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Estimate of Cost-Effective Potential for Minimum Efficiency Performance Standards in 13 Major World Economies -- Energy Savings, Environmental and Financial Impacts

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Disclaimer

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Acronyms and Abbreviations

AFUE	annual fuel utilization efficiency
AUS	Australia
BAT	best available technology
BAU	business as usual
BRA	Brazil
BUENAS	Bottom-Up Energy Analysis System
CAN	Canada
CCE	cost of conserved energy
CEP	cost-effective potential
CES	carbon dioxide emissions savings
CF	carbon factor
CFL	compact fluorescent lamp
CHN	China
CLASP	Collaborative Labeling Appliances and Standards Program
CO_2	carbon dioxide
EC	European Commission
EPACT	energy policy act
EU	European Union
GEEC	global energy-efficiency cost
GJ	gigajoule
Gt	gigaton
IDN	Indonesia
IND	India
IL	incandescent Lamp
JAP	Japan
KOR	Korea
kVA	kilovolt ampere
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LCD	liquid crystal display
LED	light-emitting diode
MEX	Mexico
MEPS	minimum efficiency performance standard
Mt	million tons (of CO_2)
NEC	national equipment cost
NEMA	National Electric Manufacturers Association
NES	national energy savings
NIA	National Impacts Analysis
NOC	national operating cost
NPV	net present value
PJ	petajoule
RAC	room air conditioner
RUS	Russia
SEAD	super-efficient appliance deployment
SEER	seasonal energy-efficiency ratio
TSD	technical support document
UEC	unit energy consumption
USA	United States of America

USD	U.S. Dollar
TWh	terawatt hour
U.S. DOE	United States Department of Energy
ZAF	South Africa

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Executive Summary

This study analyzes the financial impacts on consumers of minimum efficiency performance standards (MEPS) for appliances that could be implemented in 13 major economies around the world. We use the Bottom-Up Energy Analysis System (BUENAS), developed at Lawrence Berkeley National Laboratory (LBNL), to analyze various appliance efficiency target levels to estimate the net present value (NPV) of policies designed to provide maximum energy savings while not penalizing consumers financially. These policies constitute what we call the "cost-effective potential" (CEP) scenario. The CEP scenario is designed to answer the question: How high can we raise the efficiency bar in mandatory programs while still saving consumers money?

We present the impacts of the MEPS analyzed in this study in terms of national energy savings (NES), NPV, and carbon dioxide (CO_2) emissions reductions. By comparing different energy savings and CO_2 estimates while maintaining a positive NPV, we can identify the policies on which a government should focus to cut its emissions or energy consumption.

The impacts of MEPS implemented in 2015 are presented for each end use in terms of energy savings and CO_2 emissions savings in 2020 and in 2030.

We conclude that the cost-effective potential of MEPS in the countries studied is:

- 770 terawatt hours (TWh) of electricity savings in 2020 and 1,500 TWh in 2030
- 430 petajoules (PJ) of fuel savings in 2020 and 1,100 PJ in 2030
- 17 percent energy reduction in residential end uses and 4 percent in industrial end uses in 2030
- 540 million tons (Mt) of annual CO_2 emissions reductions by 2020 and 1,000 Mt by 2030
- 11 gigatons (Gt) of cumulative emissions savings between 2015 and 2030
- Cumulative consumer financial benefits of 1,500 billion USD

BUENAS has previously been used, in support of the Collaborative Labeling and Appliance Standards Program (CLASP) and the Super-Efficient Appliance Deployment (SEAD) initiative, to estimate potential NES and CO_2 mitigation potential from MEPS around the world. As part of an ongoing effort to estimate potential savings from MEPS best practices, LBNL developed a scenario that identifies additional cost-effective policies that could be implemented in the world's major economies.

For this study, BUENAS was enhanced to model financial impacts on consumers as an additional output to be considered by stakeholders and policy makers. To model these impacts, BUENAS now tracks national incremental equipment cost along with NES for each appliance type in each country studied. From these, the value of a given program can be determined by comparing the national costs to benefits in each year. The sum over years of discounted net benefits constitutes the NPV of the program.

Scenario Description and Rationale

The CEP scenario is built on the business-as-usual (BAU) scenario developed in BUENAS. CEP targets are determined according to the cost of conserved energy (CCE) of various design options/technologies that provide higher appliance energy efficiency. The CCE is provided by data from the Global Energy-Efficiency Cost (GEEC) database, a compilation of international cost efficiency data. By comparing the CCE with the local cost of electricity in each economy, we determine the highest cost-effective efficiency targets for that country. These targets provide the greatest energy savings while ensuring a financial benefit to consumers. The targets determined using the CCE are then propagated into BUENAS to estimate global savings and financial impacts over the full life of products shipped between 2015 and 2030.

The GEEC cost database was built using a variety of sources, including technical analysis studies performed by LBNL in support of the SEAD initiative, technical support documents (TSDs) developed for the U.S. Department of Energy (DOE) standards program, preparatory studies from the European Commission Ecodesign program, and retail price surveys. Where data are not available, we use regional market assumptions to extrapolate incremental costs for specific countries. The CCE is then recalculated using local parameters (discount rates and energy prices).

Scope of Scenario Coverage

Because BUENAS has been used to support the activities of SEAD (which is an initiative within the Clean Energy Ministerial process), BUENAS includes all SEAD participating countries as well as China.[1] Table ES-1 shows the appliances and countries covered in the CEP and BAU scenarios in the current study. The end uses and countries covered in the BAU scenario are shaded, and those covered in the CEP scenario are marked by an “X”. Commercial-sector end-use cost data were not sufficient to include in this study. In the residential and industrial sectors, the CEP scenario covers nearly all end uses. Notable exceptions are water heating and space heating, for which cost data were not available, and the specificity of the market did not allow us to extrapolate costs.

Table ES-1. Comparison of BAU and CEP Scenario Scope

Shaded cells = countries covered in BAU scenario; X = countries covered in CEP scenario

	Appliance	AUS*	BRA*	CAN*	CHN*	EU*	IND*	IDN*	JPN*	KOR*	MEX*	RUS*	USA*	ZAF*
RES	Air Conditioner	X	X	X	X	X	X	X	X	X	X	X	X	
	Central AC*			X							X		X	
	Cooking Equip.				X	X							X	
	Fans	X	X	X	X	X	X	X	X	X	X	X	X	X
	Laundry				X	X							X	
	Lighting	X	X	X	X	X	X	X	X	X	X	X	X	X
	Freezers					X							X	
	Refrigerators	X	X	X	X	X	X	X	X	X	X	X	X	X
	Boilers			X	X	X							X	
	Furnaces			X									X	
	Space Heating													
	Standby Power	X	X	X	X	X	X	X	X	X	X	X	X	X
	Televisions	X	X	X	X	X	X	X	X	X	X	X	X	X
	Water Heaters			X	X	X							X	
IND	Transformers			X	X	X	X						X	
	Electric Motors	X	X	X	X	X	X	X	X	X	X	X	X	X

AC = air conditioning; AUS = Australia; BRA = Brazil; CAN = Canada; CHN = China; EU = European Union; IND = India; IDN = Indonesia; JPN = Japan; KOR = South Korea; MEX = Mexico; RUS = Russia; USA = United States of America; ZAF= South Africa

[1] The SEAD participating countries modeled in BUENAS are Australia, Brazil, Canada, European Union, India, Indonesia, Japan, Mexico, Russia, South Korea, South Africa, and the United States. China, an observer to the SEAD process, is modeled as well.

Potential Savings Results and Conclusions

Table ES-2 presents the estimated end-use energy savings and CO_2 emissions reductions in 2020 and 2030 for the CEP scenario.

Table ES-2. Final Energy Savings and Emissions Reductions for Cost-Effective Potential Scenario

	Annual Savings in 2020				Annual Savings in 2030				Cumulative Savings	
	Electricity	Gas	% reduction vs. BAU	CO_2	Electricity	Gas	% reduction vs. BAU	CO_2	CO_2 (2015-2030)	NPV
End Use	TWh	PJ	%	Mt	TWh	PJ	%	Mt	Gt	Billion USD
Air Conditioning	120	0	11%	71	310	0	21%	180	2.1	250
Cooking	2	4	1%	3	8	11	1%	8	0.1	26
Fans	63	0	31%	54	130	0	52%	100	1.1	49
Lighting	130	0	27%	74	8	0	2%	8	1.0	120
Refrigerators and Freezers	70	0	11%	50	180	0	25%	120	1.1	79
Space Heating		290	3%	22		760	7%	58	0.5	44
Standby	110	0	47%	65	200	0	66%	120	1.2	130
Television	21	0	12%	13	42	0	19%	24	0.3	31
Laundry	24	0	9%	25	55	0	17%	48	0.5	22
Water Heating	120	140	14%	87	280	290	27%	180	1.8	460
Total Residential	**660**	**430**	**10%**	**460**	**1,200**	**1,100**	**17%**	**850**	**9.7**	**1,200**
Transformers	28		7%	16	86		18%	46	0.4	91
Motors	85		2%	62	200		3%	140	1.3	160
Total Industry	**110**		**2%**	**78**	**290**		**4%**	**180**	**1.7**	**250**
Total	**770**	**430**	**10%**	**540**	**1,500**	**1,100**	**10%**	**1,000**	**11.4**	**1,500**

Our analysis shows that:

- Cost-effective consumer efficiency targets are achievable around the world that would result in significant national energy savings and CO_2 emissions reductions.
- Final energy consumption can be reduced by 17 percent in 2030 in the residential sector and 4 percent in the industrial sector compared to BAU consumption.
- As a result of this reduced energy consumption, worldwide annual CO_2 emissions would be reduced by 540 Mt in 2020 and 1,000 Mt in 2030. Overall, between 2015 and 2030, over 11 Gt of CO_2 would avoided.
- The net present value of the programs that would achieve the above savings is estimated at about 1.5 trillion USD.

By introducing the systematic financial considerations in our analysis, we built a framework that allows for further international studies on areas such as:
- Sensitivities to the equipment incremental cost: What is the effect of a rebate program or a learning rate on the level of cost effectiveness?
- Sensitivities to price of electricity: How does the subsidization of electricity impact the cost-effectiveness of efficiency improvements from the consumer perspective?
- Additional costs: How would a carbon tax or inclusion of the social cost of carbon impact the evaluation of cost-effective potential?

