Projected Impacts of Global Energy Efficiency Standards for Appliances Implemented in SEAD Countries Since 2010

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ABSTRACT

The adoption of increasingly stringent energy efficiency standards for appliances is an established and effective method of reducing energy use and global greenhouse gas emissions. In this study, we present and analyze, using a bottom-up analytical framework, appliance efficiency standards for a number of end uses in countries participating in the Super-efficient Equipment and Appliance Deployment (SEAD) initiative. SEAD member countries account for about one half of global energy consumption. The study summarizes minimum performance standards (MEPS) that were implemented, announced, or are being considered since January 2010.

The impact of these standards is analyzed using the Bottom-Up Energy Analysis System (BUENAS). BUENAS integrates activity forecasting, unit energy consumption, and stock accounting in order to project energy consumption at a more detailed level than other forecasting models, especially those that are top-down in nature. The analytical framework underpinning BUENAS is briefly described and the model is used to project the energy and emissions savings potential of the MEPS through the year 2030. The standards analyzed are expected to save almost 660 TWh of energy in 2030, and result in cumulative emissions savings of 3.3 gigatons (Gt) of CO_2 from 2010 to 2030, a reduction of 4% and 3% respectively from a scenario without standards.

Introduction

Appliances and equipment account for the vast majority of global electricity use, and approximately half of total global energy use (IEA 2009). It is therefore crucial to increase the efficiency of appliances and equipment to reduce global greenhouse gas emissions. The Super-Efficient Equipment and Appliance Deployment (SEAD) initiative aims to transform the global market for energy-efficient equipment and appliances by supporting technical analyses on efficient products, bolstering national or regional policies like minimum energy performance standards (MEPS) and labels, and accelerating the adoption of super-efficient products through incentives, procurements and awards. SEAD was jointly announced by the U.S. and Indian governments at the United Nations Framework Convention on Climate Change Conference of the Parties in Copenhagen in December 2009, and was later launched as an initiative within the Clean Energy Ministerial Global Energy Efficiency Challenge in July 2010. As of March 2012, SEAD member governments are: Australia, Brazil, Canada, the European Commission, France, Germany, India, Japan, Korea, Mexico, Russia, South Africa, Sweden, the United Arab Emirates (UAE), the United Kingdom, and the United States. China is currently an observer.

In this study, we summarize standards programs in SEAD economies and analyze the impacts of individual standards[1] that were implemented, announced, or are being considered since January 2010 in those economies[2]. As South Africa and the UAE are in the early stages of formulating their respective appliance standards programs, they are not included in this analysis. Also, data on the Russian and Brazilian standards programs are not available at this time, and therefore these nations are not included in this analysis. French, German, and British MEPS are aligned with standards that are set by the European Commission (EC), and they are therefore included in the EU results.

The impact of standards in SEAD economies is analyzed using the Bottom-Up Energy Analysis System (BUENAS), a forecasting model developed by Lawrence Berkeley National Laboratory (LBNL) with support from the Collaborative Labeling & Appliance Standards Program (CLASP). The BUENAS model is described below.

Country-Specific Standards Programs

SEAD member governments have made extensive use of standards to improve the energy efficiency of appliances and equipment sold in their respective countries. The first such standards were implemented in the late 1970s and 1980s, mostly in the U.S., Europe and Japan. Since then, such programs have been adopted in other economies and cover a growing range of appliances and equipment from residential, commercial, and industrial sectors. A brief summary of programs implemented in each of the SEAD economies is provided below, including a short description of the history of the standards program, the regulatory process, and the criteria considered when developing a proposal for new or revised standard levels.

Australia

The standards process in Australia is led by the Equipment Energy Efficiency (E3 2012) Committee, which has a mandate to assess products for possible regulation, engage with stakeholders and complete a Regulatory Impact Statement outlining the economic and environmental effects of the standard. The development of standards is a cooperative process between government and industry, using technical and economic analysis to determine appropriate energy efficiency targets.

Twenty-four product types from 12 end-use categories are subject to mandatory MEPS or are being proposed for introduction. Since 2010, new MEPS have been introduced or proposed for water heating, air conditioning (AC), audio-visual (AV) equipment, lighting, and computers. All of these standards were analyzed in this study except computers, for which data was unavailable. Data for Australian appliances and equipment was extracted from E3 documents and provided by the Australian Department of Climate Change and Energy Efficiency.

[1] The analysis focuses on MEPS. Modeling labeling programs is difficult due to the unavailability of data on market shares.

