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Analysis of Potential Energy Saving and CO_2 Emission Reduction of Home Appliances and Commercial Equipments in China

Nan Zhou, David Fridley, Michael McNeil, Nina Zheng, Virginie Letschert, Jing Ke
Energy Analysis Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

Yamina Saheb
OpenExp

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TABLE OF CONTENTS

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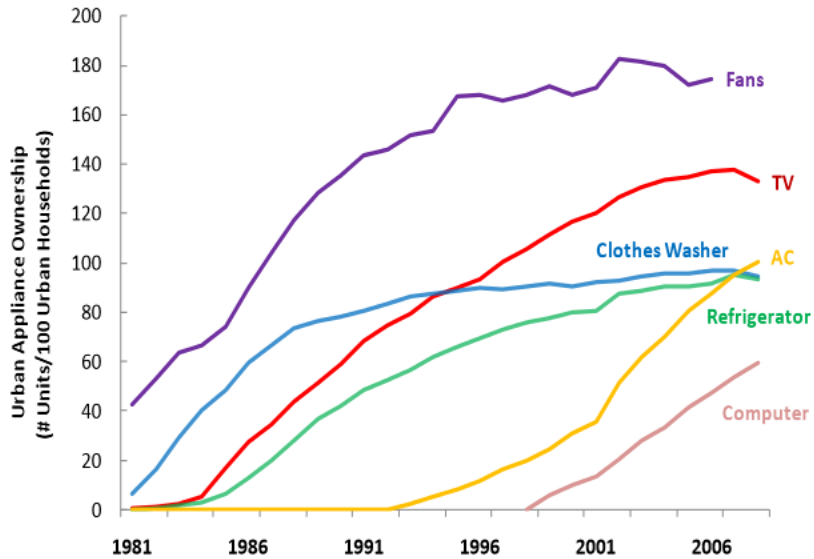
Abstract

China has implemented a series of minimum energy performance standards (MEPS) for over 30 appliances, voluntary energy efficiency label for 40 products and a mandatory energy information label that covers 19 products to date. However, the impact of these programs and their savings potential has not been evaluated on a consistent basis. This paper uses modeling to estimate the energy saving and CO_2 emission reduction potential of the appliances standard and labeling program for products for which standards are currently in place, under development or those proposed for development in 2010 under three scenarios that differ in the pace and stringency of MEPS development. In addition to a baseline "Frozen Efficiency" scenario at 2009 MEPS level, the "Continued Improvement Scenario" (CIS) reflects the likely pace of post-2009 MEPS revisions, and the likely improvement at each revision step. The "Best Practice Scenario" (BPS) examined the potential of an achievement of international best practice efficiency in broad commercial use today in 2014. This paper concludes that under "CIS", cumulative electricity consumption could be reduced by 9503 TWh, and annual CO_2 emissions of energy used for all 37 products would be 16% lower than in the frozen efficiency scenario. Under a "BPS" scenario for a subset of products, cumulative electricity savings would be 5450 TWh and annual CO_2 emissions reduction of energy used for 11 appliances would be 35% lower.

1. Introduction

In recent years, China has become one of the world's largest producers and consumers of household appliances as urban and rural ownership rates grew at an extraordinary pace. As China continues to develop its economy, urbanization and rising disposable incomes are expected to drive demand for appliances and related energy services. In fact, sustained rises in urban appliance ownership have already corresponded to growing urban residential electricity use at an annual average rate of 13.9% between 1980 and 2007 with similar paces in rural appliance ownership and electricity use (Figure 1 and Figure 2) (NBS, various years).



Source: National Bureau of Statistics, various years.

Figure 1. Urban Appliance Ownership

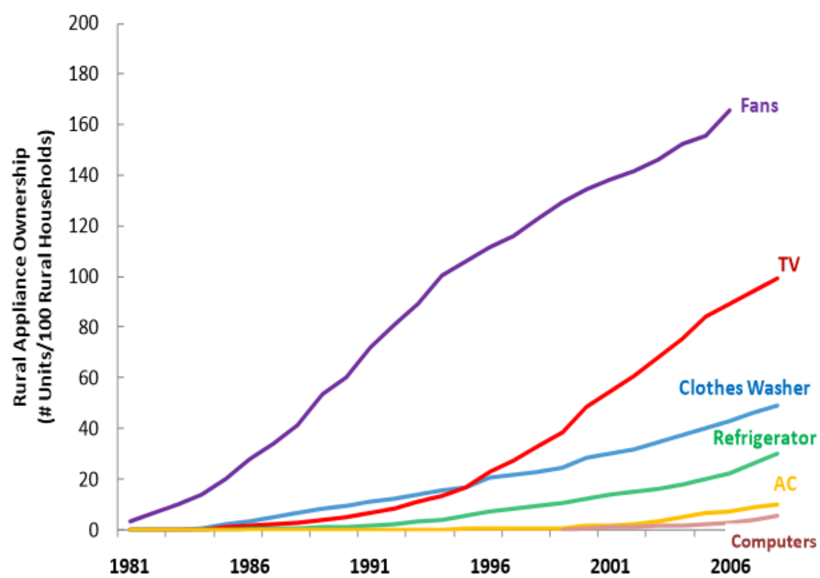


Figure 2. Rural Appliance Ownership

In light of the rapid rise in household appliance ownership, China's first equipment energy efficiency standards program was established in 1989 to cover most common household appliances such as refrigerators, air conditioners, clothes washers, televisions, radios and electric fans. [1] China's minimum energy performance standards (MEPS) program was

[1] China's first MEPS were introduced in 1989 and included eight products: household refrigerators (GB 12021.2-1989), room air conditioners (GB 12021.3-1989), clothes washers (GB 12021.4- 1989), electric irons (GB/T 12021.5-1989), automatic rice cookers (GB 12021.6-1989), televisions (GB 12021.7-1989), radio receiver and recorders (GB/T 12021.8-1989), and electric fans (GB 12021.9-1989).

