezuela	2010	20	20	20	0
Brazil	2011	20	20	20	0
Democratic Republic of the Congo	2010	20	20	20	0
Dominica	2007	20	20	20	0
Dominican Republic	2008	20	20	20	0
Gambia	2010	20	20	20	0
Grenada	2008	20	20	20	0
Guyana	2008	20	20	20	0
Jamaica	2007	20	20	20	0
Jordan	2010	20	20	20	0
Lao People's Democratic Republic	2008	20	20	20	0
Madagascar	2008	20	20	20	0
Mauritania	2010	20	20	20	0
Mozambique	2011	20	20	20	0
Russian Federation	2001	20	20	20	0
Saint Lucia	2002	20	20	20	0
Saint Vincent and the Grenadines	2007	20	20	20	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Suriname	2010	20	20	20	0
Thailand	2011	20	20	20	0
Trinidad and Tobago	2007	20	20	20	0
Uruguay	2010	20	20	20	0
Malaysia	2010	18.3	0	30	33.3
Kenya	2009	17.5	10	25	0
Tanzania	2005	17.5	10	25	0
Uganda	2009	17.5	10	25	0
Botswana	2011	16.7	0	25	33.3
Lesotho	2011	16.7	0	25	33.3
Namibia	2011	16.7	0	25	33.3
South Africa	2011	16.7	0	25	33.3
Swaziland	2011	16.7	0	25	33.3
Cambodia	2008	15	15	15	0
Colombia	2011	15	15	15	0
Cuba	2011	15	15	15	0
Fiji	2011	15	15	15	0
Guinea	2009	15	10	20	0
Myanmar	2008	15	15	15	0
Nicaragua	2009	15	15	15	0
Philippines	2010	15	15	15	0
Serbia	2005	15	15	15	0
Sri Lanka	2010	15	0	30	5.9
Mexico	2010	14.4	10	15	0
European Union	2011	14	14	14	0
Turkey	2009	14	14	14	0
Ecuador	2009	13.3	0	20	33.3
Benin	2011	12.5	5	20	0
Burkina Faso	2011	12.5	5	20	0
Côte d'Ivoire	2011	12.5	5	20	0
Guatemala	2009	12.5	10	15	0
Guinea Bissau	2011	12.5	5	20	0
Honduras	2009	12.5	10	15	0
Mali	2011	12.5	5	20	0
Niger	2011	12.5	5	20	0
Nigeria	2011	12.5	5	20	0
Senegal	2011	12.5	5	20	0
Togo	2011	12.5	5	20	0
Burundi	2003	12	12	12	0
Albania	2009	10	10	10	0
Angola	2009	10	10	10	0
Bolivia, Plurinational State of	2009	10	10	10	0
Cape Verde	2011	10	0	20	50
El Salvador	2011	10	5	15	0
Ghana	2010	10	10	10	0
India	2008	10	10	10	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Indonesia	2011	10	10	10	0
Kyrgyz Republic	2008	10	10	10	0
Solomon Islands	2008	10	10	10	0
Taipei, Chinese	2011	10	10	10	0
Ukraine	2011	10	10	10	0
Armenia	2008	9.5	0	10	5.3
Peru	2009	9	9	9	0
Korea, Republic of	2011	8	8	8	0
Costa Rica	2010	7	0	14	50
Morocco	2009	6.8	2.5	7.5	0
Chile	2011	6	6	6	0
Australia	2011	5	5	5	0
Brunei Darussalam	2010	5	5	5	0
Iceland	2010	5	0	7.5	33.3
Maldives	2010	5	5	5	0
Mongolia	2010	5	5	5	0
Panama	2009	5	5	5	0
Former Yugoslav Republic of Macedonia	2009	4.7	0	5	6.7
Moldova	2007	4.7	0	5	5.9
Canada	2010	4	0	5.5	20
Mauritius	2010	3	0	15	80
United States	2011	2.8	0	5	36.4
Switzerland	2011	CHF 0.58/kg	CHF 0.58/kg	CHF 0.58/kg	0
Bahrain, Kingdom of	2009	2.5	0	5	50
Kingdom of Saudi Arabia	2008	2.5	0	5	50
Kuwait	2009	2.5	0	5	50
Oman	2009	2.5	0	5	50
Qatar	2010	2.5	0	5	50
United Arab Emirates	2008	2.5	0	5	50
Paraguay	2010	2	2	2	0
Djibouti	2009	1	1	1	0
Croatia	2011	0	0	0	100
Georgia	2009	0	0	0	100
Haiti	2011	0	0	0	100
Hong Kong, China	2011	0	0	0	100
Israel	2009	0	0	0	100
Japan	2010	0	0	0	100
Macao, China	2011	0	0	0	100
New Zealand	2009	0	0	0	100
Norway	2011	0	0	0	100
Papua New Guinea	2010	0	0	0	100
Singapore	2009	0	0	0	100
Tonga	2011	0	0	0	100