[2] Although many of these standards may have been influenced by SEAD activities, we do not imply that all MEPS established since January 2010 can be attributed to the SEAD initiative.

Canada

Canadian standards first came into effect under the authority of the Energy Efficiency Act (1992, amended in 2009) in 1995 following consultations with provincial governments, manufacturers, utilities, consumer representatives, environmental groups, and other stakeholders. Since then, MEPS have been implemented for 28 product types from 11 end-use categories. Because the North American market is highly integrated, Canada's energy performance requirements for many products are typically aligned with regulations in the United States.

The development, monitoring, and enforcement of energy efficiency standards is led by Natural Resources Canada (NRCan). Since 2010, new MEPS have been introduced for water heating, motors, distribution transformers, standby, some AV equipment, external power supplies (EPS), refrigeration, and heating, ventilation and AC (HVAC) equipment. Standards that are not expected to result in significant savings (specifically, some ACs standards) were not analyzed. Due to the similarity of the two markets, U.S. data was used as a proxy for Canadian data with corrections for climate when Canadian data (NRCAN 2011) was unavailable.

The European Union

MEPS were first introduced in the European Community in 1994. Under two directives of the European Parliament and of the Council established in 2005 and 2009 (Directives 2005/32/EC and 2009/125/EC respectively), a framework was established to develop MEPS in the EU. Today, the program covers more than 46 appliances and equipment in 14 end-use categories in the residential, commercial, and industrial sectors.

Depending on the product, one of the EC's Directorates (i.e., Energy, Industry) leads the regulatory process including the development of a preparatory study and several consultation processes with stakeholders and regulatory groups within the EC Parliament, and Council. The process concludes with the final adoption and publication of a regulation in the Official Journal of the European Union. Since 2010, the EU has introduced MEPS requirements for refrigeration, HVAC, lighting, laundry, water heating, standby power, cooking and dishwashing appliances, motors, AV equipment, external power supply (EPS), and water pumps. These MEPS are all considered in this study. The preparatory studies provide market and energy use data used in this analysis, and are available through the EU's ecodesign website (Ecodesign 2012).

India

The standards and labeling program in India was initiated in 2006 through a voluntary comparative labeling scheme for refrigerators and air conditioners. The program, based on the Energy Conservation Act of 2001, is now mandatory for four appliances with eight additional products regulated under the voluntary labeling program. Products with a mandatory labeling program were modeled when market data was available as performance requirements to reach the first level in the labeling scheme work as de facto MEPS, since under-performing products cannot be sold or distributed. The regulatory process is led by the Bureau of Energy Efficiency (BEE), which develops and administers the standards and labeling program for appliances and equipment. The Bureau of Indian Standards (BIS) provides technical support through the development of test procedures and approves all Indian standards.

Voluntary product labeling policies are initially established, and as market receptivity increases, mandatory labeling is introduced. Stakeholders participate in the development of labeling schemes through a Steering Committee and product-specific Technical Committees. Labels are based on a 1 (least efficient) to 5 (most efficient) star rating system, and are revised every few years in a step-like scheme, where the 1 star efficiency level is eliminated, and a new, more efficient level is added at the 5 star level. Labels for products covered under the mandatory scheme, including distribution transformers, refrigerators, and air conditioners were modeled in this analysis (BEE 2012). Mandatory labels for tubular fluorescent lighting products could not be modeled due to lack of available data. The market shares by star rating were derived from annual sales data, and energy savings were obtained by assuming constant market shares over time.

Japan

The Japanese Energy Conservation Law, passed in 1979 and revised in 1999, provides the foundation for Japan's energy efficiency policy. Rather than setting MEPS, the law sets a target for the shipment-weighted average efficiency[3] for regulated products. The standards promulgated by the law are voluntary for manufacturers, importers and distributors until the target year is reached. Once the target year is reached, the standards go into effect, becoming mandatory. Failure to meet these targets are made public and fines exist for non-compliance. The first efficiency standards were established for residential refrigerators and air conditioners in 1979, and additional products have been introduced since. Existing standards are revised periodically. Today the program, known as Top Runner, covers 19 product types in ten end-use categories and is led by the Advisory Committee for Natural Resources and Energy from the Ministry of Economy, Trade and Industry (METI). The standard setting process is supported by Subcommittees, set up by the Advisory Committee, which evaluate the equipment being considered and relevant test procedures. The efficiency targets are set after considering a number of factors in collaboration with manufacturers, such as potential improvements to technologies or components of technologies.