strengthened and expanded under the Energy Conservation Law of 1997 with greater regulatory attention and now covers over 30 different types of appliances and equipment including those common in the residential and commercial sector, and industrial equipment such as transformers and motors. At the same time, it has expanded the coverage of its voluntary energy efficiency label to over 40 products (Table 1). Typically, MEPS are developed through a process involving government, industry and research experts and can take 18 to 24 months depending on the product. The China National Institute of Standardization (CNIS) is responsible for drafting new and updated standards and in some cases, MEPS test procedures are based on internationally accepted test standards. The MEPS mandate the maximum allowable energy consumption for a given appliance product and are generally updated every four to five years, with each update typically increasing stringency by about 10% over the previous level. In order to provide manufacturers with longer lead times for design and production of new products, new and revised standards since 2003 have included a second period "reach standard" of even greater stringency with a typical 3-year lead time to implementation.

China has had a voluntary energy label endorsing products that meet a certain efficiency threshold since 1998, and adopted a mandatory information label that ranks product models of the same type by efficiency category to inform consumer purchase decisions in 2005. This mandatory categorical energy information label is known as the China Energy Label and was established following legal provisions in the Energy Conservation Law with supporting regulation and support for implementation in the Product Quality Law and Legislation on Certification & Accreditation (Jin & Li, 2006). The China Energy Label includes five categories of efficiency, ranked from 1 (highest) to 5 (MEPS), and a given product's rating is based on self-reported energy consumption data from manufacturers. At its launch in March 2005, the label was implemented for use only on refrigerators and air conditioners, and now further expanded to cover 15 products by the end of 2009. Complementary to appliance standards, the Energy Label is intended to promote consumer awareness and market transformation.

Besides quantifying energy and economic impacts of standards and labeling (S&L) programs, consistent impact evaluations also help justify program funding, assess program effectiveness and identify potential weaknesses in program design or implementation and are thus a crucial factor for S&L program success (Vine et.al., 2001, Wiel and McMahon, 2005). To date, however, the impact of China's S&L programs and their saving potential has not been evaluated on a consistent basis. This research involves modeling to estimate energy saving[2] and emission reduction potential of the appliances standard and labeling program for products for which standards are already in effect, currently under development and those proposed for development in 2010.

[2] Energy use and energy savings are reported in Chinese units of standard coal equivalent (sce); values are typically expressed as metric tons of coal equivalent (tce) and million metric tons of coal equivalent (Mtce). One tce equals 29.27 gigajoules (GJs) and 27.78 million British thermal units (MBtus). Energy use and energy savings are reported in both final (site) and primary (source) values that reflect electricity conversion efficiencies as well as transmission and distribution losses. To convert electricity to a final (site) coal equivalent value, the conversion factor of 0.1229 kilogram coal equivalent (kgce)/kilowatt hour (kWh) is used. To convert electricity to a primary (source) coal equivalent value, the conversion factor of 0.404 kgce/kWh is used.

The baseline or "Frozen" scenario for evaluating the impact of S&L programs is based on the absence of any appliance efficiency policy and assumes that an appliance's energy intensity as measured by unit energy consumption is frozen at the average level of when the first standard was implemented. Two additional scenarios that have been developed differ primarily in the pace and stringency of MEPS development. The Continued Improvement Scenario (CIS) reflects the likely pace of post-2009 MEPS revisions, and the likely improvement at each revision step considering the technical limitation of the technology. The Best Practice Scenario (BPS) examined the potential of an achievement of best practice efficiency in broad global commercial use today in 2014 for a subset of products evaluated in the CIS scenario.

This paper presents the modeling methodology of three scenarios of possible efficiency improvements in residential, commercial and industrial equipment and compares the savings potential of both BPS and CIS scenarios against a frozen efficiency scenario. Conclusions are drawn to provide policymakers and other energy analysts with details of the success and shortcomings of the program as well as a guide to targets for further strengthening of the program.

Table 1. Standards and Labeling Program Development in China

		<2005	2005	2006	2007	2008	2009	2010	2011	2012	2013
INDUSTRIAL MOTORS (1-100 HP)											
Three-phase asynchronous motors	CL, VL				□	CL		→			
RESIDENTIAL REFRIGERATION											
Domestic refrigerators/freezers	CL, VL		CL				□			→	
TELEVISION											
Televisions	VL			□				→			
COMMERCIAL AND RESIDENTIAL LIGHTING											
Fluorescent lamp ballasts	VL	□									
Single-cap fluorescent lamps	VL	□									
Linear fluorescent lamps	VL	□									
Compact fluorescent lamps	CL, VL	□				CL					
HPS lamps	CL, VL	□				CL					
HPS lamp ballasts	VL	□									
MH lamps	VL			□							
MH lamp ballasts	VL			□							
Grid lighting fixtures							□				
COMMERCIAL SPACE COOLING											
Commercial packaged AC	CL, VL		□		CL						
Room air conditioners	CL, VL	□	□		CL			□			→
Variable speed air conditioners	CL, VL					□	CL				→
Multi-connected air condition (heat pump) unit	CL, VL					□	CL				
Chiller	VL	□									

		2005	2005	2006	2007	2008	2009	2010	2011	2012	2013
COMMERCIAL REFRIGERATION											
STANDBY											
External power supplies	VL				□						
RESIDENTIAL SPACE COOLING											
Room air conditioners	CL, VL	□ CL	□ □					□			→
Variable speed air conditioners	CL, VL					□ CL					→
OTHER											
Clothes washers	CL, VL	□			CL						
Set-top box (digital converter)	VL only						□				
Electric irons		□									
Automatic rice cookers	VL						□				
Microwave	VL only										
Radio receivers and recorders		□									
Air compressor		□									
Freestanding electric fans		□									
AC electric ventilating fans							□				
Industrial fans		□	□								
Pumps		□	□								
Instantaneous gas water Heaters	CL, VL				□	CL					
Electric storage water heaters	CL, VL					□	CL				
Household induction cooktop	CL, VL					□	CL				
Computer monitors	CL, VL					□	CL				
Copy machines	CL, VL					□	CL				
Printers	VL						□				
Computers	VL						□				
Servers							□				
Heat-Pump water heaters							□				
Residential range hoods	VL						□				

KEY: □□ □□ □□

- □□ **Implemented and in effect**
- → **Future second tier MEPS (reach standard)**
- □□ **Under development (new MEPS) or revision underway (existing MEPS)**
- CL **Year product was included in categorical label program ("Energy Label")**
- CL, VL **Included in categorial label and/or voluntary label programs**

Note: Updated standard for televisions (GB 24850-2010) was approved on June 30 and effective as of December 1, 2010. The motors standard is still under revision.

