# Impacts of China's 2010 to 2013 Mandatory Product Energy Efficiency Standards: A Retrospective and Prospective Look

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**ABSTRACT**

In 2012, China launched the "Hundred Energy Efficiency Standards" initiative to accelerate the development of energy-saving standards and adopted 21 product mandatory energy performance standards (MEPS) from 2012-2013, compared to only 7 MEPS adopted from 2010 to 2011. These 28 MEPS adopted from 2010-2013 include 12 revised and 16 new MEPS covering residential, commercial and industrial products. China's accelerated adoption of MEPS will help reduce national energy demand and $CO_2$ emissions but the total potential energy and $CO_2$ savings of the newest MEPS have not yet been quantified.

This paper presents an updated analysis of the potential savings of China's 2010 to 2013 MEPS using the latest data on actual and projected sales, market efficiency distribution, and retirement distributions. We collected and compared pre- and post-MEPS efficiency criteria with the 2010 market-average baseline efficiency levels, and used detailed stock turnover models and scenario analysis to quantify the MEPS' potential energy and emissions reductions through 2030. We found that the market-average baseline efficiency of clothes washers and lighting products were already very high prior to the standards revision due to incentive programs, with no attributable MEPS savings. From the selected 23 MEPS evaluated in this study, total annual savings could reach 135 TWh - the equivalent output of 28 typical coal-fired power plants – and 130 Mt $CO_2$ by 2030 with largest savings potential from motors, televisions, and electronics.

## Introduction

In 1989, China introduced the first national mandatory minimum energy performance standards to target improving minimum efficiencies for eight of the highest energy-consuming and most popular household appliances. Since then, China has rapidly expanded its MEPS program to become one of the world's largest programs, covering not only common household appliances, but also lighting products, office and commercial equipment, transport and industrial equipment. In comparison, the U.S. started its MEPS program in 1978 and now also covers more than 60 products. As of 2015, China had adopted a total of 57 MEPS, covering 15 household appliances, 13 lighting products, 14 industrial equipment, 5 office equipment and 10 commercial equipment.

Over the last five years, the pace of standards development for both new and revised standards has been accelerated under the national "100 Energy Efficiency Standards" initiative launched by the National Development Reform Commission (NDRC) and Standardization Administration of China (SAC) in June 2012. The initiative aimed to adopt 100 energy-saving standards by the end of 2012, including energy consumption limits for energy-intensive industrial production processes, MEPS for products and equipment, and standards for energy measurements, energy management and energy audits for enterprises. By the end of 2012, a total of 109 new standards had been published. A second phase of the "100 Energy Efficiency Standards" has been initiated for 2014 to 2015, with the aim of adopting another 100 new and revised energy-related standards over these two years. As part of the two phases of "100 Energy Efficiency Standards" initiative, an unprecedented 21 new and revised MEPS for products were adopted by China from 2012 to 2013, compared to only 7 new and revised MEPS adopted from 2010 to 2011. China adopted 21 new product MEPS from 2010 to 2014 and increased the total product coverage of its MEPS program by over 30%.

These new and revised standards are expected to help contribute to both national 12th Five-Year Plan (FYP) targets for reducing energy and carbon intensity per unit of GDP, respectively, by 16% and 17%, as well as the longer-term Copenhagen Accord $CO_2$ intensity reduction target for 2020 and the most recently announced $CO_2$ peaking target and intensity reduction target for 2030 (NDRC 2015). While the potential savings of each new or revised standard is estimated when the standard is developed, those estimates lag behind rapid changes in the market and sales trends. For example, the ex-ante assessment of a 2011 MEPS only considers market trends and actual sales prior to 2010 when the standard is developed. This study considers all available data and market trends through 2013 and quantifies the total potential impact of these new and revised standards on China's national energy and $CO_2$ emissions..

Similarly, their combined contribution to the national energy and carbon intensity reduction targets are not known. A previous 2011 study (Zhou et al. 2011) evaluated the total potential impacts of China's standards and labels for 37 products that had been implemented as of 2009, assuming continuous improvement of these standards over time. This study seeks to update that prospective evaluation of China's MEPS program by quantifying the additional potential energy and $CO_2$ reductions from only the newest standards that have been adopted since 2010. Unlike the 2011 study, this study focuses on quantifying only the impact of the newest standards adopted from 2010 to 2013 from 2010 through 2030, and does not attempt to evaluate the additional savings from continuous improvement of the new standards over time.