Sources: • **Ethiopia:** Ethiopian Revenue and Customs Authority (www.erca.gov.et/hscode.jsp); • **Switzerland:** Federal Customs Administration (http://xtares.admin.ch); • **All other economies:** WTO, Tariff Download Facility (http://tariffdata.wto.org).

Table A6.4. Applied import tariffs on Tungsten halogen filament lamps (excl. sealed beam lamp units) (HS 853921), latest available year

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Bahamas	2002	35	35	35	0
Cambodia	2008	35	35	35	0
Fiji	2011	32	32	32	0
Algeria	2010	30	30	30	0
Ecuador	2009	30	30	30	0
Ethiopia	2011	30	30	30	0
Jordan	2010	30	30	30	0
Mauritius	2010	30	30	30	0
Rwanda	2009	30	30	30	0
Kenya	2009	25	25	25	0
Maldives	2010	25	25	25	0
Saint Kitts and Nevis	2009	25	25	25	0
Tanzania	2005	25	25	25	0
Uganda	2009	25	25	25	0
Vanuatu	2007	25	25	25	0
Pakistan	2010	22.5	10	35	0
Antigua and Barbuda	2009	20	20	20	0
Barbados	2007	20	20	20	0
Belarus	2001	20	20	20	0
Belize	2009	20	20	20	0
Benin	2011	20	20	20	0
Bolivarian Republic of Venezuela	2010	20	20	20	0
Brunei Darussalam	2010	20	20	20	0
Burkina Faso	2011	20	20	20	0
Cameroon	2009	20	20	20	0
Central African Republic	2006	20	20	20	0
Chad	2009	20	20	20	0
Congo	2006	20	20	20	0
Côte d'Ivoire	2011	20	20	20	0
Dominica	2007	20	20	20	0
Gabon	2009	20	20	20	0
Gambia	2010	20	20	20	0
Grenada	2008	20	20	20	0
Guinea	2009	20	20	20	0
Guinea Bissau	2011	20	20	20	0
Guyana	2008	20	20	20	0
Jamaica	2007	20	20	20	0
Mali	2011	20	20	20	0
Niger	2011	20	20	20	0
Nigeria	2011	20	20	20	0
Russian Federation	2001	20	20	20	0
Saint Lucia	2002	20	20	20	0
Saint Vincent and the Grenadines	2007	20	20	20	0
Senegal	2011	20	20	20	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Sierra Leone	2006	20	20	20	0
Suriname	2010	20	20	20	0
Togo	2011	20	20	20	0
Trinidad and Tobago	2007	20	20	20	0
Argentina	2009	18	18	18	0
Brazil	2011	18	18	18	0
Uruguay	2010	18	18	18	0
Dominican Republic	2008	17	14	20	0
Former Yugoslav Republic of Macedonia	2009	15	15	15	0
Malawi	2009	15	5	25	0
Malaysia	2010	15	15	15	0
Nepal	2010	15	15	15	0
Serbia	2005	15	15	15	0
Sri Lanka	2010	15	15	15	0
Tonga	2011	15	15	15	0
Tunisia	2010	15	15	15	0
Zambia	2010	15	15	15	0
Bangladesh	2008	13	7	25	0
Djibouti	2009	13	13	13	0
Viet Nam	2009	11.2	0	23	40
Albania	2009	10	10	10	0
Armenia	2008	10	10	10	0
Bolivia, Plurinational State of	2009	10	10	10	0
Botswana	2011	10	0	20	50
Burundi	2003	10	10	10	0
Cape Verde	2011	10	10	10	0
Cuba	2011	10	10	10	0
Democratic Republic of the Congo	2010	10	10	10	0
Egypt	2009	10	10	10	0
Ghana	2010	10	10	10	0
India	2008	10	10	10	0
Indonesia	2011	10	10	10	0
Lesotho	2011	10	0	20	50
Madagascar	2008	10	10	10	0
Namibia	2011	10	0	20	50
Panama	2009	10	10	10	0
Paraguay	2010	10	10	10	0
Solomon Islands	2008	10	10	10	0
South Africa	2011	10	0	20	50
Swaziland	2011	10	0	20	50
Zimbabwe	2010	10	10	10	0
Switzerland	2011	CHF 1.25/kg	CHF 1.25/kg	CHF 1.25/kg	0
China	2008	9.1	8	10.5	0
Peru	2009	9	9	9	0
Israel	2009	8	8	8	0
Korea, Republic of	2011	8	8	8	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Canada	2010	7.5	7.5	7.5	0
Iceland	2010	7.5	7.5	7.5	0
Mozambique	2011	7.5	7.5	7.5	0
Thailand	2011	7.5	0	10	25
Chile	2011	6	6	6	0
Philippines	2010	5.5	1	15	0
Angola	2009	5	5	5	0
Bahrain, Kingdom of	2009	5	5	5	0
Colombia	2011	5	5	5	0
Costa Rica	2010	5	5	5	0
El Salvador	2011	5	5	5	0
Guatemala	2009	5	5	5	0
Honduras	2009	5	5	5	0
Kingdom of Saudi Arabia	2008	5	5	5	0
Kuwait	2009	5	5	5	0
Lao People's Democratic Republic	2008	5	5	5	0
Mauritania	2010	5	5	5	0
Mexico	2010	5	0	10	50
Moldova	2007	5	5	5	0
Mongolia	2010	5	5	5	0
Morocco	2009	5	2.5	7.5	0
New Zealand	2009	5	5	5	0
Nicaragua	2009	5	5	5	0
Oman	2009	5	5	5	0
Qatar	2010	5	5	5	0
Taipei, Chinese	2011	5	5	5	0
United Arab Emirates	2008	5	5	5	0
European Union	2011	2.7	2.7	2.7	0
Turkey	2009	2.7	2.7	2.7	0
Haiti	2011	2.5	0	5	50
Ukraine	2011	2.3	0	3	25
United States	2011	1.3	0	2.6	50
Myanmar	2008	1	1	1	0
Australia	2011	0	0	0	100
Croatia	2011	0	0	0	100
Georgia	2009	0	0	0	100
Hong Kong, China	2011	0	0	0	100
Japan	2010	0	0	0	100
Kyrgyz Republic	2008	0	0	0	100
Macao, China	2011	0	0	0	100
Norway	2011	0	0	0	100
Papua New Guinea	2010	0	0	0	100
Singapore	2009	0	0	0	100