2. Methodology

Data on production, sales, efficiency, ownership, usage patterns and other technical details of each product are challenging to acquire and compile in China. This study relies on a wide range of materials and information sources including national statistics, reports, websites, testing results, as well as judgment gained from long term working collaboration between LBNL and CNIS on standard development and implementation.

2.1 Scenarios

The analysis focused only on the standards or voluntary labeling efficiency criteria that were implemented as of 2009 and applicable "reach" standards to be implemented for air conditioners, refrigerators, televisions and lighting in 2014. Although the mandatory energy information label for refrigerators and air conditioners was implemented in 2005 and expanded to 15 products by 2009, the impact of this program was not included in the analysis because of insufficient market data. The two scenarios of efficiency improvements developed for this preliminary analysis differ primarily in the pace and stringency of MEPS development and are compared against the frozen efficiency scenario which uses the 2009 MEPS level as the baseline average energy consumption through 2030.

In the CIS, the projection is made based on the likely pace (every 4 to 5 years) of post-2009 MEPS revisions and the likely improvement (5-10%, depending on the product) at each round of update considering the technical limitation of the technology development in China. In the BPS, product efficiency was maintained at the 2009 level until 2014, when it was improved to a level consistent with best-practice efficiency found in broad commercial use internationally today. From 2014 to 2030, efficiency was maintained at this level.

In all three scenarios, basic assumptions—population, rate of urbanization, and ownership saturation were kept identical.

2.2 Modeling Methodologies

For this study, two bottom-up, end-use based models were used to model the total energy consumption and potential savings for each product under the three scenarios from 2009 to 2030. Two scopes of scenario analysis were undertaken in this study as a result of the two different modeling methodologies and product coverage (Table 2). The first scope of analysis evaluates the impact of CIS pace of standards revisions and focuses on two scenarios (frozen and CIS) that modeled all 37 products. The second scope of analysis is intended to compare the energy and emission reduction potential impacts of CIS and BPS for the subset of 11 products modeled in LEAP in all three scenarios.

Table 2. Scope and Product Coverage of Scenario Analysis

Scenario	Scope 1	Scope 2
Frozen Efficiency Scenario	37 products[a]	11 products[b]
Continued Improvement Scenario (CIS)	37 products	11 products
Best Practice Scenario (BPS)	n/a	11 products

Note: scope 1 analysis and results are presented in section 3.1; scope 2 analysis and results are presented in section 3.2

[a]37 products include the 11 LEAP modeled products (see below) and 26 spreadsheet-modeled products of rice cooker, microwaves, laser printers, fax machines, copiers, monitors, high intensity discharge lamps and ballasts, electric motors, mini and large air compressors, transformers, desktop and laptop computers, servers, double-capped fluorescent lamps, heat pump water heater, rangehoods, ventilating fans, external power supply, vending machines, LED lamps, grid lighting, commercial AC reciprocating chiller units, water-cooled screw type and centrifugal water chilling units, and unitary AC.

[b]11 LEAP modeled products include: clothes washer, TV, refrigerator, fans, standby, air conditioner, electric water heater, natural gas water heater, LPG water heater, electric stove, fluorescent lamp ballast.

For 11 products, a customized bottom-up, technology-specific Long Range Energy Alternatives Planning (LEAP[3]) model—for use in both the CIS and BPS scenarios—was developed with detailed characterization of energy intensity stock flows based on macroeconomic and demographic drivers correlated with ownership rates according to historical data in China. Major drivers are economic activity (household income, GDP growth and GDP per capita growth), persons per household, dwelling area and urbanization rates. Correlating sales with ownership rates, including saturation effects avoids the potential for overstating long term sales rate growth. In order to limit the dependence of the model on the authors' assumption of major macroeconomic parameters, forecasts of the following were aligned with the Chinese Energy Research Institute's energy demand model (CERI, 2009): GDP growth, persons per household, dwelling area and urbanization rate. Note that costs of the products are not considered in the model, with the assumption that the incremental cost of the efficient appliances will be offset by their energy savings.[4]

The projection of the sales for these products is made based on stock and vintage analysis. The saturation forecast was developed based on macroeconomic drivers projections and the historical experience in developed countries such as Japan and the U.S. This avoids the problem of forecasting sales growth and the potential for overstating ownership rates, because the target saturation rates are then "backcasted" into implied sales figures, accounting for retirement of a percentage of the stock in each year. For each scenario, the total energy consumption of each appliance (measured in terms of electricity) is calculated by the model using given assumptions about annual unit energy consumption, lifetime, and calculated stock. For some products such as refrigerators and air conditioners, expected changes in the average size of models and of usage patterns that impacts total electricity consumption are taken into consideration. Since the only difference among the three scenarios is the efficiency levels of

[3] LEAP is an accounting framework developed by the Stockholm Environment Institute for scenario-based, integrated energy environment modeling. Detailed introduction to the LEAP model can be found at http://www.energycommunity.org/default.asp?action=47

[4] There is a broad array of literature on the cost-effectiveness of standards, see for example Geller, 1997 and Schiellerup, 2002.

appliances resulting from S&L efforts, the subsequent divergence in modeled energy consumption from the frozen scenario can be attributed to energy savings from different pace of efficiency improvements.