Targets have been set or updated since 2010 for ACs, lighting, electric toilet seats, computing equipment, televisions, and vending machines. The targets for electric toilet seats and computing equipment could not be modeled due to lack of data. Data for the analysis was primarily obtained from Top Runner documentation (Top Runner Program 2010).

South Korea

The Energy Efficiency Standards and Labeling Program in South Korea was launched in 1992 to improve the energy efficiency of common appliances. The program now covers 20 product types in ten end-use categories in the residential, commercial, and industrial sectors.

The regulatory process, led by the Korean Energy Management Corporation (KEMCO), involves three main stages: the development, review and approval of a standard proposal. Data is collected to support an analysis that results in an efficiency standard proposal. Proposals are reviewed in consultation with stakeholders, such as manufacturers and academic experts, and

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[3] The weighted average performance value of all products shipped by the manufacturer should exceed the standard, allowing manufacturers to sell equipment with lower efficiency than the standard as long as a suitable number of efficient products in the same category is also sold.

final recommendations provided by KEMCO are approved by the Ministry of Knowledge Economy (MKE). MKE establishes effective dates and specifies test procedures for the standard.

Targets have been set or updated since 2010 for lighting, residential and commercial refrigerators, clothes washers, rice cookers, standby power, distribution transformers, water heaters, and dishwashers. Some of the standards, such as the standard for residential refrigerators, are expected to provide modest savings due to the very high efficiency level of products on the Korean market and were not modeled. Others, such as the standard for Kimchi refrigerators, were not modeled due to lack of available data.

Mexico

Energy efficiency standards were first adopted in Mexico in 1995 after the enactment of the Federal Law for Metrology and Standardization. Standards for refrigerators, ACs and motors were developed under the National Commission for Energy Saving (CONAE). In 2008, the Law for Sustainable Use of Energy transferred the authority for energy efficiency standards from CONAE to the National Commission for Energy Efficiency (CONUEE). Today, there are 18 energy efficiency standards for products from seven end-use categories.

The regulatory process is led by CONUEE, but it is the responsibility of the National Consultative Committee of Standards for the Preservation and Rational Use of Energy Resources (CCNNPURRE) to review all MEPS proposals. Due to market similarities between North American economies, the Mexican appliance standards program has pursued a strategy of harmonization with the program administered by the U.S. Department of Energy. Since 2010, Mexican standards have been introduced for lighting, refrigerators, motors, AC, laundry, and water heating equipment; these products are considered in this study. Data was extracted from CONUEE regulatory documents (CONUEE 2012).

The United States

The first federal appliance standards in the United States were enacted in 1987 by the National Appliance Energy Conservation Act. Congress set initial federal energy efficiency standards and established schedules for the Department of Energy (DOE) to review these standards. Since then, standards for 42 types of appliances and equipment used in 13 end-use categories of the residential, commercial, and industrial sectors have been established.

The regulatory process led by DOE takes three years on average and usually goes into effect three years afterwards, for a total timeline of six years. The standard setting process is supported by extensive market and technical analyses. Documents are made available for comment by stakeholders at different times during the regulatory process. Criteria such as technological feasibility, practicability to manufacture, economic viability, adverse impacts on health and safety and environmental impacts are considered when selecting the standard level.

Since 2010, MEPS have been implemented for refrigerators, HVAC, lighting, laundry equipment, cooking equipment, water heating, distribution transformers, and motors; these products are all considered for this analysis. Data for this analysis was obtained from DOE's technical support documents and associated spreadsheets for each analysis (DOE 2012).

The standards modeled in this analysis are broken down by end use and country in Table 1. The majority of MEPS are in the residential sector, as this is historically where MEPS programs have focused. Countries that have more mature standards programs in the residential sector are now seeking additional savings opportunities in the commercial and industrial sectors, where the potential is quite large.