Sources: • **Ethiopia:** Ethiopian Revenue and Customs Authority (www.erca.gov.et/hscode.jsp); • **Switzerland:** Federal Customs Administration (http://xtares.admin.ch); • **All other economies:** WTO, Tariff Download Facility (http://tariffdata.wto.org).

Table A6.5. Applied import tariffs on fluorescent lamps (HS 853931), latest available year

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Bahamas	2002	35	35	35	0
Viet Nam	2009	34	34	34	0
Fiji	2011	32	32	32	0
Algeria	2010	30	30	30	0
Ethiopia	2011	30	30	30	0
Rwanda	2009	30	30	30	0
Kenya	2009	25	25	25	0
Maldives	2010	25	25	25	0
Saint Kitts and Nevis	2009	25	25	25	0
Tanzania	2005	25	25	25	0
Uganda	2009	25	25	25	0
Vanuatu	2007	25	25	25	0
Antigua and Barbuda	2009	20	20	20	0
Belize	2009	20	20	20	0
Benin	2011	20	20	20	0
Bolivarian Republic of Venezuela	2010	20	20	20	0
Brunei Darussalam	2010	20	20	20	0
Burkina Faso	2011	20	20	20	0
Cameroon	2009	20	20	20	0
Central African Republic	2006	20	20	20	0
Chad	2009	20	20	20	0
Congo	2006	20	20	20	0
Côte d'Ivoire	2011	20	20	20	0
Dominica	2007	20	20	20	0
Gabon	2009	20	20	20	0
Gambia	2010	20	20	20	0
Grenada	2008	20	20	20	0
Guinea	2009	20	20	20	0
Guinea Bissau	2011	20	20	20	0
Guyana	2008	20	20	20	0
Jamaica	2007	20	20	20	0
Mali	2011	20	20	20	0
Niger	2011	20	20	20	0
Nigeria	2011	20	20	20	0
Pakistan	2010	20	20	20	0
Saint Lucia	2002	20	20	20	0
Saint Vincent and the Grenadines	2007	20	20	20	0
Senegal	2011	20	20	20	0
Sierra Leone	2006	20	20	20	0
Suriname	2010	20	20	20	0
Togo	2011	20	20	20	0
Trinidad and Tobago	2007	20	20	20	0
Bangladesh	2008	18.5	12	25	0
Argentina	2009	18	18	18	0
Brazil	2011	18	18	18	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Botswana	2011	17.5	15	20	0
Egypt	2009	17.5	5	30	0
Lesotho	2011	17.5	15	20	0
Namibia	2011	17.5	15	20	0
South Africa	2011	17.5	15	20	0
Swaziland	2011	17.5	15	20	0
Belarus	2001	15	15	15	0
Colombia	2011	15	15	15	0
Former Yugoslav Republic of Macedonia	2009	15	15	15	0
Malawi	2009	15	5	25	0
Malaysia	2010	15	15	15	0
Nepal	2010	15	15	15	0
Russian Federation	2001	15	15	15	0
Serbia	2005	15	15	15	0