In the case of the other twenty six products, data challenges do not permit the development of a full age profile approach to modeling in the same manner as the other 11 products modeled in LEAP and current best practice efficiency levels are not available. As a consequence, they have been modeled differently and evaluated only under the CIS scenario. Owing to the poor characterization of the domestic market, a standard unit efficiency gain and sales projection using simple turnover analysis for each product has been modeled. For each of these products, lifetime assumptions, historical and projected Chinese sales and stock data for each product were provided by CNIS where available and collected from Chinese statistical sources, published market studies, analysis of recent growth trends, and historical experiences of other developed countries.

2.3 Shipments and Diffusion Rate

Calculation of unit equipment sales (shipments) and stock turnover is essential in understanding the rate at which products enter the household population and thus impact the overall energy consumption. This shipments rate impacts both the base case and efficiency scenarios. After the standard is passed, savings come from the households acquiring the appliances for the first time but also from replacement of older products by efficient products as they are retired.

Shipments are calculated as the sum of the first purchases and replacements. The first purchases are the increase in appliance stock from one year to the next, where stock is the product of number of households and the diffusion rate measured in China as the number of units owned per 100 households. Replacements are calculated based on the age of the appliances in the stock and a retirement function that gives the percentage of surviving appliances in a given vintage. The incremental retirement function is derived from a normal distribution around the average lifetime of the product.

$$\text{Shipments} = \text{First Purchases} + \text{Replacements} \qquad (1)$$

First purchases are shipments due to increases in the stock, either from new households, increases in diffusion, or urbanization. Replacements are given from past shipments according to Equation 2.

[illegible] (2)

In Equation 2, Retirement (i) is the probability of retirement in each year after installation, up to the maximum lifetime L.

For refrigerators, air conditioners, televisions, stand by[5] and clothes washers, diffusion rates of each year were calculated based on a regression model developed in an earlier study (Letschert et al., 2009), in which the diffusion of the appliances is a function of household income, as given by the following equation:

$$Diff(year) □ \frac{□}{1 □ □ \exp □ □_{Inc} □ I(year) □} \quad (3)$$

In Equation 3, all parameters are determined separately for urban and rural households. The parameter □ is the maximum diffusion per 100 households, which may be greater than 100. For rural households, □ is the diffusion in urban household for the same income level. I (year) is the average per household income in year and □ and $□_{Inc}$ are scale parameters. In the case of air conditioners in urban households a dummy variable ($□_{year}$) was added to the equation to account for the rapid diffusion of that technology when it becomes more available and affordable. Details about methodology used to establish these equations can be found in Letschert et al. (2009). Table 2 and Table 3 provide a summary of the parameters used in the model.

Table 2. Parameters for diffusion model for Urban Households

End Use		l n□	□ year	□I nc	2
Clothes Washer	00	- 0.9		- 6.64E-05	.97
TV	50	1 .06		- 9.63E-05	.96
Refrigerator	00	0 .93		- 9.76E-05	.98
Air Conditioner	00	4 39.54	- 0.22	- 1.12E-04	.99

Table 3. Parameters for diffusion model for Rural Households

End Use	□	n□	□Inc	2
Clothes Washer	Urban Diff	.2	- 1.61E-04	.95
TV	Urban Diff	.28	- 3.62E-04	.92
Refrigerator	Urban Diff	.98	- 2.26E-04	.93
Air Conditioner	Urban Diff	.52	- 3.59E-04	.8

[5] The standby power consumption of various plugloads including electronic devices, office equipment, home entertainment equipment have been aggregated into a single end-use category to distinguish the potential impacts of regulating standby power consumption.

2.4 Assumptions on Efficiency

The assumption of the efficiency improvement of the appliances in CIS scenario is made based on the likely pace (every 4 to 5 years) of post-2009 MEPS revisions, and the likely improvement (5-10%, depending on the product) at each round of update considering the technical limitation of the technology. The one-time improvement tested in the BPS scenario reflects fully realizing in 2014 the current best practice efficiency in broad commercial use globally. Table 4 shows the efficiency improvement of the key products for both CIS scenario and the BPS scenarios. The "frozen efficiency" scenario assumes no improvement from the base year.

Table 4. Assumptions for Energy Efficiency Improvement of the Standard for Key Products and the International Best Practice Level

Product	CIS Figures			BPS Figures	
	Standard Dates	Baseline Average Unit Energy Consumption	Efficiency Improvement per standard	Standard Date	Efficiency Improvement in 2014
AC	2012 (compressor standard), 2014, 2019 and every 5 years thereafter	396 kWh/yr	10%	2014	Baseline of 2.6 EER increases to 4 EER
Electric Motors	2010	21, 816 kWh/yr	4.50%	2014	Average efficiency of 87.9% increases to 92.4%
Refrigerators	2009, 2014, 2019 and every 5 years thereafter.	525 kWh/yr	10%	2014	Efficiency improves 38%
Heat Pump Water Heater	2011, 2016, 2021, 2026 and 2031	2065 kWh/yr	10%	2014	N/A
TV	2009, 2014 and every 5 years thereafter	132 kWh/yr	10%	2014	35% improvement
External Power Supply	2012	80 kWh/yr	28%	2014	N/A
Standby	2020	64 kWh/yr	50%	2014	5W baseline lowered to 1W
Transformers	2011	8342 kWh/yr	25%	2014	N/A
Computers/Servers	2011	Desktop - 201 kWh/yr Laptop - 50 kWh/yr Servers - 2854 kWh/yr	Desktops - 17% Laptops - 10%, Servers - 28.3%	2014	N/A
Clothes Washers	2010, 2015 and every 5 years thereafter	135 kWh/yr	10%	2014	47% Improvement
Electric WH	2013, 2018 and every 5 years thereafter	617 kWh/yr	5%	2014	Baseline efficiency of 76% improves to 88%

3. Result of S&L Impact in Energy and Emissions

The results of the study are presented in two sections: in the first section, all products subject to standards in China are examined on the basis of the CIS, explained further below. In the second section, results are presented for a subset of 11 products for which standards exist widely and for which targets representing international best practice can be established. For all products except gas water heaters, the savings are in electricity.