1. Introduction

Minimum efficiency performance standards (MEPS) are a common tool used in a wide range of countries to cover a large number of appliances and end uses in the building and industrial sectors (CLASP, 2011). This paper analyzes financial impacts on consumers of MEPS for appliances that could be implemented in 13 countries. We use the Bottom-Up Energy Analysis System (BUENAS), developed at Lawrence Berkeley National Laboratory (LBNL), to analyze various appliance efficiency target levels and estimate the net present value (NPV) of policies designed to provide maximum energy savings while not penalizing consumers financially. These policies constitute what we call the “cost-effective potential” (CEP) scenario. The CEP scenario is designed to answer the question: How high can we raise the efficiency bar in mandatory programs while still saving consumers money? The CEP scenario is built on the “business-as-usual” (BAU) scenario in BUENAS as described in more detail in Section 3.

This study also aims to quantify the worldwide value of untapped energy and financial savings as well as CO_2 emission reductions from MEPS. Using this information, policy makers can optimize future MEPS designs.

This study builds on previous BUENAS work described in McNeil, Letschert et al. (2008b) and McNeil, Letschert et al. (2012a). In this study, BUENAS for the first time estimates financial impacts by tracking national equipment cost (NEC) along with national energy cost savings. The value of a given efficiency performance standard program can be determined by comparing national costs to benefits in each year. The sum over years of net benefits is known as the net present value (NPV). This report explains how efficiency targets are determined as well as the global impacts of policy measures to enforce these targets under a set of international MEPS.

Determination of cost effective targets relies on appliance specific cost vs efficiency relationships. For this study, previous LBNL data collection efforts for the U.S, China and India (McNeil and Bojda, 2012b, McNeil, Bojda et al., 2011a, McNeil, Bojda et al., 2011b) is extended to cover all SEAD countries. These countries represent 77% of the total energy consumed globally in 2005 (McNeil et al., 2012). Additional data was collected using “deep dive” technical analysis developed by LBNL researchers under the Super-Efficient Appliance Deployment (SEAD) project (Park et al., 2011; Sathaye et al., 2012; Shah et al., 2012).

2. Scope of Work

Because BUENAS is being used to support the activities of SEAD, which is an initiative within the Clean Energy Ministerial process, BUENAS includes SEAD participating countries as well as China, which is an observer to the SEAD process. The countries covered in BUENAS and their International Standards Organization acronyms are:

- Australia (AUS)
- Brazil (BRA)
- Canada (CAN)
- China (CHN)
- European Union (EU)
- India (IND)
- Indonesia (IDN)
- Japan (JAP)
- Mexico (MEX)
- Russia (RUS)

- South Korea (KOR)
- United States (USA)
- South Africa (ZAF)

Table 1 shows the countries and end uses covered under the CEP and business-as-usual (BAU) scenarios in this study. The end uses and countries covered in the BAU scenario are shaded, and those in the CEP are marked by an “X.” Commercial-sector end-use cost data were not sufficient to include in this study. In the residential and industrial sectors, the CEP covers nearly all end uses. Notable exceptions are water heating and space heating, for which cost data were not available, and the specificity of the market did not allow for cost extrapolation.

Table 1. Comparison of BAU and CEP Scenario Scope

Shaded cells = countries covered in BAU scenario; X = countries covered in CEP scenario

	Appliance	AUS*	BRA*	CAN*	CHN*	EU*	IND*	IDN*	JPN*	KOR*	MEX*	RUS*	USA*	ZAF*
RES	Air Conditioner	X	X	X	X	X	X	X	X	X	X	X	X	
	Central AC*			X							X		X	
	Cooking Equip.				X	X							X	
	Fans	X	X	X	X	X	X	X	X	X	X	X	X	X
	Laundry				X	X							X	
	Lighting	X	X	X	X	X	X	X	X	X	X	X	X	X
	Freezers					X							X	
	Refrigerators	X	X	X	X	X	X	X	X	X	X	X	X	X
	Boilers			X	X	X							X	
	Furnaces			X									X	
	Space Heating													
	Standby Power	X	X	X	X	X	X	X	X	X	X	X	X	X
	Televisions	X	X	X	X	X	X	X	X	X	X	X	X	X
	Water Heaters			X	X	X							X	
IND	Distribution Transformers			X	X	X	X						X	
	Electric Motors	X	X	X	X	X	X	X	X	X	X	X	X	X

AC = air conditioning; AUS = Australia; BRA = Brazil; CAN = Canada; CHN = China; EU = European Union; IND = India; IDN = Indonesia; JPN = Japan; KOR = South Korea; MEX = Mexico; RUS = Russia; USA = United States of America; ZAF= South Africa

3. Scenario Rationale and Description

The CEP scenario is built on the BAU scenario in BUENAS. CEP targets are determined according to the cost of conserved energy (CCE) of various design options for the appliance classes studied. By comparing the CCE with local energy prices, we identify the largest energy savings that still provide a financial benefit to consumers. The targets determined using the CCE are then propagated into BUENAS to estimate global savings and financial impacts over the full life of products shipped between 2015 and 2030.

Construction of the CEP scenario is facilitated by LBNL’s Global Energy Efficiency Cost (GEEC) database. The GEEC database has been built using a variety of sources, including: technical analysis studies performed in support of the SEAD initiative, TSDs developed for United States Department of Energy (U.S. DOE) standards programs, preparatory studies from the European Commission Ecodesign program, and retail price surveys. Where data are not available, we use regional market assumptions are used to extrapolate incremental equipment prices to other countries. The CCE is then recalculated according to local parameters (discount rates and energy prices).

Table 2 shows the sources of cost-efficiency data for the end uses and countries covered in this analysis.

- Primary source: The data were taken from an official government document or collected and processed by LBNL (pink).
- Extrapolated: Data were not available at the time of the study, and data from other countries were used as a proxy (beige).
- No estimation: The end use is not covered in the BAU scenario (gray), or no data were available (white).

Table 2. Study Coverage and Cost Efficiency Data Type

	Appliance	AUS	BRA	CAN	CHN	EU	IND	IDN	JPN	KOR	MEX	RUS	USA	ZAF
RES	Boilers													
	Central AC*													
	Cooking Equip.													
	Dishwashers													
	Dryers													
	Fans													
	Freezers													
	Furnaces													
	Lighting													
	Refrigerators													
	RAC* – Split													
	RAC – Window													
	Standby													
	Televisions													
	Washing Machines													
	Water Heaters													
IND	Distribution Transformers													
	Electric Motors													

* AC = air conditioning; RAC = room air conditioner

4. Methodology – Determination of Cost-Effective Targets

Although there are various metrics for measuring the economic implications of a given investment, this study uses CCE because this metric allows for easy identification of the greatest energy savings that still provide a net savings to consumers. The subsections below present the analysis of a single product and discuss the parameters and formula for CCE evaluation.

For each country, we evaluate the appliance groups for which we have sufficient data. Each appliance group can encompass multiple product classes, each of which might fit a specific need or constraint. The general category refrigerators, for example, can be broken into refrigerators with a top-mount, bottom-mount, or side-by-side freezer. Within each product class, we define a baseline product, which is the market average and the basis of comparison for higher-efficiency design options. For refrigerators, higher-efficiency design options include units with increased insulation or a higher-performance compressor.

4.1 The CCE Metric and CEP evaluation

CCE divides annual incremental appliance cost by the energy saved in a year, which shows the investment needed per unit of energy savings as follows:

$$CCE = \frac{\Delta I(\$) \times q}{\Delta UEC(kWh)} = USD / kWh \quad \textbf{Equation 1}$$

where
I = initial capital investment
q = capital recovery factor
UEC = annual unit energy consumption
kWh = kilowatt hours

Typically, efficiency-driven decreases in annual unit energy consumption (UEC) are accompanied by higher equipment prices as a result of increased manufacturing costs. *ΔUEC* denotes efficiency savings compared to the baseline, expressed in either kWh of electricity or GJ of natural gas. The additional initial capital investment *(ΔI)* is the additional cost of an appliance's up-front purchase price as compared to the baseline appliance (although it sometimes includes installation cost). CCE is calculated using a capital-recovery factor, *q*. A capital recovery factor converts a present value into a future stream of payments. In this case, *q* is given by:

$$q = \frac{1}{\sum_{n=1}^{L} \frac{1}{(1+d)^n}} = \frac{d}{(1-(1+d)^{-L})} \quad \textbf{Equation 2}$$

where

d = discount rate, an interest rate used to determine annual payments of an investment over *L* years.
L = the average number of years an appliance is used before it fails and is retired.

The consumer discount rate, *d*, represents estimated interest charges on any debt for the appliance purchase. The incremental investment, *ΔI*, times the capital recovery factor, *q*, gives the annualized extra cost of purchasing a high-efficiency appliance. CCE indicates cost effectiveness when compared to utility rates. For example, if CCE is 0.07 U.S. dollars (USD) for the efficiency improvement of a particular refrigerator product class, and the electricity tariff is 0.11 USD, then the efficient design option will pay for itself and provide a net savings of 0.04 USD to the consumer for each kWh saved. The consumer can either purchase another kWh for 0.11 USD from the electric utility or can use an appliance that doesn't require another kWh to accomplish the same task, at a cost of 0.07 USD for the additional investment.

The average consumer electricity or natural gas tariff is expressed in USD per kWh or USD per GJ. When we identify the design option that maximizes *ΔUEC* and has a CCE below tariff*,* we have determined the CEP target.

4.2 Equipment Price and Unit Energy Consumption

Unless otherwise noted in Section 4.4, data are from the sources listed below:

- *Australia* – Standards Program Registry + Web-based Retail Data
- *Brazil* – International Energy Initiative Life-cycle Cost Analysis
- *Canada and Mexico* – based on U.S. data adjusted to reflect the different baseline energy consumption. Canada's and Mexico's markets are very similar to the U.S. market in many regards, and Canadian and Mexican efficiency standards are frequently harmonized to match U.S. standards.
- *China, Korea, and Japan* – web-based retail data for each country, from which we obtained UECs and prices, with statistical analysis to determine the correlation between price and efficiency. This correlation was used to derive the bins of different ranges of UECs and corresponding prices.
- *European Union* – Ecodesign program preparatory studies
- *India* – Efficiency literature, labeling program studies
- *Indonesia* – based on India data
- *Russia* – based on EU or eastern European market data when available
- *South Africa* – based on EU data, adjusted for lower market efficiency
- *United States* – U.S. DOE program rulemaking documents

Equipment prices are determined using international studies for five types of equipment: general service lighting, split room air conditioners, televisions, fans, and motors. For countries for which cost data are not available, we use a regional proxy to develop a local cost curve that combines local UECs with the incremental cost of equipment. To extrapolate cost data to every country, we defined the following regional groupings based on trade flows and market similarities:

- North America: U.S., Canada, Mexico
- Europe: EU, Russia
- Southeast Asia: India, Indonesia
- Pacific Asia: Australia, Japan, Korea
- Africa: South Africa (proxies for South Africa differed by end use)

4.3 Market Share Weighting

For some countries, data were available regarding the distribution of efficiency, which allowed us to calculate the market-weighted average UEC and equipment price, yielding a *market weighted baseline*, which is generally more efficient than the technical baseline. For example, in the U.S. standards, studies for bottom- mount-freezer refrigerators (USDOE, 2011c) show that the technical baseline design is more than 700 kWh per year, but most of the market is around 600 kWh. Because the baseline market efficiency is different from the engineering analysis baseline, CCE is calculated relative to the market baseline.