Tonga	2011	15	15	15	0
Tunisia	2010	15	15	15	0
Zambia	2010	15	15	15	0
Djibouti	2009	13	13	13	0
Philippines	2010	12	3	15	0
Uruguay	2010	12	0	18	33.3
Albania	2009	10	10	10	0
Armenia	2008	10	10	10	0
Bolivia, Plurinational State of	2009	10	10	10	0
Burundi	2003	10	10	10	0
Cuba	2011	10	10	10	0
Democratic Republic of the Congo	2010	10	10	10	0
India	2008	10	10	10	0
Madagascar	2008	10	10	10	0
Solomon Islands	2008	10	10	10	0
Thailand	2011	10	10	10	0
Zimbabwe	2010	10	10	10	0
Peru	2009	9	9	9	0
China	2008	8	8	8	0
Israel	2009	8	8	8	0
Korea, Republic of	2011	8	8	8	0
Iceland	2010	7.5	7.5	7.5	0
Indonesia	2011	7.5	5	10	0
Mozambique	2011	7.5	7.5	7.5	0
Cambodia	2008	7	7	7	0
Canada	2010	7	7	7	0
Dominican Republic	2008	7	0	20	66.7
Chile	2011	6	6	6	0
Angola	2009	5	5	5	0
Australia	2011	5	5	5	0
Bahrain, Kingdom of	2009	5	5	5	0
Barbados	2007	5	5	5	0

Reporter	Data year	Average of ad valorem duties	Minimum ad valorem duty	Maximum ad valorem duty	Duty-free tariff lines (%)
Ghana	2010	5	0	10	50
Haiti	2011	5	5	5	0
Kingdom of Saudi Arabia	2008	5	5	5	0
Kuwait	2009	5	5	5	0
Lao People's Democratic Republic	2008	5	5	5	0
Mauritania	2010	5	5	5	0
Mexico	2010	5	0	10	50
Moldova	2007	5	5	5	0
Mongolia	2010	5	5	5	0
New Zealand	2009	5	5	5	0
Oman	2009	5	5	5	0
Panama	2009	5	5	5	0
Qatar	2010	5	5	5	0
Sri Lanka	2010	5	0	15	66.7
Taipei, Chinese	2011	5	5	5	0
United Arab Emirates	2008	5	5	5	0
Ukraine	2011	3	3	3	0
European Union	2011	2.7	2.7	2.7	0
Switzerland	2011	CHF 0.35/kg	CHF 0.35/kg	CHF 0.35/kg	0
Turkey	2009	2.7	2.7	2.7	0
Morocco	2009	2.5	2.5	2.5	0
United States	2011	2.4	2.4	2.4	0
Paraguay	2010	2	2	2	0
El Salvador	2011	2	0	5	66.7
Guatemala	2009	2	0	5	66.7
Honduras	2009	2	0	5	66.7
Nicaragua	2009	2	0	5	66.7
Myanmar	2008	1	1	1	0
Costa Rica	2010	1	0	5	87.5
Cape Verde	2011	0	0	0	100
Croatia	2011	0	0	0	100
Ecuador	2009	0	0	0	100
Georgia	2009	0	0	0	100
Hong Kong, China	2011	0	0	0	100
Japan	2010	0	0	0	100
Jordan	2010	0	0	0	100
Kyrgyz Republic	2008	0	0	0	100
Macao, China	2011	0	0	0	100
Mauritius	2010	0	0	0	100
Norway	2011	0	0	0	100
Papua New Guinea	2010	0	0	0	100
Singapore	2009	0	0	0	100