3.1 Continued Improvement Scenario Impacts

For all products, under a "continued improvement" scenario, cumulative electricity consumption through 2030 could be reduced by 9503 TWh below what would be the case if standards were frozen at 2009 levels (Table 5 and Figure 3). Over the period 2009 to 2030, these savings would result in a CO_2 emissions reduction of over 9.1 billion metric tons (Figure 4).[6] In 2030, annual electricity savings would be equivalent to the output of 145 1-GW power plants, and annual CO_2 emissions would be 15% lower than in the frozen scenario. Cumulatively, the existence of these standards could reduce energy consumption by 3,338 million tons of coal equivalent (Mtce), which is higher than China's total energy consumption in 2009.

Continued improvement of the S&L program alone could thereby contribute to great reduction in energy and carbon emissions given continuous actions by government and industries beyond efforts initiated during the last five years, particularly for those products for which standards have already been enacted and the least efficiency have been removed from the market.

[6] This analysis is based on a constant CO_2 emission factor of 0.9109 kg CO2/kWh, which is calculated using national data on fuel input to China's 2007 power generation and IPCC emission coefficients. Changing fuel composition of power generation over time was not considered as this study focuses primarily on energy impacts. However, estimates suggest that China's CO_2 emission factor could be as much as 40% lower by 2030 if China achieves its goals in expanding renewable and non-fossil fuel generation.

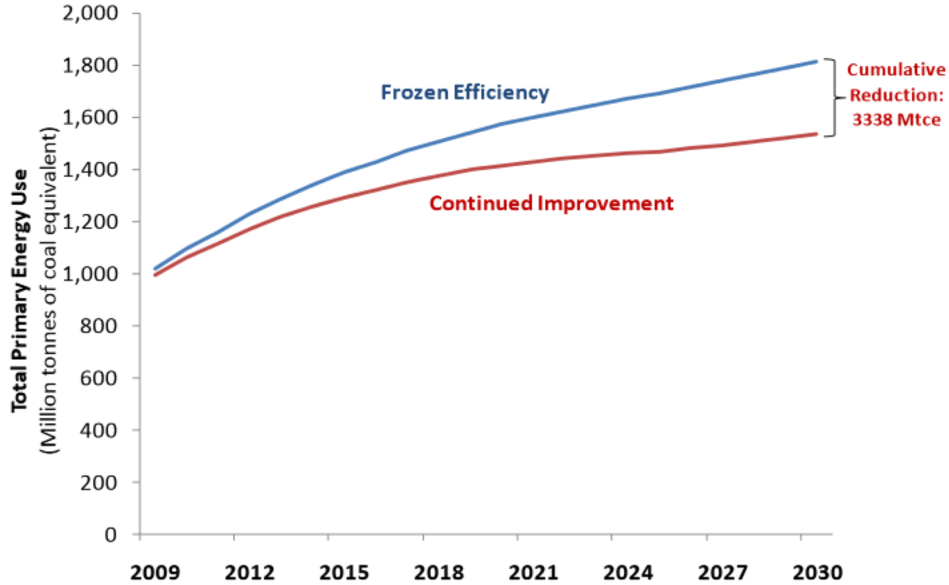
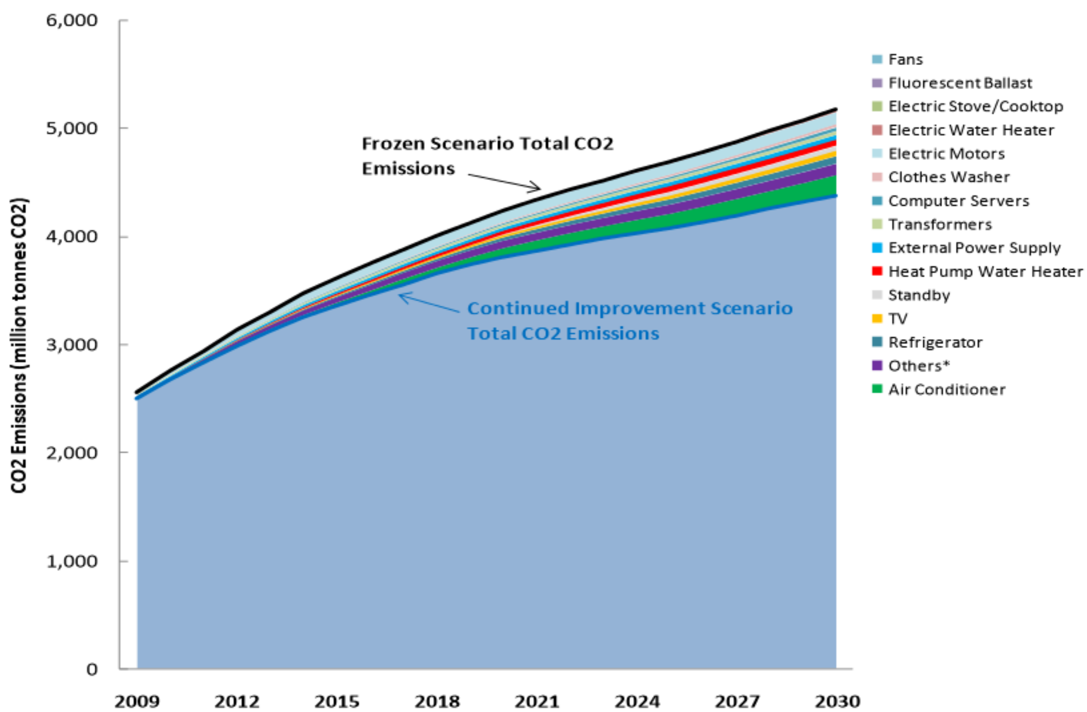