Table 1. Number of standards modeled by country and end use

End Use	Australia	Canada	EU	India	Japan	Korea	Mexico	US	Total
Commercial		**1**	**3**		**2**			**3**	**9**
Heating & AC					1			1	2
Laundry								1	1
Pumps			2						2
Refrigeration		1			1			1	3
Ventilation, Fans & Blowers			1						1
Industrial		**1**	**2**	**1**			**1**	**3**	**8**
Motors		1	1				1	2	5
Power Supply & Conversion			1	1				1	3
Residential	**4**	**6**	**12**	**2**	**3**	**3**	**4**	**13**	**47**
Cooking & Dishwashing			1			1		1	3
Heating & AC	2	2	2	1	1		1	3	12
Laundry			2			1	1	1	5
Lighting	1							2	3
Power Supply & Conversion		1	1						2
Refrigeration			2	1	1		1	2	7
Space Heating		1						1	2
Total	**4**	**8**	**17**	**3**	**5**	**3**	**5**	**19**	**64**

The BUENAS Modeling Framework

BUENAS is an end-use energy demand projection tool developed by Lawrence Berkeley National Laboratory (LBNL) with support from the Collaborative Labeling & Appliance Standards Program (CLASP). BUENAS is used to model energy demand by various types of energy consuming equipment and aggregate the results to the end use, sector or national level. BUENAS is designed as a policy analysis tool that creates scenarios differentiated by the level of actions taken – generally toward higher energy efficiency. Impacts of policy actions towards market transformation, in this case the implementation of MEPS, are calculated by comparing energy demand in the "business as usual" (BAU) case to a specific policy case. BUENAS covers multiple countries, models various fuels, and projects energy and carbon savings. National energy demand of each end use is constructed according to the following modification of the Kaya identity (Kaya, Yokobori 1993):

$$Energy = \frac{Activity \times Intensity}{Efficiency}$$

Here, *Activity* refers to the size of the stock, such as the number of refrigerators or the air-conditioned area of commercial buildings. *Intensity* is driven by the fuel usage and capacity of each unit, such as the size of a water heater or the hours of use of an air conditioner. Finally, *Efficiency* is the technological performance of the equipment, which can be affected by government policies such as mandatory MEPS.

BUENAS is implemented using the Long-Range Energy Alternatives Planning (LEAP, 2012) system, developed by the Stockholm Environment Institute. LEAP is a general-purpose energy accounting model in which the model developer inputs all data and assumptions in a format that is transparent to other users.

BUENAS projects energy consumption by end use from 2005 (base year) to 2030. The strategy implemented by the model is to first project end use activity, which is driven by increased ownership of appliances in the residential sector and economic growth in the commercial and industrial sectors. The total stock of appliances can be modeled either according to an econometric diffusion model or according to unit sales projections, if forecasts are available. Electricity consumption or intensity of the appliance stock is then calculated according to estimates of the baseline intensity of the prevailing technology in the local market. Finally, the total final energy consumption of the stock is calculated by modeling the flow of products into the stock and the marginal intensity of purchased units, either as new sales or as replacements of old units according to equipment retirement rates. The MEPS scenario is created by the assumption of increased unit efficiency relative to the baseline starting in a certain year. For example, if the average baseline unit energy consumption (UEC) of new refrigerators is 450 kWh/year, but a MEPS taking effect in 2012 requires a maximum UEC of 350 kWh/year, the stock energy in the policy scenario will gradually become lower than that of the base case scenario due to increasing penetration of high-efficiency units under the standard. By 2030, the entire stock will generally be impacted by the standard.

BUENAS Modeling Methodology

The two main outputs of BUENAS are national-level final energy savings and carbon dioxide emissions mitigation. Final energy savings are important because final energy demand drives fuel imports and the construction of additional generation capacity. Final energy demand is also what consumers pay for directly. Carbon dioxide comprises the majority of greenhouse gas emissions from electricity generation and is therefore the most important environmental impact of energy consumption. Carbon dioxide emissions mitigation is obtained by weighting the final energy demand by the appropriate carbon conversion factors.

BUENAS calculates final energy demand according to unit energy consumption of equipment sold in previous years:

$$E_{BAU}(y)=\sum_{age} Sales(y\text{-}age)\times UEC_{BAU}(y\text{-}age)\times Surv(age)$$

where *Sales(y)* is the unit sales (shipments) in year *y*, *UEC(y)* is the unit energy consumption of units sold in year *y* and *Surv(age)* is the probability of surviving to *age* years.