Sources: • **Ethiopia:** Ethiopian Revenue and Customs Authority (www.erca.gov.et/hscode.jsp); • **Switzerland:** Federal Customs Administration (http://xtares.admin.ch); • **All other economies:** WTO, Tariff Download Facility (http://tariffdata.wto.org).

Table A6.6. Energy-efficiency labels and energy-performance standards for electrical appliances in selected developing and emerging economies

Product	Argentina	Brazil	China	Chinese Taipei	Colombia	Costa Rica	Egypt	FSU***	GEA countries	Hong Kong, China	India	Indonesia	Iran	Malaysia	Philippines	Russia	Saudi Arabia	Singapore	South Africa	Thailand	Venezuela
Ballasts		L_v,S_v	L_v,S_m		L_m,S_m	L_m,S_m								S_m	L_m,S_m			L_v		L_v	
Boilers		L_v,S_v		S_m																	
Central AC		L_v,S_v	S_m															L_v			
Clothes Dryers		L_v		L_v						L_v								L_v			
Clothes Washers		L_v,S_v	L_v,S_m	L_v			L_m,S_m			L_v			L_m,S_m					L_v	L_v	L_v	
Computers			L_v	L_v				S_m	L_v							S_m		L_v		L_v	
Copiers			L_v	L_v					L_v	L_v										L_v	
Dishwashers		L_v		L_v				S_m								S_m					
Fans			S_m	L_v,S_m																	
Fax Machines			L_v	L_v					L_v												
Freezers	L_m	L_v,S_v	L_v	L_v	L_m,S_m	L_m,S_m	L_m,S_m	L_m,S_m					L_m,S_m	L_v	L_m	L_m,S_m		L_v			L_m,S_m
Lamps	L_v	L_v,S_v	L_v,S_m	L_v,S_m	L_m,S_m	L_m,S_m				L_v	L_v				L_m,S_m,L_v			L_v	L_v	L_v	
Microwave Ovens		L_v	L_v	L_v																	
Monitors		L_v	L_v	L_v				S_m	L_v	L_v						S_m		L_v		L_v	
Ranges/Ovens		L_v,S_v		L_v,S_m		L_m,S_m		S_m			L_v					S_m					
Refrigerators	L_m	L_v,S_v	L_m[4],S_m, L_v	L_v,S_m	L_m,S_m	L_m,S_m	L_m,S_m	L_m,S_v		L_v	L_v,S_v,L_m	L_v	L_m,S_m	L_v	L_m	L_m,S_m		L_v	L_v	L_m	L_m,S_m
Room AC		L_v,S_v	L_m[5],S_m, L_v	L_v,S_m	L_m,S_m	L_m,S_m	L_m,S_m	S_m		L_v	S_v		L_m,S_m		L_m,S_m	S_m	S_m	L_v,S_m		L_v,S_v[7]	L_v,S_v
Televisions		L_v	L_v,S_m	L_v				S_m	L_v	L_v	L_v					S_m					
Water Heaters		L_v, S_v	L_v	L_v,S_m	L_m,S_m	L_m,S_m		S_m		L_v	L_v		L_m,S_m			S_m		L_v			

Source: www.clasponline.org/clasp.online.worldwide.php.