Figure 3. Primary Energy Demand from Residential, Commercial and Industrial Equipment in Frozen and Continued Improvement Scenarios



*Others include: rice cookers, microwaves, laser printers, fax, copiers, computer monitors, HID lighting, mini and large air compressors, desktop and laptop computers, double-capped fluorescent lamps, rangehoods and vent fans, LED lamps, grid lighting, commercial air conditioners

Figure 4. CO_2 Emission Reduction from Residential, Commercial and Industrial Products by Product Type in Continued Improvement Scenario

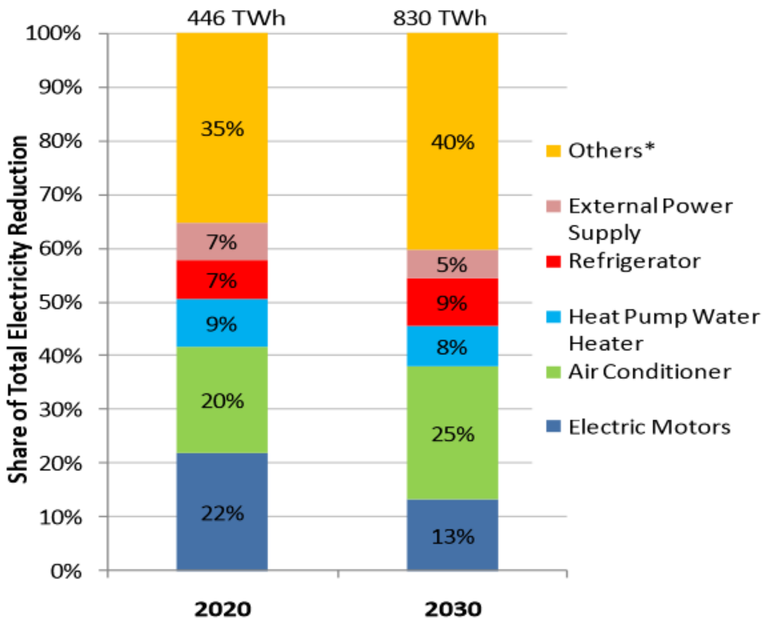
Table 5. Annual Reduction, Frozen Minus Continued Improvement Scenario, Final Energy (TWh unless noted otherwise)

	2009	2014	2020	2025	2030	2009 - 30 Cumulative
Clothes Washer	0.0	3.7	13.1	22.3	31.9	298.5
TV	0.9	8.1	25.0	42.0	60.3	566.0
Refrigerator	1.6	11.2	33.2	53.5	73.7	725.7
Fans	0.1	0.5	1.3	2.0	2.8	27.1
Stand By	0.0	0.0	5.6	33.2	46.8	331.5
AC	0.0	20.8	88.1	145.5	205.5	1891.9
Electric WH*	0.0	0.9	6.2	12.4	21.2	157.3
Natural Gas WH* (billion m^3)	0.0	0.2	1.0	2.2	3.9	28.4
LPG WH (million metric tons)	0.0	0.1	0.6	1.1	1.8	14.8
Electric Stove/Cooktop	0.0	1.3	3.8	5.7	7.1	77.0
Fluorescent Lamp Ballast	0.0	0.6	1.2	2.7	3.4	33.4
Rice Cooker	1.5	5.2	7.5	7.5	7.5	138.0
Microwave Ovens	0.2	1.4	3.1	4.2	5.6	63.1
Office Equipment	1.5	3.7	5.1	6.5	8.3	110.5
HID (High Intensity Discharge) Lamps and Ballasts	3.0	1.9	0.8	0.1	0.0	24.1
Electric Motors	24.5	70.4	98.0	104.7	110.0	1884.2
Air Compressors	4.8	8.4	9.8	10.2	10.7	200.3
Transformers	8.3	15.0	22.1	27.3	33.9	471.5
Computers & Servers	NA	13.2	15.7	28.7	49.6	472.5
Double-capped Fluorescent Lamps	1.3	1.5	1.2	2.0	2.3	38.3
Heat Pump WH	NA	15.2	33.3	60.1	63.2	779.5
Rangehoods	NA	2.3	5.9	8.5	10.8	121.5
Ventilating Fans	NA	0.7	2.0	2.8	3.5	39.7
External Power Supply	NA	22.4	30.5	37.2	44.0	633.8
Vending Machines	NA	0.1	0.4	0.7	0.9	8.5
LED Lamps	NA	0.7	2.4	2.9	3.4	41.6
Grid Lighting	NA	0.1	0.2	0.3	0.3	3.7
Commercial AC Recp Chiller Units	2.3	4.2	4.9	5.4	5.9	103.0
Water-cooled Screw Type Water Chilling Units	2.6	5.8	7.4	8.2	9.1	150.3
Water-cooled Centrifugal Water Chilling Units	1.0	2.2	3.8	5.3	6.7	82.6
Unitary AC	0.4	0.9	1.4	1.6	1.8	27.6
Annual Electricity Reduction (TWh)	61.5	222.5	446.2	643.5	830.4	9502.7
Coal-fired Generation Capacity Equivalent (GW)					118	
Number of Three Gorges Dams Hydro Generation Capacity Equivalent					10.4	

Note: * Urban Only

Standards in place in China for residential and commercial appliances (excluding motors, transformers, and air compressors) are expected to save a cumulative 6947 TWh by 2030, or 14% of the cumulative consumption of building electricity to that year.

Of the energy consumption reduction, air conditioners and electric motors are the two largest contributors and together accounts for 42% of the total reduction in 2020, and 38% in 2030. The potential for motors is higher in the early years, but will be surpassed by air conditioners to become the second largest contributor in the year of 2030. In cumulative terms, the total reduction from the motor standard amounts to 1884 TWh, whereas the standard for air conditioners could save up to 1892 TWh. After motors and air conditioners, the largest energy consumption reduction potential is in heat pump water heaters, refrigerators and external power supplies. The top five products combined account for approximately 60% of the total reduction potential (Figure 5).