In the MEPS scenario, the market shares are calculated by rolling up (or summing) the market shares of the levels below the MEPS to the MEPS level, while the market shares above the MEPS are unaffected. This simulates a MEPS which brings all of the inefficient part of the market to the new standard. For example, the level 2 UEC in table 3 is calculated with the baseline and level 1 market shares rolled up to level 2, and level 3 market shares are unaltered.. We then weight UEC and price based on these new shares. Finally, we calculate CCE for all the roll-up scenarios, and then evaluate the cost-effectiveness of those CCEs against the cost of energy.

Table 3. Baseline Adjustment

Energy-efficiency Level	UEC (kWh)	Market Shares						
		Base Case	Efficiency Level					
			1	2	3	4	5	6
Baseline	716	13%						
1	645	1%	12%					
2	609	19%	20%	32%				
3	573	67%	68%	68%	100%			
4	537	0%	0%	0%	0%	100%		
5	501	0%	0%	0%	0%	0%	100%	
6	457	0%	0%	0%	0%	0%	0%	100%
Sales-weighted UEC		597	589	585	573	537	501	457

When market efficiency distribution is not available, but there is a known single average value for the market (e.g., the entire market is at design option 3), then the baseline is shifted above the engineering baseline to the known average.

4.4 Appliance Group Data

Boilers

The U.S. boiler baseline has an 80-percent annual fuel utilization efficiency (AFUE). The efficiency options available from the U.S. technical support documents include electronic ignition, two-stage modulation, induced draft, and an improved heat-transfer coefficient The highest design level specified by the U.S. technical support document is 99-percent AFUE for gas boilers and 95-percent AFUE for oil boilers. Both are found to be cost effective and taken to be the target. The U.S. incremental price and efficiency curve is used for the EU and Canada, with an adjusted baseline. China's smaller gas boilers start with an 84-percent AFUE and graduate to a 96-percent target. Table 4 shows the baselines, targets, and CCE for boilers for Canada, China, the EU, and the U.S.

Table 4. Boilers

Country	Category	Baseline UEC (GJ/yr)	Baseline Price (USD)	Target UEC (GJ/yr)	Target Price (USD)	CCE (USD/GJ)	References / Assumptions
CAN	Gas	93	4,200	86	4,600	3.8	U.S. proxy, baseline from NRCAN, 2011
CHN	Gas	11	730	9	880	11	Retail price analysis 163.com, 2011
EU	Gas	44	4,200	40	5,100	16	U.S. proxy
	Oil	44	4,600	38	6,400	25	
USA	Gas	80	4,500	76	5,100	11	USDOE, 2008
	Oil	83	5,000	74	7,300	18	

Central Air Conditioners

Central air conditioners are most common in North America. Because of the large capacity and heavy usage of most central air conditioning systems, small percentage improvements in efficiency result in large reductions in energy use. The baselines and targets are a market-weighted average of split systems (coil as well as combined blower and coil) and packaged and heat pump systems, with seasonal energy-efficiency ratios (SEERs) ranging from 13 to 24.5. Table 5 shows the baseline, targets, and CCE for central air conditioners in Canada, Mexico, and the U.S.

Table 5. Central Air Conditioners

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
CAN	1,700	3,400	No CCE below tariff			U.S. Proxy
MEX	3,200	3,400	2,700	3,800	0.06	U.S. Proxy
USA	3,200	2,800	2,900	3,200	0.08	USDOE, 2011f

Cooking Equipment

Cooking equipment includes electric ranges and ovens. The engineering designs of these products tend to be simple, converting electricity directly to heat, and the U.S. technical analysis identifies relatively few design enhancements. As a result, savings are minimal. Chinese data are based on induction stoves sold on the market there; U.S. cooking equipment data, from engineering-based technical analyses, include cooktops and standard and self-cleaning ovens. Table 6 shows the baselines, targets, and CCE for electric cooking equipment in China and the U.S. Table 7 shows baselines, targets, and CCE for gas cooking equipment in the U.S.

Table 6. Electric Cooking Equipment

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
CHN	399	34	363	51	0.05	Retail Price Analysis Price.ea3w.com, 2011, and Appliance Database 国家能效标识网, 2008a
USA	153	277	152	278	0.07	USDOE, 2009

Table 7. Gas Cooking Equipment

Country	Baseline UEC (GJ/yr)	Baseline Price (USD)	Target UEC (GJ/yr)	Target Price (USD)	CCE (USD/GJ)	References / Assumptions
USA	0.9	480	0.7	500	6.0	USDOE, 2009

Dishwashers

Dishwashers and clothes dryers are not as commonly included in national efficiency programs as other major appliances. Therefore, efficiency and cost data are sparse. Dishwasher data were available for the EU only. Table 8 shows the baselines, targets, and CCE for dishwashers in the EU.

Table 8. Dishwashers

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
EU	290	780	No CCE below tariff			EC, 2007d

Dryers

U.S. technical support documents evaluate both standard and compact dryers. Analyzed design options are limited to standby modes improvement and heat pumps (most efficient technology level). We omitted gas dryers because there were no cost-effective targets for these products. In the EU, heat-pump dryers with improved insulation are the most efficient and cost-effective products. Table 9 shows the baselines, targets, and CCE for electric dryers in the EU and U.S.

Table 9. Electric Dryers

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
EU	540	660	490	780	0.21	EC, 2009a
USA	700	460	680	470	0.04	USDOE, 2011e

Ceiling Fans

Raw data on fan component costs in the U.S. and India were taken from Sathaye, Phadke et al. (2011). For other countries, we divided the world into developed countries (for which we used U.S. prices as a proxy) and developing countries (for which we used Indian prices as a proxy). We assumed a manufacturer mark-up of 200-percent and a four-blade fan design. The baseline price is not available; therefore, we calculated the CCE using the incremental costs of the design options, not the unit prices. The three design options we evaluated are:

1. Improved fan blades (13-percent improvement).
2. Improved fan blades and materials with higher-efficiency induction motor (27-percent improvement).
3. Improved fan blades and induction motor replaced with brushless direct current (DC) motor (54-percent improvement).

Table 10 shows the baselines, targets, and CCE for ceiling fans.

Table 10. Ceiling Fans

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Incremental Target Price (USD)	CCE (USD/kWh)	References / Assumptions
AUS	21	N/A *	No CCE below tariff			Sathaye et al., 2012) w/ U.S. proxy
BRA	88	N/A	41	17	0.08	Sathaye et al., 2012 w/ India proxy
CAN	11	N/A	No CCE below tariff			Sathaye et al., 2012) w/ U.S. proxy
CHN	100	N/A	47	17	0.04	Sathaye et al., 2012 w/ India proxy
EU	11	N/A	No CCE below tariff			Sathaye et al., 2012) w/ U.S. proxy
IND	100	N/A	47	17	0.06	Sathaye et al., 2012
IDN	150	N/A	69	17	0.03	Sathaye et al., 2012 w/ India proxy
JAP	21	N/A	No CCE below tariff			Sathaye et al., 2012) w/ U.S. proxy
KOR	21	N/A	No CCE below tariff			
MEX	88	N/A	No CCE below tariff			
RUS	11	N/A	No CCE below tariff			
ZAF	88	N/A	41	17	0.05	Sathaye et al., 2012 w/ India proxy
USA	78	N/A	36	29	0.09	Sathaye et al., 2012

* Target prices are based on incremental costs; baseline prices are not available.

Freezers

Our evaluation of freezers includes upright and chest freezers for both the U.S. and the EU. The U.S. targets are near the most efficient design option, with upright freezers 40-percent below the baseline energy consumption, and chest freezers 35-percent below. For the EU, the most efficient option is cost effective and represents the EU's A++ efficiency designation. Table 11 shows the baselines, targets, and CCE for freezers.

Table 11. Freezers

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
EU	200	770	190	790	0.21	EC, 2007c
USA	520	490	330	690	0.08	USDOE, 2011b

Furnaces

The baseline for furnaces is 80-percent AFUE, and efficiency improvement potential as high as 98-percent AFUE. The U.S. targets identified were near the high end, around 95-percent AFUE. Table 12 shows the baselines, targets, and CCE for furnaces.

Table 12. Furnaces

Country	Category	Baseline UEC (GJ/yr)	Baseline Price (USD)	Target UEC (GJ/yr)	Target Price (USD)	CCE (USD/GJ)	References / Assumptions
CAN	Gas	81	1,500	69	2,500	5.5	U.S. Proxy
USA	Non-Weatherized Gas Furnace	37	2,200	32	3,000	12	USDOE, 2011f
	Mobile Home Gas Furnace	46	1,500	40	2,300	12	
	Oil-fired Furnace	70	3,300	60	4,900	11	

General Service Lighting

For lighting, we used detailed cost data from the websites 1000bulbs.com, elightbulbs.com, and bulbs.com (Gerke, 2012).[2] We analyzed price data for 60-watt incandescent bulbs, excluding non-standard items such as neodymium bulbs, glass coloring or coatings, and specialty bulbs with a cost greater than 5 USD. CFL price data were selected for 13- to 15-watts bulbs and LED data for products from 6 to 8 watts. These ranges were selected so that the median price we calculated would be representative of the incandescent bulbs one typically founds in households. The price data were matched to the BUENAS UECs, which assign different annual usage hours for different countries. Prices are assumed to be constant, and three technologies are considered: incandescent, CFL, and LED. These technologies have different lifetimes, so their prices were annualized with different capital recovery factors (q), according to Equation 2.

Because we expect a gradual transition away from incandescent bulbs, we model the cost effectiveness of general service lighting using the NPV metric of the market average in the efficiency case versus the business-as-usual case. NPV is calculated for each country's transition to CFLs; if the result is positive, then the transition is cost effective. LED technology was not found to be cost effective relative to CFLs; therefore, LED market shares are the same in both the CEP and business-as-usual scenarios. Table 13 shows the baselines, targets, and CCE for lighting.