Stock turnover (mostly done by LEAP). When unit sales (shipments) are not given as direct data inputs, BUENAS derives them from increases in stock and replacements:

$$Sales(y)=Stock(y)-Stock(y-1)+\sum_{age} Ret(age)\times Sales(y-age)$$

where *Stock(y)* is the number of units in operation in year *y*, and *Ret(age)* is the probability that a unit will be retired (and replaced) at a certain age. The shape of the retirement function is assumed to be either a Weibull distribution, if the Weibull parameters are available, or it is assumed to be a normal distribution with mean equal to the lifetime of the product and standard deviation equal to one-third of the mean. Stock is rarely given directly as input data. Instead, if sales data are not available, BUENAS uses diffusion (ownership) rates for residential end uses:

$$Stock(y) = Saturation\ (y) \times HH(y)$$

where *Saturation(y)* is the number of units (owned and used) per household in year *y* and *HH(y)* is the number of households in year *y*. In turn, diffusion rates are generally not given by input data, but are projected according to a macroeconomic model which is a function of GDP, urbanization rate, electrification rate, and model parameters obtained using a regression analysis.

Aggregate activity. When sales data and UECs are unavailable for commercial end uses, BUENAS uses commercial floor area and end use intensity, since these data are more readily available from national statistics**:**

$$E_{BAU}(y) = \sum_{age} Turnover(y-age)\times uec_{BAU}(y-age)\times Surv(age)$$

where *Turnover(y)* is equipment floor space coverage added or replaced in year *y* and *uec*(*y*) is energy intensity (kWh/m^2) of equipment installed in year y (lower case used to distinguished from unit energy consumption, UEC). Turnover is driven by increases in floor space, and replacement of existing equipment occupying floor space:

$$Turnover(y)= F(y)-F(y-1)+\sum_{age} Ret(age)\times Turnover(y-age)$$

where *F(y)* is total commercial floor space in year *y*. When floor space is not given by direct data inputs, it is modeled as:

$$F(y) = N_{SSE}(y)\times f(y)$$

where N_{SSE} is the product of the economically active population and the service sector share of GDP, and *f(y)* is the floor space per employee, which is modeled as a function of GDP per capita and parameters obtained using a regression analysis. A more detailed explanation of the BUENAS model is given in (McNeil, Letschert, de la Rue de Can, Ke, 2011).

Energy Demand Scenario Definition

Business as usual (BAU) scenario. Much of the modeling content of BUENAS is contained in the construction of the BAU case; other scenarios are modifications of BAU. Most important in the construction of the BAU scenario is the projection of growth in total energy demand, which is driven by growth in both activity and intensity. Activity and intensity projections are assumed equal for all scenarios in BUENAS. This assumption implies that scenarios differ only by the efficiency of products; changes in stock and usage patterns are not included as effects of policy.

In addition to growth in activity and intensity, the BAU case includes a specific assumption of efficiency. By default the BAU case assumes "frozen efficiency": while usage may evolve over time, the efficiency of new products remains constant. Exceptions to this arise when projections are available that include "market-driven" efficiency improvements, which are then included in BUENAS. The assumption of frozen efficiency is a consequence of the absence of systematic estimates of market-driven improvement.

Recent achievements scenario. BUENAS has been used to forecast the impacts of existing MEPS in SEAD countries. The following regulations have so far been modeled according to the schedule of announcement and implementation:

- Regulations implemented between January 1, 2010 and March 1, 2012 (effective date)
- Regulations issued between January 1, 2010 and March 1, 2012 (announcement date)
- Regulations in progress between January 1, 2010 and March 1, 2012 (included only if a implementation date has been announced, and sufficient data is available).

Best practice scenario. The best practice scenario models aggressive but achievable efficiency improvements via MEPS for all countries. The scenario assumes that all countries adopt stringent standards in modeled end uses by 2015, where "stringent" is interpreted as follows:

- Where efficiency levels are readily comparable across countries: the most stringent standard issued by April 1, 2011 anywhere in the world.
- Where efficiency levels are not readily comparable across countries: the most stringent comparable (e.g., regional) standard issued by April 1, 2011.
- Where an obvious best comparable standard was not available: an efficiency level was set that was deemed to be aggressive or achievable, such as the most efficient products in the current rating system.