## Scope of Analysis

This study evaluated the impact of 23 of the 28 new and revised MEPS that were adopted by China between 2010 and 2013. There were five MEPS[1] that were excluded from our analysis due to limited data and narrow scope of these five industrial and commercial products. The 23 analyzed MEPS were grouped into 14 major product categories, with some MEPS for product technologies (e.g., room air conditioners, lighting technologies) combined into one overarching product category. Table 1 shows the product categories and sub-categories included in our analysis.

[1] The excluded MEPS covered centrifugal blower fan, permanent magnet asynchronous motors, cage three-phase high voltage induction motors, lithium bromide absorption chillers and commercial refrigerated display cabinets with remote condensing units.

Table 1. Product Scope for Analyzing 2010 – 2013 Product MEPS

| Sector | Product category | Product sub-category for technology |
|---|---|---|
| Residential | Room air conditioner (2 MEPS) | Fixed-speed |
| | | Variable-speed |
| | Televisions (2 MEPS) | LCD |
| | Television set-top box (1 MEPS) | |
| | Clothes washer (1 MEPS) | Front-load/Horizontal impeller |
| | | Top-load/Vertical drum |
| | External power supplies (1 MEPS) | |
| | Microwave (1 MEPS) | |
| | Kitchen rangehood (1 MEPS | |
| | Heat pump water heater (1 MEPS) | |
| | Solar water heater (1 MEPS) | |
| | Computer (1 MEPS) | Desktop |
| | | Laptop |
| | Multi-functional imaging equipment (copier/printer/fax machine) (1 MEPS) | |
| | Refrigerator (1 Draft MEPS) | |
| Lighting | Lighting (8 MEPS) | CFL |
| | | Linear Fluorescent |
| | | LED |
| Industrial | Three-phase distribution transformers (1 MEPS) | Small, Medium and Large sizes |
| | Small and medium three-phase asynchronous motors (1 MEPS) | Small, Medium and Large sizes |

## Modeling Methodology

A bottom-up energy end-use modeling framework is used for analyzing the expected change in appliance and equipment ownership, usage, and energy efficiency from the base year of 2010 through 2030. Major drivers for increased appliance and equipment ownership and usage for some products are economic activity (e.g., household income, GDP growth and GDP per capita growth), persons per household, dwelling area and urbanization rates. The projection of the sales for these products is made based on stock and vintage analysis where possible. For key household appliances, a 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 other products, particularly industrial and commercial products, where saturation forecasts are not feasible, sales forecasts are used to project future sales and to calculate the stock for a given year.

For each product, lifetime assumptions, historical and projected Chinese sales and stock data were provided and/or reviewed where possible by the China National Institute of Standardization (CNIS), the technical body responsible for developing MEPS and managing the mandatory energy labeling program in China. The most up-to-date data was also collected from Chinese statistical sources, published market studies, analysis of recent growth trends, and historical experiences of other developed countries. All of this data is used in shipments and diffusion rate calculations that feed into the stock turnover model. More specifically, calculation of unit equipment sales (shipments) and stock turnover is essential in understanding the rate at which products enter households and thus impact the overall energy consumption. This shipments rate impacts both the base case and the MEPS scenario. 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. The first purchases are the increase in the product stock from one year to the next, driven by increased ownership, increased market saturation of new technologies or urbanization. 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 a normal distribution around the average lifetime of the product. A detailed discussion of the stock turnover modeling methodology with underlying equations can be found in McNeil et al. 2011.

## Scenario Analysis and Efficiency Assumptions

Two efficiency scenarios are developed to evaluate the impact of the MEPS adopted between 2010 and 2013: a counterfactual baseline scenario and a MEPS scenario. The baseline scenario, or what is commonly known as a counterfactual "frozen" scenario, is used to evaluate the impact of S&L programs based on the absence of any appliance efficiency policy. It assumes that an appliance's energy intensity as measured by its unit energy consumption (UEC) per year is frozen at the average baseline level prior to the implementation of the new or revised MEPS. Due to limited data on the autonomous market and technological improvement trends of each individual product type, we do not attempt to account for autonomous efficiency change in the baseline scenario, which could result in over-estimated savings potential from MEPS. For this study, the baseline is set by calculating the UEC based on one of two levels:

- New MEPS Products and Selected Products with Revised MEPS: the reported 2010 market (e.g., sales-weighted) average efficiency of that product if sales-weighted efficiency data is available
- Most Products with Revised MEPS: the minimum efficiency requirement of the previous MEPS for products that were already covered by MEPS

For selected major household appliances that were covered by a previous MEPS prior to 2010, the preferred baseline efficiency level is set at the reported 2010 sales-weighted reported average efficiency level if this data is available. For these key energy-consuming residential products, the actual market average efficiency is used where possible because using the previous MEPS level as a market-average baseline is likely outdated and will not reflect market transformation that has occurred since the previous MEPS was implemented. This could result in underestimated market-average efficiency, and overestimating the savings potential of the revised MEPS. This is particularly true for products such as room air conditioners, clothes washers, televisions, and lighting products, which were included in the "Benefit to the People" Energy Efficient Subsidy[2] program and lighting subsidy program that began in June 2009 and continued through 2012. For these products, the subsidy dramatically increased the market adoption of energy efficient models. As a result, the sales-weighted, market average efficiency for these products in 2010 was already equal to or higher than the subsequent revised MEPS

[2] These subsidy programs provided an upstream subsidy to manufacturers for products that are labeled as "efficient" in the China Energy Label program and purchased by qualifying consumers.

level. In these cases, we used the 2010 sales-weighted average efficiency reported in the annual CNIS White Papers rather than the previous MEPS as the baseline (CNIS, various years). For products that were not previously covered by a MEPS, the baseline efficiency was also set at an average efficiency level for the 2010 market. This average efficiency level was determined through literature review and online searches of the best available market efficiency data, or based on CNIS input where possible.

The second scenario is a MEPS scenario which is used to measure the impact of the 23 new or revised MEPS implemented between 2010 and 2013. Under the MEPS scenario, the UEC of a given product is calculated using the minimum efficiency requirement set by the new or revised MEPS. The UEC of a given product will decrease from the baseline level to the new MEPS level beginning with the year that the MEPS is implemented and is expected to remain constant thereafter. In other words, for every product, there is a one-step improvement in efficiency and decrease in UEC that is directly attributed to the adoption of the new or revised product. In the absence of sufficient data, we make the simplifying assumption that for all products, the MEPS have 100% compliance although this is unlikely to be the case for all products. Previous pilot energy performance check-testing in different Chinese cities found that most products have high overall compliance rates of over 70% but few products achieved 100% compliance (Xia et al. 2010). Because this study is focused solely on quantifying the specific impacts of MEPS adopted from 2010 to 2013, future expected improvements in efficiency as a result of future standard revisions are not considered in this study as it was considered in the previous 2011 study.

For each of the two scenarios, the specific efficiency criteria for each product are determined through technical analysis of the MEPS documents, literature review and online research of product-specific market efficiency trends, and discussions with Chinese experts from CNIS. These efficiency criteria are then combined with data on typical usage patterns such as average hours of active mode or standby mode power consumption derived mostly from data obtained in the first China Residential Energy Consumption Survey by Renmin University (Zheng et al. 2014) or from Zhou et al. 2011. Table 2 shows the baseline and MEPS unit energy consumption for the 14 product categories and the efficiency improvement attributed to the new or revised MEPS.