[2] Using cost data available as of February 9th 2012. Elightbulbs.com was excluded from the CFL analysis because many of their prices are 5 times higher than those of any other retailer, for reasons currently unknown.

Table 13. Lighting

Country	Base-line	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/ kWh)	Target	References / Assumptions
AUS	IL*	47	1.2	15	6.8	0.01	CFL	Gerke, 2012 and assume baseline same as U.S.
BRA	IL	88	1.2	22	6.8	0.01	CFL	Gerke, 2012 and assume baseline 60W for 4 hours per day
CAN	IL	47	1.2	15	6.8	0.01	CFL	Assume same as U.S.
CHN	IL	50	1.2	13	6.8	0.01	CFL	Gerke, 2012 and assume baseline 60W for 2.3 hours per day
EU	IL	22	1.2	14	6.8	0.03	CFL	Gerke, 2012 and baseline 54W for 1.1 hours per day EC, 2009b
IND	IL	88	1.2	22	6.8	0.01	CFL	Gerke, 2012 and assume baseline 60W for 4 hours per day
IDN	IL	88	1.2	22	6.8	0.01	CFL	
JAP	IL	22	1.2	13	6.8	0.04	CFL	Assume same as EU
KOR	IL	22	1.2	13	6.8	0.04	CFL	
MEX	IL	50	1.2	13	6.8	0.01	CFL	Gerke, 2012 and assume baseline 60W for 2.3 hours per day
RUS	IL	88	1.2	22	6.8	0.01	CFL	Gerke, 2012 and assume baseline 60W for 4 hours per day
ZAF	IL	88	1.2	22	6.8	0.01	CFL	Gerke, 2012 and assume baseline 60W for 4 hours per day
USA	IL	47	1.2	15	6.8	0.01	CFL	Gerke, 2012 and baseline 67 W 1.9 hours per day

* IL = incandescent lamp

Fluorescent Tube Lighting

We evaluate tubular fluorescent ballasts and lighting separately from CFL and incandescent technology because tubular fluorescents require a different fixture and thus are not considered replacements for those technologies. In India, fluorescent lighting accounts for approximately 43-percent of residential-sector lighting (Prayas Energy Group). In China, a recent study (McNeil et al., 2011a) assumes that fluorescent tube lights account for 20-percent of lighting fixtures in residences. In both countries, we assume that residential lighting is turned on for four hours per day. In China, the baseline for a magnetic ballast system is estimated at 38.6W and for a high-efficiency electronic ballast system at 33.6W. In India, the baseline fluorescent ballast is taken to be a 40W T12 lamp coupled with a magnetic ballast and is estimated at 46W total (McNeil et al., 2011b). For a high-efficiency option, we consider a high-performance T8 lamp with an electronic ballast, estimated at 41W. Table 14 shows the baselines, targets, and CCE for fluorescent lighting.

Table 14. Fluorescent Lighting

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Incremental Target Price (USD)	CCE (USD/kWh)	References / Assumptions
CHN	56	N/A*	49	4.4	0.06	McNeil et al., 2011a
IND	67	N/A	60	3.5	0.06	McNeil et al., 2011b

* Target prices are based on incremental costs; baseline prices not available.

Refrigerators

Refrigerators are among the appliances most frequently targeted by efficiency standards and policies. So, although newer national policy regimes can achieve significant savings through refrigerator efficiency improvements, in countries that have older, more developed efficiency programs, refrigerators are no longer the lowest-hanging fruit. Because of the variation in the extent to which refrigerator efficiency has already been addressed by policies in different countries, our modeling of the effect of refrigerator efficiency standards produced the widest range of results. Potential improvements range from only 4-percent for the EU up to 71-percent for South Africa (see Table 28). In the EU, 70-percent of the refrigerator market is already made up of products that consume relatively little energy, so the additional savings potential is small. Table 15 shows the baselines, targets, and CCE for refrigerators.

Table 15. Refrigerators

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/ kWh)	References / Assumptions
AUS	700	1,300	430	1,700	0.16	Retail Price Analysis
BRA	360	390	220	510	0.11	Jannuzzi, 2002
CAN	560	390	460	710	0.07	U.S. Proxy
CHN	550	320	290	440	0.05	Retail Price Analysis Price.ea3w.com, 2011 and Appliance Database 国家能效标识网, 2008b
EU	240	830	200	920	0.22	EC, 2008
IND	470	N/A*	330	29	0.03	Estimates for refrigerator improvement potential based on India's current Building Energy Efficiency labeling scheme. Market shares from Tathagat and Anand, 2011.
IDN	470	N/A*	330	29	0.03	India Proxy
JAP	370	1,400	320	1,500	0.23	Retail Price Analysis
KOR	690	510	440	700	0.07	
MEX	370	500	310	510	0.03	U.S. Proxy
RUS	540	320	No CCE below tariff			Eastern Europe Proxy (GfK, 2004)
ZAF	540	320	160	540	0.08	
USA	560	630	460	710	0.07	USDOE, 2011b

* Target prices are based on incremental costs; baseline prices not available.

Room Air Conditioners

Room air conditioners are separated into window units and split units. Split units are divided into cooling-only systems and reversible units that also provide heat during the cold season. Window units are becoming less common worldwide but are still used in India, Mexico, the United States, and in Canada to a lesser extent. The engineering analysis for split systems was taken from (Shah et al., 2012). Data were compiled into efficiency range bins to reflect the average cost of improvements as a function of efficiency. South Africa data were not available in the engineering analysis, so Indian prices and Australian UECs were used as a best approximation of use, technology, and cost. Tables 16, 17, and 18 show the baselines, targets, and CCE for room air conditioners, reversible split, and cooling only split air conditioners, respectively.

Table 16. Room Air Conditioners – Window

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
CAN	130	480	No CCE below tariff			U.S. Proxy
IND	1,900	400	1,600	500	0.05	Tathagat and Anand, 2011
MEX	3,000	490	2,500	610	0.02	U.S. Proxy
USA	530	470	470	490	0.08	USDOE, 2011d

Table 17. Room Air Conditioners – Reversible Split

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
AUS	1,500*	580	730	1,400	0.13	Shah et al., 2012
CAN	2,000	650	1200	1,200	0.08	
CHN	690	510	560	670	0.14	
EU	1,500	700	740	1,400	0.08	
JAP	1,200	770	800	1,400	0.16	
KOR	2,300	530	1300	1,200	0.08	
MEX	2,000	430	760	1,300	0.07	
RUS	860	490	490	600	0.03	

* Technical baseline for Australia because no market data was available at the time of the study.

Table 18. Room Air Conditioners – Cooling Only Split

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
AUS	270	580	No CCE below tariff			Shah et al., 2012.
BRA	710	480	430	810	0.18	Shah et al., 2012
CAN	140	650	No CCE below tariff			
CHN	310	510	No CCE below tariff			
IND	1,400	450	880	720	0.07	
IDN	1,400	450	1,000	600	0.05	India Proxy
KOR	490	810	420	900	0.14	Shah et al., 2012
MEX	1,400	430	640	890	0.07	

Standby Power

Standby power is one of the newest end uses to be addressed by efficiency programs. Unlike the other appliance groups analyzed here, it is not an independent product but a component of electronic products. Standby power efficiency can be improved by several means. Marginal improvement can be achieved by enhancing the power supply unit that feeds electricity to the product. This is the most cost-effective option for Russia, India, South Africa, and Indonesia. Another level of improvement can come from changing the standby electricity consumption profile of the electronics themselves, resulting in microchip systems requiring less power during standby. Canada, Mexico, and the U.S. achieve the best available efficiency through design improvements of this type. The last level of improvement we consider is making power mode transitions more efficient; this improvement adds to the previously described electricity consumption profile improvement type by changing the programming which that controls the transition between power modes. This is a cost-effective improvement for Australia, Brazil, China, the EU, Japan, and Korea.

The energy consumption and cost data necessary to evaluate standby power efficiency improvements come from the European Commission (EC) Lot 6 standby study (EC, 2007b). We assume that the changes in consumption and costs are the same for all countries, so cost effectiveness is differentiated by each country's unique consumer discount rates and tariffs. The EC study also included user behavior enhancements, such as implementing a "hard off" switch that allows the user to turn off a unit completely so that it does not go into standby mode. Because the policies we model do not affect behavior, we did not consider these options. Table 19 shows the baselines, targets, and CCE for standby power.

Table 19. Standby Power

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Incremental Target Price (USD)	CCE (USD/kWh)	References / Assumptions
AUS	18	N/A*	4	12	0.14	EC, 2007b
BRA	18	N/A	4	12	0.15	
CAN	18	N/A	5.5	5.8	0.07	
CHN	18	N/A	4	12	0.13	
EU	18	N/A	4	12	0.11	
IND	18	N/A	15	0.3	0.02	
IDN	18	N/A	15	0.3	0.02	
JAP	18	N/A	4	12	0.12	
KOR	18	N/A	4	12	0.12	
MEX	18	N/A	5.5	5.8	0.07	
RUS	18	N/A	15	0.3	0.01	
ZAF	18	N/A	15	0.3	0.02	
USA	18	N/A	5.5	5.8	0.07	

Televisions

We took cost-efficiency data for televisions from (Park et al., 2011). All television markets are predicted to be almost entirely composed of LED backlit Liquid Crystal Displays (LCDs) by the year 2015. Cold-cathode fluorescent lamp (CCFL) technology remains in almost all markets, but only up to 4% of the market. Organic LED (OLED) are forecast to enter all markets by 2015 but only marginally (the EU has the highest market share at 2%). To compare different types of TVs on the same basis, we assumed that all TVs are the same screen size as the baseline LED-backlit LCDs and we have corrected prices accordingly. India data serve as a proxy for Indonesia. TV technologies evaluated in Park et al. (2011) are listed below.

- CCFL
- CCFL with Dual Brightness Enhancement Film (DBEF)
- LED-backlit LCD
- LED-backlit + DBEF
- LED-backlit + DBEF + Screen Dimming
- OLED

LED technology with DBEF and dimming is found to be cost effective in over half of the countries. In Canada, Mexico and South Africa, CCFL+DBEF targets are found to be cost-effective whereas no options are found to be cost-effective in India, Indonesia, and Russia. Even though, the cost of OLEDs is forecast to drop sharply in the next few years, they are still not cost effective by 2015.

Table 20 shows the baselines, targets, and CCE for televisions.