*Others include: TV, standby, transformers, computer servers, clothes washers, electric water heater, electric stove, fluorescent ballast, fans, rice cookers, microwaves, laser printers, fax, copiers, computer monitors, HID lighting, mini and large air compressors, desktop and laptop computers, double-capped fluorescent lamps, rangehoods and vent fans, LED lamps, grid lighting, commercial air conditioners

Figure 5. Contribution of Savings by Product (Frozen Minus Continued Improvement)

3.2 Best Practice Scenario Impacts

In a "BPS" scenario in which the efficiency of each of the 11 LEAP modeled product reaches a best-practice level in broad commercial use today by 2014, the total cumulative reduction in electricity consumption by 2030 would reach 5450 TWh compared to the frozen standards base case. Natural gas savings would reach 25 billion m^3 and LPG savings 13 million tons (Table 6). Over the period 2009 to 2030, these savings would result in a CO_2 reduction of over 5 billion tons (Table 7). In 2030, annual electricity savings would be equivalent to the output of 72 1-GW coal-fired power plants, and annual CO_2 emissions would be 35% lower than in the frozen scenario for the subset of 11 products (Table 7, Figure 6).

Table 6. Annual Reductions, Frozen Minus BPS Scenario, Final Energy (TWh unless noted otherwise)

	2009	2014	2020	2025	2030	2009 - 30 Cumulative
Clothes Washer	0	0.0	27.1	41.6	47.7	514.6
TV	0	3.5	26.7	40.5	46.8	506.9
Refrigerator	0	6.5	48.7	76.1	88.3	944.2
Fans	0	0.6	3.7	5.5	6.1	68.6
Stand By	0	7.2	49.2	64.1	75.1	852.8
AC	0	18.3	132.9	183.5	206.7	2357.1
Electric WH	0	1.2	10.9	16.4	20.0	205.9
Natural Gas WH (billion m^3)	0	0.1	1.2	2.0	2.6	25.1
LPG WH (million tons)	0	0.1	0.7	1.1	1.2	13.4

Table 7. Annual Reductions, Frozen Minus BPS Scenario, CO_2 Emissions (million metric tons)

	2009	2014	2020	2025	2030	2009 - 30 Cumulative
Clothes Washer	0.0	3.3	24.7	37.9	43.4	472.0
TV	0.0	3.2	24.3	36.9	42.6	461.7
Refrigerator	0.0	5.9	44.4	69.3	80.4	860.1
Fans	0.0	0.5	3.4	5.0	5.6	62.5
Stand By	0.0	6.6	44.8	58.4	68.4	776.8
AC	0.0	16.7	121.1	167.2	188.3	2147.1
Electric WH	0.0	1.1	9.9	14.9	18.2	187.6
Natural Gas WH	0.0	0.3	2.6	4.4	5.7	54.8
LPG WH	0.0	0.3	2.2	3.3	3.9	42.4
Total	0.0	37.9	277.4	397.4	456.6	5065.0

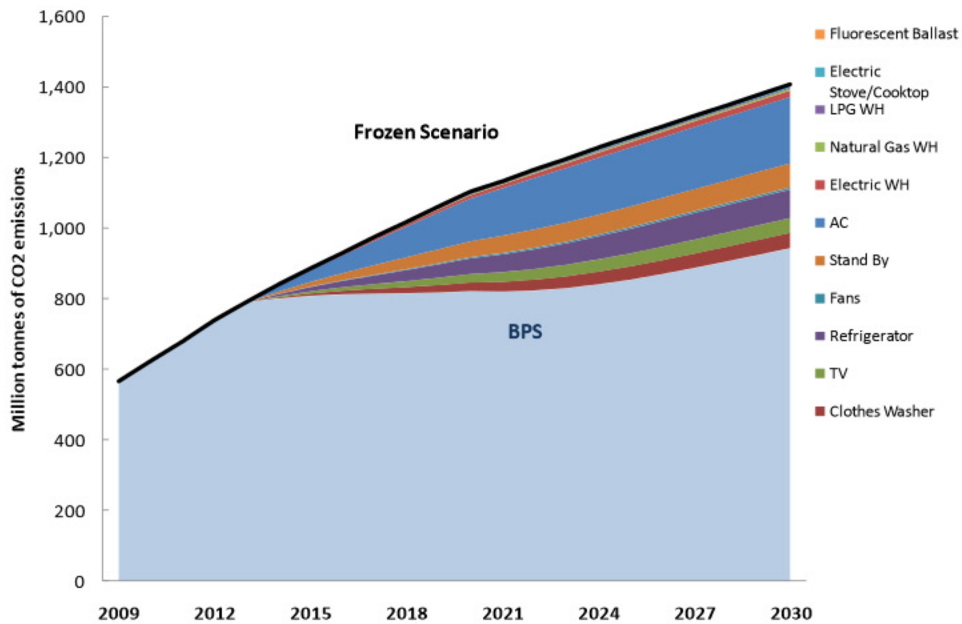


Figure 6. CO_2 Emission Impact, BPS Scenario

By contrast, over the same period cumulative consumption for these same 11 products in the "CIS" scenario would be reduced by 3998 TWh of electricity and 28 billion m^3 LPG, with a CO_2 reduction of 3.8 billion tons. Annual electricity savings in 2030 in CIS would be equivalent to the output of 65 1-GW coal-fired power plants, and annual CO_2 emissions would be 31% lower than in the frozen scenario.

A comparison of the two scenarios for the key products suggests that up to 801 Mtce of energy or 1,314 million tons of CO_2 could be further reduced cumulatively depending on technical and market conditions by product (Figure 7 and Figure 8).