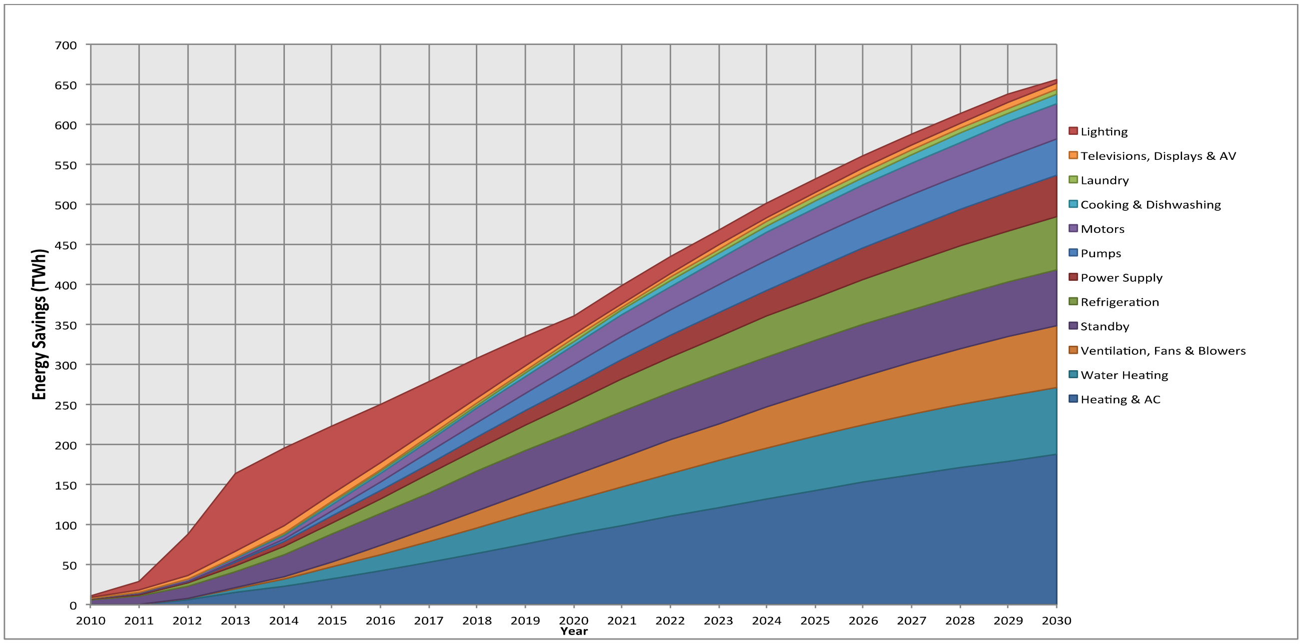
In addition, the best practice scenario assumes that standards are further improved in the year 2020, by an amount estimated on a product-by-product basis. In-depth results of the best practice scenario are outside the scope of this document, but will be presented with the results of the recent achievements scenario to illustrate the potential achievable energy savings of MEPS.

Results

The results of the BUENAS analysis of MEPS implemented since January 2010 in SEAD countries are shown in Figure 1 and summarized in Table 2. As some end-uses were not modeled due to a lack of available data, as detailed in the country summaries above, the results presented in Table 2 are a conservative estimate of the total impact of energy efficiency standards if all end uses could have been modeled using the BUENAS framework.

The demand for energy in the BAU scenario by modeled appliances and equipment is expected to grow from 12,374 TWh in 2010 to 16,963 TWh in 2030. Energy efficiency standards already implemented or planned to be implemented by SEAD economies are expected to yield savings of approximately 656 TWh, or 3.9% in 2030 – about 219 Rosenfelds (Koomey et al., 2010), or as much energy as produced by 219 500-MW coal-fired power plants. The cumulative energy savings from 2010 to 2030 as a result of modeled standards is expected to be 7,631 TWh. The energy savings are expected to result in avoided emissions of 279 million tons of CO_2 in 2030, and cumulative savings of 3.3 gigatons (Gt) of CO_2 from 2010 to 2030, a reduction of 2.8% from the baseline. Aggregated energy savings results of the BUENAS model have been compared to independent top-down, macro-economic estimates of national energy consumption at the sectoral level. The availability of such data is fairly limited and future projections are rare. However, when available, comparisons between BUENAS results and such top-down data provide a sanity check of our results. These bottom-up to top-down matching exercises have yielded consistent results, providing confidence in the BUENAS modeling methodology. In addition, comparisons to other bottom-up results are made, when available and are used to cross-check the BUENAS model.

Figure 1. Energy savings over time due to implemented MEPS (savings from lighting are realized early on due to the transition from inefficient incandescent lighting to CFLs and LED lighting).



The net present value, (discounted to 2010 using country-specific discount rates) of the energy savings is expected to be approximately \$48 billion in 2030, and approximately \$746 billion cumulatively. The dollar value of energy saved was calculated using present country specific energy prices with no attempt made to forecast the prices into the future. The dollar values are therefore approximate and give only an order of magnitude indication of the value of the energy savings.