Table 20. Televisions

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	Target	References
AUS	61	290	38	310	0.08	LED + DBEF+ Dimming	Park et al., 2011
BRA	40	300	25	320	0.14	LED + DBEF+ Dimming	
CAN	64	510	63	510	0.05	CCFL + DBEF	
CHN	47	380	30	400	0.12	LED + DBEF+ Dimming	
EU	41	370	27	380	0.10	LED + DBEF+ Dimming	
IND	33	290	No CCE below tariff				
IDN	33	290	No CCE below tariff				
JAP	41	340	26	350	0.10	LED + DBEF+ Dimming	
KOR	56	290	35	300	0.08	LED + DBEF+ Dimming	
MEX	40	300	39	300	0.05	CCFL + DBEF	
RUS	43	360	No CCE below tariff				
ZAF	40	300	39	300	0.07	CCFL + DBEF	
USA	71	510	45	530	0.10	LED + DBEF+ Dimming	

Washing Machines

The EU clothes washer target includes an optimized mechanical action, improvements to multiple sensors, and an optimized rinse phase. The optimized mechanical action had the largest effect on the UEC while remaining cost effective. The Chinese baseline model is the 5th grade of the 2004 Chinese clothes washer energy-efficiency specifications, and the cost-effective target is the 1st grade, which is a 54-percent improvement in UEC. Table 21 shows the baselines, targets, and CCE for washing machines.

Table 21. Washing Machines

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
EU	210	640	200	640	0.01	EC, 2007d
CHN	180	220	97	290	0.09	Retail Price Analysis Price.ea3w.com, 2011 and Zhou et al., 2011

Water Heaters

Water heaters, along with other heating appliances (furnaces and boilers), are long-term residential investments with high initial cost. Larger-percentage savings are identified for electric systems for which heat pump water heaters are found to be cost effective for the U.S. and the EU. Tables 22 and 23 show the baselines, targets, and CCE for fuel and electric water heaters, respectively.

Table 22. Fuel Water Heaters

Country	Category	Baseline UEC (GJ/yr)	Baseline Price (USD)	Target UEC (GJ/yr)	Target Price (USD)	CCE (USD/GJ)	References / Assumptions
CAN	Gas	17.0	1,100	15.0	1,300	9.5	U.S. Proxy
CHN	Gas	5.1	240	1.5	440	5.8	Retail Price Analysis Price.ea3w.com, 2011, and Appliance Database 国家能效标识网, 2006
EU	Gas	12.0	1,100	8.6	1,600	10	U.S. Proxy
	Gas Instantaneous	17.0	1,800	8.8	1,830	8.6	
USA	Gas	17.0	1,200	13	1,600	11	USDOE, 2010b
	Gas Instantaneous	11.0	2,600	11	2,630	7.9	

Table 23. Electric Water Heaters

Country	Category	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
CHN	Electric	620	200	370	410	0.08	Price.ea3w.com, 2011 and 国家能效标识网, 2006
EU	Electric	2,200	580	830	1,600	0.05	U.S. Proxy
USA	Electric	2,500	660	1,200	1,700	0.09	USDOE, 2010b

Distribution Transformers

Distribution transformers, which reduce the primary voltage of the electricity distribution system to the voltage that serves customers, have long life spans and have only recently been scrutinized by efficiency programs. Increased international electrification and retirement of earlier generations of transformers offer new opportunities for electricity savings in distribution transformers. We analyze Chinese and Indian dry-type distribution transformers with capacities from 25 to 200 kilovolt amperes (kVA). For the U.S. and Canada, we evaluate both dry and liquid transformers with rated capacities from 25 to 1,500 kVA. For the U.S., many of the targets identified within a product class are not very close to the maximum technology design level, but even mid-range savings can result in large long-term savings because the transformer is always on. The EU scenario includes both dry and liquid transformers from 400 kVA to 100 megavolt amperes. Table 24 shows the baselines, targets, and CCE for distribution transformers.

Table 24. Distribution Transformers

Country	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References / Assumptions
CAN	2,500	5,400	1,400	6,200	0.06	U.S. Proxy
CHN	11,000	2,300	2,000	4,200	0.26	Retail Price Analysis Detail.china.alibaba.com, 2011 and Appliance Database 国家能效标识网, 2009
IND	2,700	1,600	1,100	2,100	0.04	Star rating defined by the Bureau of Energy Efficiency BEE and McNeil et al., 2008a
USA	2,500	5,400	1,400	6,200	0.06	USDOE, 2011a
EU	17,000	23,000	10,000	34,000	0.12	EC, 2010

Electric Motors

We identified more than 400 unique motor models from the MotorMaster+ software version 4.01.01(USDOE, 2010a) and grouped them into three distinct bins according to capacity rating, looking specifically at the levels of National Electrical Manufacturers Association (NEMA) Premium, Energy Policy Act (EPACT) , and pre-EPACT motors. Prices for NEMA and EPACT come directly from MotorMaster+ version 4, and pre-EPACT prices come from a 2003 version of the MotorMaster+ database (USDOE, 2003). We determined the current price of pre-EPACT motors by adjusting the 2003 prices using the ratio of current EPACT prices to those in the 2003 database. The baseline price for each country is a weighted average of the three motors, according to the market shares in the country. Using the national average efficiency for each country from BUENAS, and the UECs for the EU, we derived the UECs for all countries. The majority of EU, Indian, Japanese, Korean, South African, Indonesian, and Russian motors are at pre-EPACT levels. The remaining countries are known to have standards that are assumed to have forced national markets to consist predominantly of EPACT motors. Table 25 shows the baselines, targets, and CCE for electric motors.

Table 25. Electric Motors

Country	Category (kW)	Baseline UEC (kWh/yr)	Baseline Price (USD)	Target UEC (kWh/yr)	Target Price (USD)	CCE (USD/kWh)	References
AUS	0.75-7.5	1,400	160	1,300	180	0.04	USDOE, 2010a, McNeil et al., 2011a, Brunner, 2006, and de Ameida et al., 2008
	7.5-75	19,000	1,600	19,000	1,800	0.05	
	> 75	390,000	16,000	390,000	18,000	0.04	
BRA	0.75-7.5	1,400	160	1,300	180	0.05	
	7.5-75	19,000	1,600	19,000	1,800	0.07	
	> 75	390,000	16,000	390,000	18,000	0.06	
CAN	0.75-7.5	1,400	160	1,300	180	0.04	
	7.5-75	19,000	1,600	19,000	1,800	0.05	
	> 75	390,000	16,000	390,000	18,000	0.04	
CHN	0.75-7.5	1,500	130	1,300	180	0.04	
	7.5-75	20,000	1,100	19,000	1,800	0.09	
	> 75	400,000	11,000	390,000	18,000	0.10	
EU	0.75-7.5	1,500	130	1,300	180	0.03	
	7.5-75	20,000	1,100	19,000	1,800	0.07	
	> 75	400,000	12,000	390,000	18,000	0.08	
IND	0.75-7.5	1,500	130	1,300	180	0.04	
	7.5-75	20,000	1,100	No CCE below tariff			
	> 75	400,000	11,000	No CCE below tariff			
IDN	0.75-7.5	1,500	130	1,300	180	0.04	
	7.5-75	20,000	1,100	19,000	1,800	0.10	
	> 75	400,000	11,000	No CCE below tariff			
JAP	0.75-7.5	1,500	130	1,300	180	0.04	
	7.5-75	20,000	1,100	19,000	1,800	0.08	
	> 75	400,000	11,000	390,000	18,000	0.09	
KOR	0.75-7.5	1,500	130	1,300	180	0.04	
	7.5-75	20,000	1,100	19,000	1,800	0.08	
	> 75	400,000	11,000	390,000	18,000	0.09	
MEX	0.75-7.5	1,400	160	1300	180	0.03	
	7.5-75	19,000	1,600	19,000	1,800	0.05	
	> 75	390,000	16,000	390,000	18,000	0.04	
RUS	0.75-7.5	1,500	130	1300	180	0.04	
	7.5-75	20,000	1,100	No CCE below tariff			
	> 75	400,000	11,000	No CCE below tariff			
ZAF	0.75-7.5	1,500	130	1,300	180	0.05	
	7.5-75	20,000	1,100	No CCE below tariff			
	> 75	400,000	11,000	No CCE below tariff			
USA	0.75-7.5	1,400	160	1,300	180	0.04	
	7.5-75	19,000	1,600	19,000	1,800	0.05	
	> 75	390,000	16,000	390,000	18,000	0.04	

4.5 Lifetime Assumptions

The number of years during which an end-use product is functional, known as its lifetime, influences the cost effectiveness of a design option. Longer lifetimes imply greater total operating cost savings, which are more likely to offset incremental equipment costs. For the U.S. analyses, we used the values from U.S. DOE TSDs . In the residential sector, most of the TSDs refer to the comprehensive study on appliance lifetime from Lutz et al. (Lutz et al., 2011). EU analyses use lifetimes are from Ecodesign documents. For room air conditioners (split), fans, televisions and motors, we use lifetimes from international analyses. For lighting, we assume that incandescent bulbs have a one-year lifetime, CFLs five years, and LEDs 10 years. Where we use regional proxies, we take lifetimes from the proxy country; for example, the U.S. is the proxy country for Mexico and Canada. The end use lifetimes for China and India are based on the literature found for those countries. Specific references are available in tables 4 to 25. Table 26 shows appliance lifetimes in years.

Table 26. Appliance Lifetimes (Years)

End Use / Country	AUS	CHN	EU	IND/ IDN	JAP/ KOR/ RUS	MEX/ BRA/ ZAF	USA/ CAN
Boilers		17	15				30
Central Air Conditioners						19	19
Cooking Equipment		15					13
Dishwashers			15				
Dryers			13				16
Fans	10	10	10	10	10	10	10
Freezers			15				23
Furnaces							24
Incandescent Lighting	1	1	1	1	1	1	1
CFLs	5	5	5	5	5	5	5
LEDs	10	10	10	10	10	10	10
Fluorescent Tube Lighting		15		15			
Refrigerators	16	15	15	15	15	15	17
RAC – Split type	12	12	12	12	12	12	12
RAC – Window type				15		10	10
Standby	8	8	8	8	8	8	8
Televisions	8	8	8	8	8	8	8
Washing Machines		15	15				
Water Heaters		15	18				13
Distribution Transformers		30	27	22			32
Electric Motors - 0.75-7.5 kW	12	12	12	12	12	12	12
Electric Motors - 7.5-75 kW	15	15	15	15	15	15	15
Electric Motors - > 75 kW	20	20	20	20	20	20	20

4.6 National Economic Parameters

The lowest electricity tariff among the countries in this analysis is in Russia; this significantly lower tariff makes very few design options cost effective in that country. Two other notable outliers are Japan's high residential electricity tariff and the EU's low discount rate; both have the effect of making more cost-effective targets available. Table 27 shows the economic parameters used in calculating the CCE.