Table 2. Baseline and MEPS Efficiency Parameters for Impact Analysis

| | MEPS years | Baseline UEC (kWh/unit/yr) | MEPS improvement in efficiency criteria (%) | MEPS UEC (kWh/unit/yr) |
|---|---|---|---|---|
| Fixed-speed Room AC | 2004, 2010 | 129 | 2% | 126 |
| Variable-speed Room AC | 2008, 2013 | 108 | 11% | 96 |
| LCD-LED TV | 2010, 2013 | 128 | 31% | 95.3 |
| Top-load Clothes Washer | 2004, 2013 | 26 | 1% | 25.9 |
| Front-load Clothes Washer | 2004, 2013 | 247 | 0% | 247 |
| Microwave | 2010 | 74 | Standby only: 50% | 65 |
| Copier/Printer/Fax | 2010, 2014 | 530 | 40% | 389 |
| Desktops | 2012 | 250 | 11% | 225 |
| Laptops | 2012 | 70 | 10% | 63 |
| Rangehood | 2013 | 62 | Active mode: 33%<br>Standby mode: 50% | 37 |
| TV Set-top Box | 2010 | 60 | Active mode: 17%<br>Standby mode: 50% | 34 |
| Heat Pump Water Heater | 2013 | 317 | 17% | 271 |
| CFLs | 2003, 2013 | 20.3 | N/A | 21.1 |
| Linear Fluorescent Lamps | 2003, 2013 | 21.1 | 0% | 21.1 |
| External Power Supplies | 2007, 2013 | 80 | Active mode: 8%<br>Standby mode: 60% | 77 |
| Small Motors: 0.75 - 7.5 kW | 2006, 2012 | 2,750 | 7% | 2,574 |
| Medium Motors: 7.5 - 75 kW | 2006, 2012 | 44,000 | 2% | 43,314 |
| Large Motors: > 75 kW | 2006, 2012 | 770,000 | 0% | 770,000 |

Note: The 2010 sales-weighted lumens per watt for CFLs were higher than the 2013 MEPS requirement, resulting in higher MEPS UEC.

## Results of the Impacts of 2010-2013 MEPS on Electricity and $CO_2$ Emissions

The total energy consumption of each product (measured in terms of electricity) is calculated annually from 2010 to 2030 by the model using assumptions about annual unit energy consumption, lifetime, and calculated stock. Since the only difference among the two scenarios is the efficiency levels of the product as a result of the new MEPS implementation, the difference in energy consumption between the baseline and MEPS scenarios is taken as the energy savings attributable to the MEPS adopted between 2010 and 2013. The $CO_2$ emissions results are calculated from the electricity results by multiplying kWh consumed by a dynamic, projected $CO_2$ emissions factors for electricity that take into consideration China's evolving fuel mix for the power sector that emphasizes more renewable and nuclear power generation over coal-fired generation until 2030.

**MEPS Electricity Savings**

The one-time adoption of the 23 new or revised MEPS from 2010 to 2013 for the 19 categories of products evaluated in this study could reduce cumulative electricity consumption by 1517 TWh between 2010 and 2030 compared with the baseline scenario without these new or revised MEPS as seen in Table 3.

Table 3. MEPS Annual and Cumulative Electricity Savings by Product

| | 2015 (TWh) | 2020 (TWh) | 2025 (TWh) | 2030 (TWh) | 2010 – 2030 Cumulative Savings (TWh) |
|---|---|---|---|---|---|
| Room AC: Fixed Speed | 0.3 | 0.3 | 0.1 | 0.0 | 4.0 |
| Room AC: Variable Speed | 0.8 | 3.2 | 5.2 | 6.3 | 64.4 |
| TV | 5.6 | 14.0 | 17.2 | 18.1 | 235.8 |
| Clothes Washers: Front Load | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Clothes Washers: Top Load | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| CFLs | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Linear Fluorescent Lamps | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Small Motors | 5.8 | 16.5 | 25.9 | 31.6 | 333.4 |
| Medium Motors | 3.0 | 8.8 | 15.1 | 19.9 | 192.5 |
| Large Motors | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| External Power Supplies | 4.8 | 10.5 | 13.0 | 15.8 | 186.3 |
| Microwave | 0.4 | 0.7 | 0.8 | 1.0 | 13.0 |
| Copier  Printer and Fax Machine | 2.3 | 8.0 | 12.4 | 14.5 | 155.3 |
| Desktop Computer | 3.9 | 5.8 | 6.1 | 6.4 | 98.2 |
| Laptop Computer | 1.0 | 1.5 | 1.8 | 2.1 | 27.5 |
| Rangehood | 1.1 | 3.6 | 6.3 | 9.0 | 80.5 |
| Heat pump water heaters | 0.1 | 0.4 | 0.9 | 2.0 | 12.0 |
| Set-top box | 3.4 | 4.7 | 5.9 | 7.6 | 95.0 |
| Distribution Transformers | 0.8 | 1.0 | 1.0 | 0.8 | 18.9 |
| *Total* | *33.4* | *78.9* | *111.8* | *135.1* | *1517.2* |