The U.S. has begun to incorporate the social cost of carbon (SCC) into appliance standard rule makings in order to have a more comprehensive accounting of the benefits of the standards being considered. By using the guidelines set out by the Interagency Working Group on the Social Cost of Carbon (SCC) (Interagency Working Group on Social Cost of Carbon. 2010), we estimate the monetary impact of the avoided carbon emissions. The working group employed three Integrated Assessment Models in order to encapsulate costs due to "changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services". The Working Group provides a range of damages due to the emission of an additional ton of CO_2 for each future year in order to account for the uncertainty inherent in such estimates of future damages. We present results using a value in the midpoint of

Table 2. Energy and emissions savings due to MEPS implemented by SEAD countries since 2010

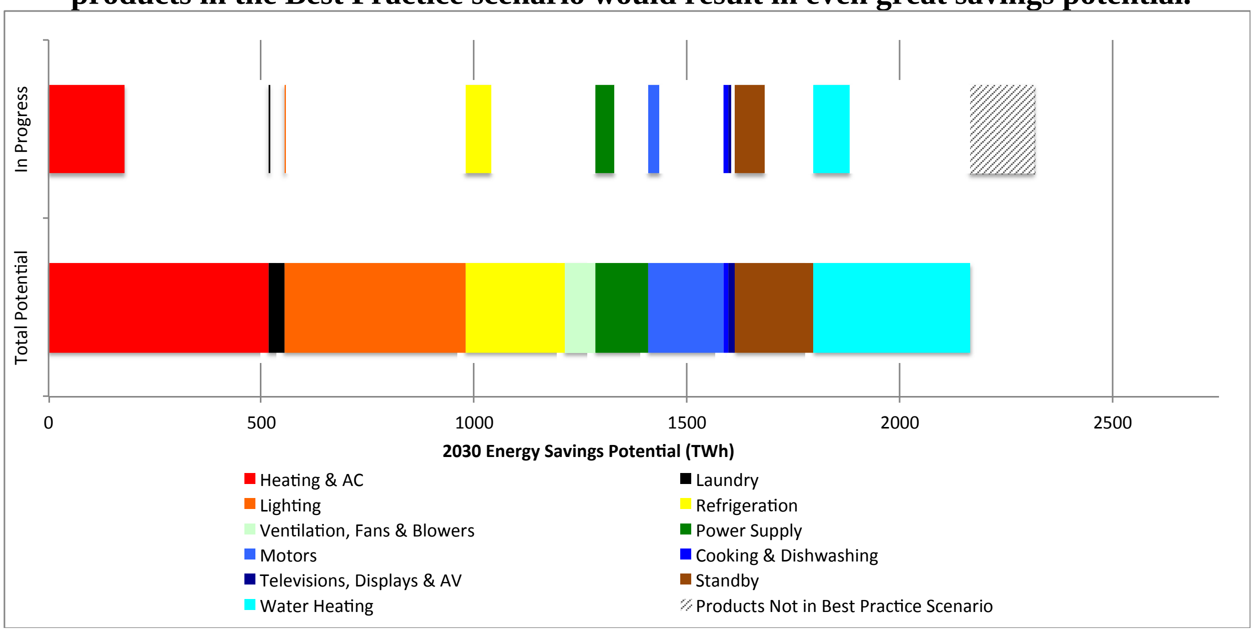
	Energy Savings 2030 (TWh)	Emissions Savings 2030 (Mt CO2)	SCC Savings 2030 (Millions 2010 $)	Cumulative Energy Savings (TWh)	Cumulative Emissions Savings (Mt CO2)	Cumulative SCC Savings (Millions 2010 $)
Total	**656**	**279**	**9620**	**7631**	**3304**	**98800**
Electricity	**529**	**253**	**8728**	**6312**	**3034**	**90566**
Commercial	**135**	**47**	**1619**	**1365**	**498**	**15222**
Heating & AC	3	1	43	45	18	526
Laundry	1	0	16	10	6	173
Pumps	45	15	517	487	170	5196
Refrigeration	9	4	151	129	63	1876
Ventilation, Fans & Blowers	77	26	892	693	241	7451
Industrial	**89**	**44**	**1513**	**866**	**444**	**13566**
Power Supply (Transformers)	45	22	745	390	194	5981
Motors	44	22	767	475	250	7585
Residential	**305**	**163**	**5597**	**4081**	**2092**	**61777**
Heating & AC	144	89	3075	1390	858	26345
Laundry	6	3	90	60	28	854
Cooking & Dishwashing	10	3	119	100	35	1074
Power Supply	7	2	79	89	31	901
Refrigeration	58	34	1164	593	338	10321
Lighting	5	4	123	734	382	9992
Televisions, Displays, & AV	7	4	139	125	64	1838
Standby	69	23	807	991	356	10452
Water Heating	25	11	362	267	117	3564
Gas	**119**	**24**	**822**	**1235**	**248**	**7561**
Commercial	**1**	**0**	**7**	**10**	**2**	**62**
Heating & AC	1	0	7	10	2	62
Residential	**118**	**24**	**815**	**1225**	**246**	**7499**
Heating & AC	116	23	801	1204	242	7371
Laundry	0	0	2	3	1	16
Cooking & Dishwashing	2	0	12	18	4	112
Water Heating	59	12	411	607	122	3728