Table 27. Economic Parameters for CCE Calculation

	Electricity Price		Natural Gas Price	Source	Consumer Discount Rate	Source
	RES	IND	RES			
	$/kWh	$/kWh	$/GJ		%	
AUS	0.17	0.09	N/A	Shah et al., 2012	7.5	Strategies, 2008
BRA	0.19	0.17	N/A	Shah et al., 2012	10.0	Assumption
CAN	0 .08	0.08	10.62	Shah et al., 2012, NRCAN, 2012	5.0	Assumption
CHN	0 .15	0.17	17.5	Beijing Electric Power Corporation, 2011	5.6	BV, 2011
EU	0.23	0.14	20.1 (25.8 Fuel Oil)	Eurostat nrg_pc_202 to 205 Eurostat, 2011 and EC, 2007a	1.8	Ecodesign Studies
IDN	0.06	0.12	N/A	PricewaterhouseCoopers, 2011	10.0	Assumption
IND	0.08	0.10	N/A	Central Electricity Authority, 2007	10.0	McNeil et al., 2008a
JAP	0.23	0.23	N/A	Shah et al., 2012, industrial tariff assumed same as residential	5.0	Assumption
KOR	0.15	0.15	N/A		5.0	
MEX	0.08	0.08	N/A	Federal Commission of Electricity	3.8	Banamex and Citigroup
RUS	0.04	0.04	N/A	Industrial tariffs assumed for all sector	5.0	Assumption
USA	0.11	0.10	12.3 (19.3 Fuel Oil)	EIA, 2010 Scenario Table 3	5.0	USDOE, 2011c
ZAF	0.08	0.07	N/A	Shah et al., 2012	10.0	Assumption

Note: When discount rates are unknown or uncertain, we assume 5 percent for more developed countries and 10 percent for others.

4.7 Summary of Cost-effective Improvements

Lighting and standby power offer the highest per-unit percentage improvement in this analysis, and motors showed the lowest percent improvement. Although motor efficiency improvements are small in percentage terms, they are typically used for a large number of hours annually, so even modest improvements can result in significant energy savings.

Table 28 shows 0 percent improvement for instances in which we were not able to identify a cost-effective potential. A gray cell indicates that no data were available to perform the cost-benefit analysis for the particular end use and country.

Table 28. Cost-Effective Improvements: Percentages by End Use and Country

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	USA	ZAF
Boilers			8%	15%	9%							6%	
Central Air Conditioners			0%							16%		10%	
Cooking Equipment				9%	0%							6%	
Dryers					9%							3%	
Fans	0%	54%	0%	54%	0%	54%	54%	0%	0%	0%	0%	54%	54%
Freezers					4%							36%	
Furnaces			15%									13%	
Lighting*	67%	75%	67%	75%	75%	75%	75%	75%	75%	75%	75%	75%	67%
Fluorescent Lighting				13%		11%							
Refrigerators	38%	40%	18%	47%	14%	29%	29%	15%	70%	15%	0%	18%	71%
Room Air Conditioners - Split Heat Pump	53%		41%	19%	51%			34%	42%	62%	44%		
Room Air Conditioners - Split Cooling	0%	39%	0%	0%		38%	29%		14%	53%			
Room Air Conditioners - Window			0%			17%				16%		11%	
Standby	78%	78%	70%	78%	78%	17%	17%	78%	70%	70%	17%	70%	17%
Televisions	38%	38%	0%	37%	36%	0%	0%	36%	38%	1%	0%	36%	1%
Washing Machines				46%	3%								
Water Heaters			11%	20%	41%							36%	
Distribution Transformers **			46%	82%	41%	59%						46%	
Electric Motors**	4%	4%	3%	10%	10%	11%	11%	11%	11%	3%	10%	3%	10%

*Lighting percentage improvement is based on an incandescent baseline.
**All end uses are from the residential sector with the exception of transformers and motors, which are from the industrial sector.

5 National Impacts Analysis

In BUENAS, the National Impacts Analysis (NIA) forecasts final NES by comparing the total energy of the equipment stock in the CEP scenario against the BAU scenario. The NIA also evaluates the net financial impacts of MEPS on consumers as a result of increased equipment prices and reduced energy bills. The financial impacts of a program are expressed as NPV. Finally, the NIA evaluates the annual carbon emissions reduction potential of the CEP scenario. The CEP scenario is defined as a set of MEPS that mandates, starting in the year 2015, the targets defined in Section 4.

5.1 National Energy Savings

BUENAS uses the sales forecast as described in McNeil, Letschert et. al. (2011) as an input to calculate the energy consumption of the appliance stock in a given country according to base case (market-driven) efficiency improvements, changes in the market-share of efficiencies as a result of MEPS, and turnover of the equipment.

The baselines and targets determined using the GEEC database are estimated in the year of the standard and therefore are static. By using these targets in combination with the time series in BUENAS, we are assuming that:

- Market-driven improvements in efficiency do not affect the price of equipment.
- The incremental price of efficiency remains the same, no matter what the baseline.

Once the time series of UECs in the BAU and CEP scenarios are determined, BUENAS calculates NES ($\Delta E(y)$) for each year by comparing the national final energy consumption $E(y)$ of the end use under study in the BAU to that in the CEP case, as follows:

$$\Delta \boldsymbol{E}(\boldsymbol{y}) = \boldsymbol{E}_{\boldsymbol{BAU}}(\boldsymbol{y}) - \boldsymbol{E}_{\boldsymbol{CEP}}(\boldsymbol{y}) \quad \textbf{Equation 3}$$

BUENAS calculates final energy demand according to the UEC of equipment sold in previous years:

$$\boldsymbol{E}_{\boldsymbol{BAU}} = \sum_{\boldsymbol{age}} \boldsymbol{Sales}(\boldsymbol{y} - \boldsymbol{age}) \times \boldsymbol{UEC}_{\boldsymbol{BAU}}(\boldsymbol{y} - \boldsymbol{age}) \times \boldsymbol{Surv}(\boldsymbol{age}) \quad \textbf{Equation 4}$$

where:

Sales (y) = unit sales (shipments) in year *y*
UEC(y) = unit energy consumption of units sold in year *y*
Surv(age) = probability of surviving to *age* years

Annual NES values resulting from a set of MEPS targeting maximum cost-effective technologies are presented in Tables 29 (in year 2020) and 30 (in year 2030). Savings from fuel and oil are converted into kWh.

Table 29. Annual National Energy Savings in TWh (2020)

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	ZAF	USA	Total
Boilers			2.08	23	51								4	80
Central AC										0.04			20	20
Cooking Products				2									1	3
Dryers					2								1	3
Fans		3		26		22	3			0.88		0.38	8	63
Freezers					2								1	4
Furnaces													26	26
Lighting	0.4	19	3.96	35	20	14	7			7.04	18	3.06		126
Refrigerators	1.7	6	1.49	29	4	3	3	0.4	2	0.27		2.09	12	66
Room AC*		8				25	3		1	2.97			2	42
Heat Pumps*	2.4		0.22	11	14			27.7	1	0.63	3			59
Televisions	0.4	1	0.01	6	5			0.7	1	0.02		0.01	7	21
Washing Machines				23	1									24
Stand by	0.9	4	1.25	30	34	3	1	4.3	5	1.74	1	0.14	23	108
Water Heaters			2.30	70	114								73	259
Residential	5.7	42	11.30	256	247	67	15	33.0	9	13.60	21	5.68	178	905
Transformers			0.26	4	13	4							7	28
Electric Motors	0.5	2	0.70	40	15	5	3	5.8	3	0.60	3	0.50	5	85
Industry	0.5	2	0.96	44	28	8	3	5.8	3	0.60	3	0.50	13	112
Total	6.2	44	12.30	300	275	76	18	38.8	13	14.20	24	6.18	191	1,020

*The commercial sector has been removed from the original study(Shah et al., 2012).

Table 30. Annual National Energy Savings in TWh (2030)

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	USA	ZAF	Total
Boilers			5.38	73	120								10	210
Central AC										0.1			48	48
Cooking Products				8									3	11
Dryers					4								2	7
Fans		7		51		45	5			1.7		0.70	16	130
Freezers					6								4	10
Furnaces													69	69
Lighting				8										8
Refrigerators	4	17	3.77	73	9	11	8	1	6	0.7		5.13	31	170
Room ACs		23				82	8		1	9.2			4	130
Heat Pumps	6		0.87	24	36			61	2	2.2	7			140
Televisions	1	3	0.02	12	10			1	2	0.03		0.01	13	42
Washing Machines				46	2									49
Stand by	2	8	2.11	63	57	6	1	7	8	3.1	1	0.25	41	200
Water Heaters			4.92	130	290								150	570
Residential	12	57	17.10	490	540	140	23	69	19	16.9	8	6.09	390	1800
Transformers			0.71	10	44	13							20	86
Electric Motors	1	5	1.60	93	34	14	8	13	9	1.7	8	1.20	14	200
Industry	1	5	2.31	100	78	26	8	13	9	1.7	8	1.20	33	290
Total	14	62	19.40	590	610	170	30	83	28	19.0	16	7.29	420	2,100

A few key results:

- Water heating is the end use from which the most savings can be achieved by 2030. Heat-pump water heaters, which represent a large technological improvement compared to the baseline, are found to be cost effective in the U.S. and the EU. Heat-pump water heaters have a high cost premium but save significant energy, which is why this end use has the greatest potential of all.

- The EU and China are the countries where the most cost-effective savings are possible. Both have very high savings potential for boilers and water heaters.

- Savings from lighting are maximized in 2015 and dropping to 0 by 2030 because the BAU scenario assumes a gradual phase-out of incandescent bulbs by 2030[3]. Cumulative 2015-2030 savings are presented for lighting (Table 33).

- In the industrial sector, almost half of the potential savings for motors are in China because of the intensive use of motors in that country.

- Cost data are more readily available for larger economies (because of existing MEPS programs based on engineering analysis and LBNL retail price data collection research). There is a strong correlation between countries that have cost data available and the largest savings potentials. As one might expect, China, U.S. and the EU have the highest cost-effective potential. Together, they represent 85 percent of total cost-effective potential.