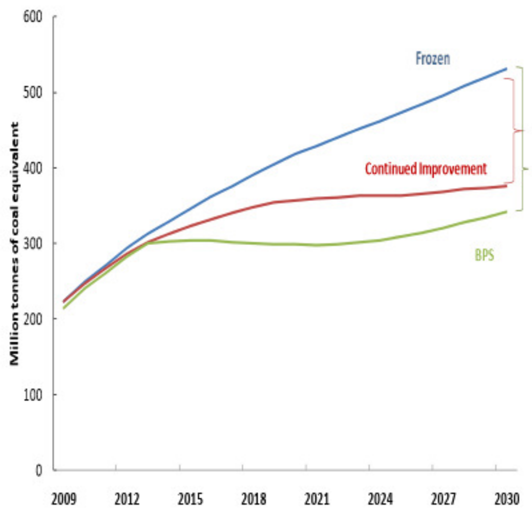


Figure 7. Primary Energy Demand of Different Scenarios

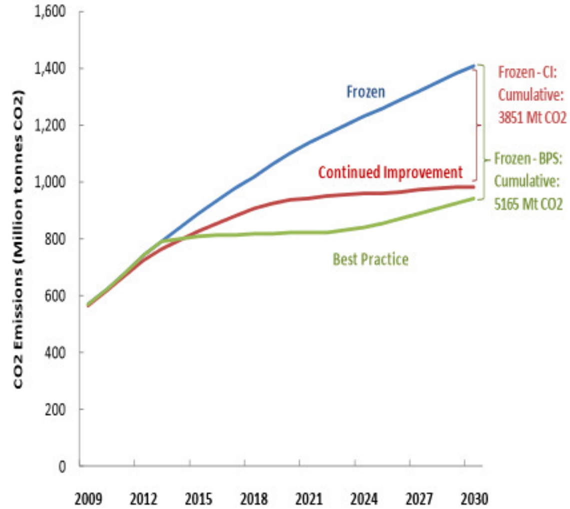
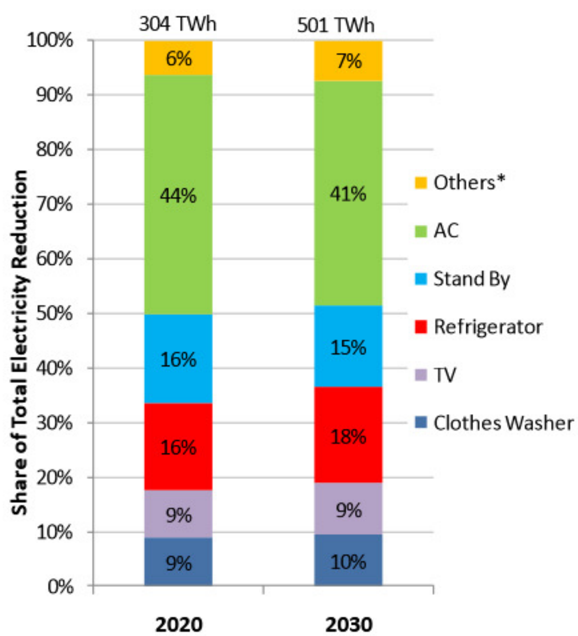


Figure 8. CO2 Emissions of Different Scenarios

Of the reduction from the standards for these products, the air conditioner standard dominates the reduction potential and accounts for 44% of the total reduction in 2020 and 41% in 2030. The second largest contributor is refrigerator standard, which accounts for 16% to 18% of the reduction in these products, followed by standby power include, TV, and clothes washers (Figure 9).



*Others include: TV, standby, transformers, computer servers, clothes washers, electric water heater, electric stove, fluorescent ballast, fans, rice cookers, microwaves, laser printers, fax, copiers, computer monitors, HID lighting, mini and large air compressors, desktop and laptop computers, double-capped fluorescent lamps, rangehoods and vent fans, LED lamps, grid lighting, commercial air conditioners

Figure 9. Contribution to Electricity Savings by Product (Frozen Minus Best Practice Scenario)

4. Outcomes and Conclusions

In a rapidly growing economy like China, energy efficiency is more likely to slow the rate of demand growth than to reduce consumption below current levels. Nevertheless, the efficiency programs modeled in this paper will likely result in significantly lower CO_2 emissions than would have occurred if the programs had not been developed. This analysis is particularly important in highlighting the value of China's standards and labeling programs in the absence of consistent impact evaluations and underscores the program's future energy savings and emission reduction potential.

This paper concludes that under the CIS scenario of regularly scheduled MEPS revisions to 2030, cumulative electricity consumption for all products could be reduced by 9503 TWh, and CO_2 emissions in 2030 would be 16% lower than in the frozen scenario. Under a BPS scenario for a subset of 11 products that account for 22% of the electricity consumption of the larger total set of 37 products, cumulative electricity savings would be 5450 TWh and CO_2 emissions in 2030 would be 35% lower than in the frozen scenario.

Standards in place in China for residential and commercial appliances (excluding motors, transformers, and air compressors) are expected to save a cumulative 6947 TWh by 2030, or 14% of the cumulative consumption of building electricity to that year. Scenario analysis in this study have shown that significant amount of energy savings and emission reduction of similar magnitudes can be achieved either through a large one-time improvement to current international best practice efficiency levels (BPS scenario) or through more frequent and incremental efficiency improvements (CIS scenario) as is the current process for China.

Unlike the U.S. which emphasizes consensus-building amongst multiplicity of stakeholders including government, industry, environmental non-government organizations and consumer groups in the standards development process, China's MEPS are typically updated more frequently but at smaller increments because its process focuses on reaching compromises between government and industry. China's current standards development framework suggests that a CIS path of efficiency improvements is more realistic in the future. Although the scenario analysis show that a process of continued improvement alone can deliver large energy and CO_2 emission reduction, realization of these savings will require continuous strengthening of the standards program.

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