	Energy Savings 2030 (TWh)	Emissions Savings 2030 (Mt CO2)	SCC Savings 2030 (Millions 2010 $)	Cumulative Energy Savings (TWh)	Cumulative Emissions Savings (Mt CO2)	Cumulative SCC Savings (Millions 2010 $)
Oil	**8**	**2**	**69**	**85**	**22**	**673**
Residential	**8**	**2**	**69**	**85**	**22**	**673**
Heating & AC	8	2	69	85	22	673

this range, using a 3% discount rate to discount future damages to the present. The global monetary savings from SCC due to energy efficiency standards implemented by the SEAD economies in 2030 is expected to be $9.6 billion (2010 $), and the cumulative savings are expected to be $99 billion from 2010 to 2030.

While the energy and monetary savings of implemented appliance and equipment standards in SEAD economies are substantial, it is instructive to model the savings accrued if all governments were to adopt the Best Practice scenario. This scenario is illustrative of the additional potential of MEPS to reduce energy consumption and greenhouse gas emissions. If all SEAD countries adopt best practice MEPS, the energy savings as a result of those standards relative to the BAU scenario would be 2164 TWh in 2030, and the electricity savings would be 1814 TWh. Emissions savings in 2030 would be 890 Gt of CO_2, resulting in SCC savings of $33 billion dollars (2010 $). Figure 2 compares the energy savings under the Best Practice scenario with the savings from standards that are already in progress. The energy savings potential illustrated by the Best Practice scenario is similar to the results of other studies that have studied the adoption of stringent MEPS standards (Waide et al., 2010).

Figure 2. Energy (includes both electricity and fuel) savings in 2030 in progress under the Recent Achievements scenario compared to savings possible if the Best Practice scenario were implemented. Note the large potential for savings in nearly every end use. The hatched box to the extreme right in the in progress row represents savings from products which are not modeled in the Best Practice scenario due to lack of data. Inclusion of these products in the Best Practice scenario would result in even great savings potential.



In order to put these savings in context, we compare the effect of the efficiency standards to the International Energy Agency's (IEA) World Energy Outlook 450 scenario (IEA 2010) which aims to present an energy roadmap to limit the increase in global temperatures to 2° C by limiting the concentration of greenhouse gases in the atmosphere to 450 parts per million (ppm) of CO_2 equivalent. The scenario calls for global electricity consumption in the buildings (both commercial and residential) and industrial sectors to be reduced by 2400 TWh and 1680 TWh respectively in 2030. The efficiency standards already implemented by SEAD economies account for 13% of the necessary reductions, assuming that no further increases in MEPS are implemented. Adopting the Best Practice scenario would, however, result in savings that would account for 44% of the necessary reductions.

Conclusions

Energy efficiency standards for appliances and equipment put in place by SEAD governments since 2010 will have a substantial impact in reducing future greenhouse gas emissions and worldwide energy consumption. In addition, the monetary benefit via avoided damages due to global warming is expected to be around $850 billion cumulatively between 2010 and 2030. As SEAD expands to include new member nations, and as existing and new efficiency programs mature and grow, it is expected that savings due to MEPS will only increase. The Best Practice scenario is indicative of the potential of these efforts. As energy efficiency is typically the lowest-cost policy option for emissions reductions in comparison to other clean energy alternatives (McKinsey & Company, 2007), the shift to energy-efficient technologies not only has the potential to contribute significantly to reductions in carbon emissions to mitigate the effects of global warming, but to do so cost-effectively (McNeil, Letschert, de la Rue de Can, Ke, 2011).

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