[3] With the exception of China, where the switch from electromagnetic (baseline technology) to electronic ballast is expected to provide savings until 2030.

5.2 National Financial Impacts

NPV is calculated according to total incremental costs of equipment over a given forecast period, electricity bill dollars saved, and the national discount rate.

National financial impacts in year *y* are the sum of equipment first costs (1) and operating costs (2).

- **(1) NEC** is equal to the retail price (or Equipment Cost, *EC*) times the total number of sales.

NEC is given by:

$$\text{NEC(y)} = EC(\text{y}) \times Sales(y) \quad \textbf{Equation 5}$$

- **(2) National Operating Cost (NOC)** is the total (site) energy consumption (*E*) times the energy price (*P*).

NOC is given by:

$$\text{NOC(y)} = E(\text{y}) \times P(y) \qquad \textbf{Equation 6}$$

The net savings in each year arises from the difference in first and operating costs in the efficiency scenario versus the BAU scenario, ΔNEC and ΔNOC.

We define the NPV of a policy as the sum over a given period of time of the net national savings in each year, multiplied by the appropriate national policy discount factor:

$$NPV = \sum_{y=y_0} \frac{\Delta NOC(\text{y}) - \Delta NEC(y)}{(1+DR_N)^{(y-y_0)}} \qquad \textbf{Equation 7}$$

where
y_0 = the current year
DR_N = the national discount rate

Table 31 shows the discount rates for SEAD countries.

Table 31. National Discount Rates for all SEAD Countries

	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	USA	ZAF
National Discount Rate	3%	10%	3%	10%	2%	10%	10%	3%	3%	4.5%	3%	3%	10%

Source: National discount rates are estimates from official sources for the U.S. (U.S. DOE), the EU (Ecodesign), and Mexico (CONUEE). When discount rates are not available, we assume 10 percent for developing countries and 3 percent for developed countries.

In the BAU and CEP scenarios, we calculate the NEC of the sales of new appliances entering the national stock between the year the MEPS is implemented and the year 2030. The NOC savings from appliances sold between 2015 and 2030 are calculated beyond 2030 because those appliances continue to produce savings over their lifetimes. LEAP[4] (Heaps, 2012) calculates the financial impacts, ΔNEC and ΔNOC, between 2015 and 2050, and the sum over all the years is an estimate of the NPV. Because savings are discounted to the current year, we assume that the impacts of MEPS after 2050 are negligible.

Figure 1 shows the timeline of national cost savings for one product class (U.S. residential water heaters). The graph displays incremental equipment costs with negative savings in red and positive operating cost savings in green. The policy evaluation period ends in 2030; incremental costs are not counted after that date. Energy savings continue, however, as products entering the stock up to 2030 will remain in operation.

Figure 1. National Costs Savings from Electric Water Heaters in the U.S.

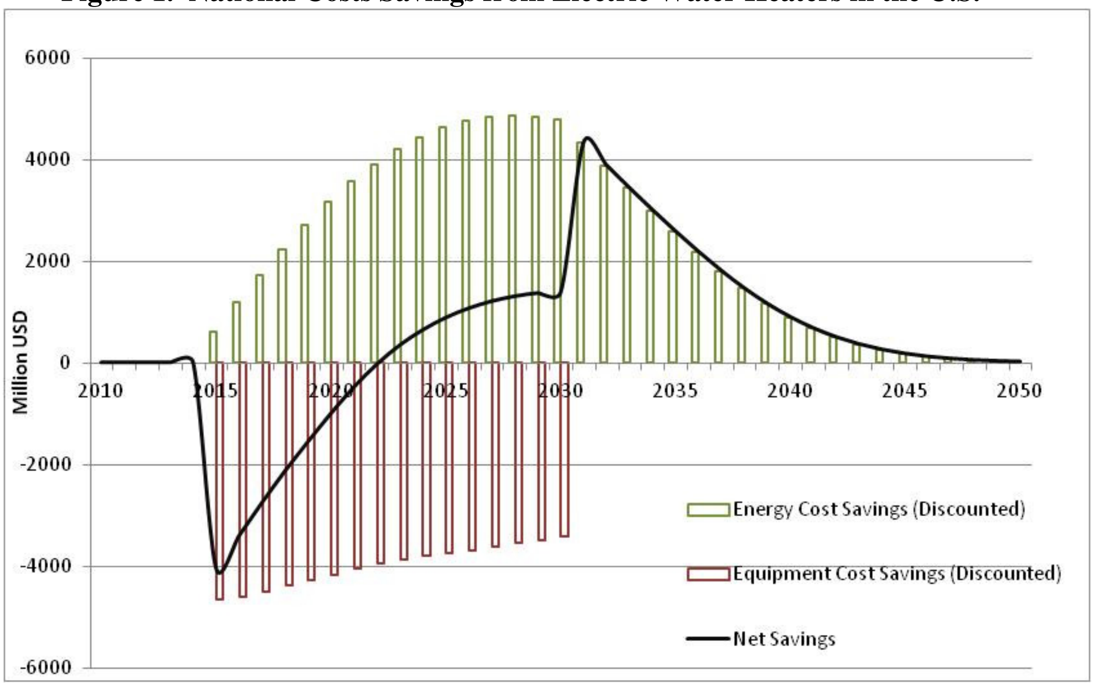


Figure 1 shows that during the first years of the program, the overall cost of the appliances is higher than the resulting savings. In 2022, the incremental costs are equal to the energy savings. After 2022 and until the last appliances purchased during the program period retire from the stock, the program benefits consumers. The total value of the program or NPV (the sum of the net savings from 2015 to 2050) is equal to 20 Billion USD.

[4]LEAP, the Long range Energy Alternatives Planning System, is an integrated modeling tool developed at the Stockholm Environment Institute that can be used to track energy consumption in all sectors of an economy for energy policy analysis and climate change mitigation assessment.

Table 32 presents the NPV results of all the MEPS considered in our analysis.

Table 32. Net Present Value, in Billions 2010 USD

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	ZAF	USA	Total
Boilers			2.1	13	24								0.5	40
Central AC										44			72	120
Cooking				5	20								0.6	26
Dryers					3								1.6	4.2
Fans		2.8		34		6.4	0.5			0.7		0.10	4.5	49
Freezers					15								1.8	17
Furnaces													4.0	4.0
Lighting	0.5	17	2.4	32	41	4.3	2.1			4.3	5.5	1.1	15	120
Refrigerators	2.3	4.1	1.3	20	7	1.6	0.8	0.3	2.9	0.2		0.2	21	62
Room ACs		1.2				2.6	0.2		0.3	2.5			1.3	8.0
Heat Pumps	3.9		0.1	4.4	61			49.8	1.2	0.4	0.8			120
Televisions	1.0	0.6		4	18			1.8	1.7				4.4	31
Washing Machines				12	6.3									18
Stand by	0.9	1.3	0.4	10	84	1.1	0.2	7.7	1.9	0.7	0.3	0.1	18	130
Water Heaters			0.3	34	400								25	460
Residential	8.6	26.6	6.5	170	680	16	3.8	59.6	8	53.0	6.6	1.3	170	1,200
Transformers			0.3	5.1	70	1.9							14	91
Electric Motors	0.7	1.9	0.8	69	43	2.2	1.3	24.0	2.6	0.5	0.9	0.1	8.8	160
Industry	0.7	1.9	1.1	74	110	4.1	1.3	24.0	2.6	0.5	0.9	0.1	22	250
Total	9.3	28.5	7.7	240	790	20.0	5.1	83.6	10.5	53.7	7.5	1.4	190	1,500

In the CEP scenario, because the focus is on maximizing energy savings, the NPV has to be seen as an additional or even side benefit of the programs. Because of the nature of the cost curves, the CCE target can be at any distance from the electricity price. This distance will determine the magnitude of the NPV. Overall, the value of all programs is found to be more than one and a half trillion USD.

5.3 CO_2 Emissions Reduction Potential

We calculate total reduction in CO_2 emissions in million tons (Mt) using national electricity generation fuel mix and fuel combustion factor.

CO_2 emissions savings (*CES*) are calculated from energy savings, by applying a carbon factor (*CF*) to site energy savings, as follows:

$$CES = E(y) \times CF$$ [5] **Equation 8**

[5] CF takes into account electricity system transmission and distribution losses.

Tables 33 and 34 present the annual CO_2 emissions reduction resulting from the MEPS, per end use and country in 2020 and 2030.

Table 33. CO_2 Emissions Mitigation in 2020 (Mt)

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	ZAF	USA	Total
Boilers			0.4	5	11								0.9	17
Central AC										0.02			11	12
Cooking				2									0.3	2
Dryers					0.6								0.5	1
Fans		0.3		27		19	1.7			0.58		0.3	4.7	54
Freezers					0.9								0.9	2
Furnaces													5.2	5
Lighting	0.3	1.7	0.8	35	7.1	13	4.5			4.62	5.3	2.3		74
Refrigerators	1.3	0.5	0.3	30	1.4	3.1	1.8	0.1	1.0	0.18		1.5	7.2	48
Room ACs		0.7				23	2.0		0.2	1.95			1.4	29
Heat Pumps	1.9			11	4.9			11	0.4	0.41	0.8			31
Televisions	0.3	0.1		6	1.8			0.3	0.4	0.01			3.9	13
Washing Machines				24	0.4									24
Stand by	0.7	0.4	0.3	30	12	2.7	0.4	1.7	1.9	1.14	0.2	0.1	13.3	65
Water Heaters			0.5	23	34								29.6	87
Residential	4.6	3.7	2.3	190	75	61	10.0	13	3.9	8.91	6.3	4.2	79.3	464
Transformers			0.1	4	4.7	3.3							4.2	16
Electric Motors	0.4	0.2	0.1	41	5.5	4.2	1.9	2.3	1.3	0.39	1.0	0.4	3.1	62
Industry	0.4	0.2	0.2	45	10	7.5	1.9	2.3	1.3	0.39	1.0	0.4	7.2	78
Total	5.0	3.9	2.5	240	85	68	12	16	5.3	9.30	7.2	4.6	86.5	542

Table 34. CO_2 Emissions Mitigation in 2030 (Mt)

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	ZAF	USA	Total
Boilers			1.1	15	26								2	44
Central AC										0.1			27	27
Cooking				7									1	8
Dryers					2								1	3
Fans		0.6		49		38	3.4			1.1		0.5	9	100
Freezers					2								2	4
Furnaces													14	14
Lighting				8										8
Refrigerators	3.1	1.4	0.8	70	3	10	5.6	0.3	2.2	0.4		3.4	18	120
Room ACs		2.0				70	5.4		0.5	5.9			2	86
Heat Pumps	4.3		0.2	23	12			23.0	0.8	1.4	1.9			66
Televisions	0.7	0.2		11	4			0.5	0.8				7	24
Washing Machines				45	1									45
Stand by	1.2	0.7	0.4	61	19	5	0.7	2.4	3.1	2.0	0.3	0.2	23	120
Water Heaters			1.0	41	83								60	180
Residential	9.3	4.9	3.4	330	150	120	15.0	26.0	7.4	11.0	2.2	4.1	170	850
Transformers			0.1	9	15	11							11	46
Electric Motors	1.0	0.5	0.3	89	11	12	5.0	4.9	3.4	1.1	2.1	0.8	8	140
Industry	1.0	0.5	0.5	98	26	23	5.0	4.9	3.4	1.1	2.1	0.8	19	180
Total	10.3	5.4	3.9	430	180	150	20.1	31.0	10.8	12.0	4.4	4.9	190	1,000

Considering carbon emissions (Tables 33 and 34) on top of energy savings (Tables 29 and 30) redistributes savings a bit differently, giving more emphasis to countries with heavy carbon-generation systems like China and India and less emphasis to fuel savings in regions like the EU. We find that 90 percent of the emissions reduction potential is concentrated in China, the U.S., India and the EU together. Table 35 shows the cumulative emissions reductions between 2015 and 2030.

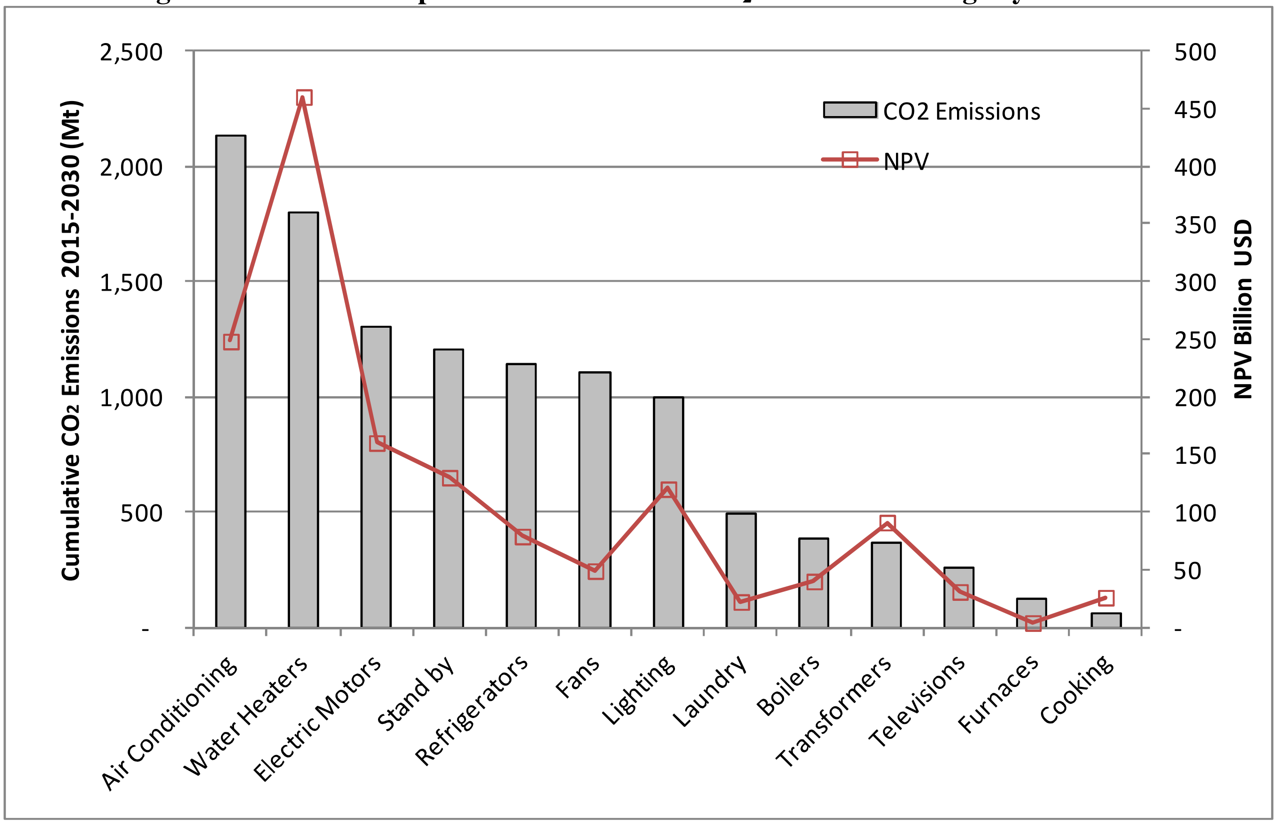
Table 35. Cumulative CO_2 Emissions Reductions between 2015-2030 (Mt)

End Use / Country	AUS	BRA	CAN	CHN	EU	IND	IDN	JAP	KOR	MEX	RUS	ZAF	USA	Total
Boilers			9	120	230								20	380
Central AC										0.6			250	250
Cooking				55									6	61
Dryers					13								12	25
Fans		6		520		390	35			11.2		5.3	92	1,100
Freezers					19								20	38
Furnaces													120	120
Lighting	3	20	10	450	83	150	54			55.1	63	27.1	110	1,000
Refrigerators	29	13	7	650	29	76	44	3	21	4.0		32.5	160	1,100
Room AC		28				850	46		5	47.8			26	1,000
Heat Pumps	68		2	230	300			230	10	10.7	40			880
Televisions	7	2		120	36			5	9	0.2		0.1	77	260
Washing Machines				460	7									470
Stand by	13	7	5	600	220	51	7	29	35	21.4	4	1.9	250	1,200
Water Heaters			10	440	750								600	1,800
Residential	120	75	41	3,600	1,700	1,500	190	260	79	151.0	107	66.8	1,700	9,700
Transformers			1	79	120	83							95	370
Motors	9	4	3	860	110	100	44	48	30	9.3	20	7.8	70	1,300
Industry	9	4	4	940	230	180	44	48	30	9.3	20	7.8	170	1,700
Total	130	79	45	4,600	1,900	1,700	230	310	110	160.0	128	74.6	1,900	11,400

Annual emissions savings and cumulative emissions are roughly proportional, except for end uses for which we consider a moving baseline such as lighting. Lighting saving potential is estimated at 1Gt of CO_2 through 2030. The overall cumulative savings are 11 Gt of CO_2 through 2030.

Figure 2 shows the financial impacts combined with cumulative CO_2 emission savings by end use. It is interesting to note that air conditioners have the largest emissions savings and water heaters result in the greatest savings to consumers.

Figure 2. Financial Impacts and Cumulative CO_2 Emissions Savings by End Use



6 Summary of Results and Conclusions

Table 36 summarizes the savings from the standards studied, for every country covered in BUENAS.

Table 36. Savings from MEPS: Summary Results

	Annual Savings in 2020				Annual Savings in 2030				Cumulative Savings	
	Electricity	Gas	% red vs. BAU	CO_2	Electri-city	Gas	% red vs. BAU	CO_2	CO_2 (2015-2030)	NPV
End Use	TWh	PJ	%	Mt	TWh	PJ	%	Mt	Gt	Billion$
Air Conditioning	120	0	11%	71	310	0	21%	180	2.1	250
Cooking	2	4	1%	3	8	11	1%	8	0.1	26
Fans	63	0	31%	54	130	0	52%	100	1.1	49
Lighting	130	0	27%	74	8	0	2%	8	1.0	120
Refrigerators & Freezers	70	0	11%	50	180	0	25%	120	1.1	79
Space Heating		290	3%	22		760	7%	58	0.5	44
Standby	110	0	47%	65	200	0	66%	120	1.2	130
Television	21	0	12%	13	42	0	19%	24	0.3	31
Laundry	24	0	9%	25	55	0	17%	48	0.5	22
Water Heating	120	140	14%	87	280	290	27%	180	1.8	460
Total Residential	**660**	**430**	**10%**	**460**	**1,200**	**1,100**	**17%**	**850**	**9.7**	**1,200**
Transformers	28		7%	16	86		18%	46	0.4	91
Motors	85		2%	62	200		3%	140	1.3	160
Total Industry	**110**		**2%**	**78**	**290**		**4%**	**180**	**1.7**	**250**
Total	**770**	**430**	**10%**	**540**	**1,500**	**1,100**	**10%**	**1,000**	**11.4**	**1,500**

This study demonstrates that:

- Efficiency targets that are cost effective for the consumer can result in significant national energy savings and CO_2 emissions reductions.
- Cost-effective MEPS can reduce final energy consumption in SEAD countries and China by 17 percent in 2030 in the residential sector and 4 percent in the industrial sector compared to business as usual.
- As a result of the above energy savings, worldwide annual CO_2 emissions would be reduced by 540 Mt in 2020 and 1000 Mt in 2030. Overall, between 2015 and 2030, over 11 Gt of CO_2 would be avoided.
- The net present value of the savings would be an estimated 1.5 trillion USD.
- Water heating is the end use that would provide the most energy savings with high technological jumps to heat pumps, or a switch to solar water heating where climate allows. It is also the most cost effective measure out of all the MEPS analyzed here
- Standby power is the end use with the most potential reduction in relative terms, with a 66-percent cost effective improvement.
- Cost effectiveness is a criterion among others in evaluating different energy efficiency design options. The case of TV shows that in the BAU, consumers and manufacturers make a choice that is not necessarily cost effective to them.

For comparison to the savings from the CEP scenario, recently implemented or in-progress standards in SEAD partner countries will save an estimated 250 Mt of CO_2 annually by 2030 (Kalavase, McNeil, et al. 2012), or about one-fourth of the 1,000 Mt CO2 emissions identified in the CEP study (in SEAD countries only, 610Mt savings are identified). Our analysis shows far greater savings potential than what is captured by current and upcoming regulations.

By introducing the systematic financial considerations in our analysis, we built a framework that allows for further international studies on areas such as:

- Sensitivities to the equipment incremental cost: What is the effect of a rebate program or a learning rate on the level of cost effectiveness?
- Sensitivities to price of electricity: How does the subsidization of electricity impact the cost-effectiveness of efficiency improvements from the consumer perspective? What about considering marginal electricity prices as opposed to average?
- Additional costs: How would a carbon tax or inclusion of the social cost of carbon impact the evaluation of cost-effective potential?

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