Televisions and electric motors are the two products with the largest MEPS electricity savings, together accounting for more than half of the annual electricity savings from 2020 onwards as seen in Figure 1. Despite a lower absolute unit energy savings under the revised MEPS when compared to the 2010 weighted-average market efficiency, televisions still hold relative large energy savings potential as a result of having the largest projected sales amongst all residential and commercial equipment. Small motors alone account for nearly one-quarter of the annual electricity savings because of the large stock of small motors and the large absolute unit energy savings between the old and revised MEPS. In cumulative terms, the total reduction from the revised motors standard amounts to 333 TWh for small motors and 193 TWh for medium motors, while the revised standard for flat panel televisions could save 234 TWh from 2010 to 2030. Clothes washers, CFLs and linear fluorescent lamps have virtually zero electricity savings from the revised MEPS because the 2010 sales-weighted baseline efficiency was the same or worse than the revised MEPS efficiency requirement as previously documented in Table 1.

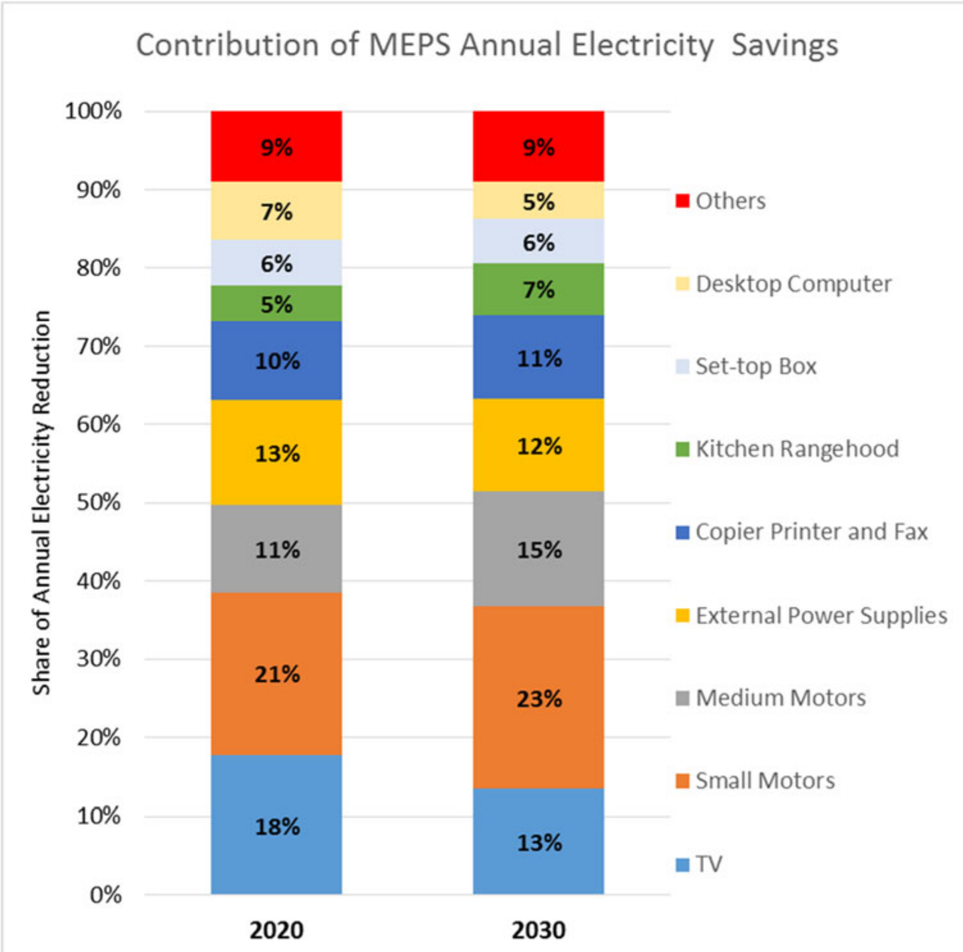


Figure 1. 2020 and 2030 MEPS Annual electricity Savings by Product Shares

Note: Others include fixed speed and variable speed room AC, top-load clothes washers, microwave, laptop computer and heat pump water heaters, distribution transformers. No savings for CFL, front-load clothes washer and refrigerators.

In our 2011 analysis, motors and air conditioners were identified as the two products with the greatest savings potential from revised MEPS. The savings potential for the revised 2013 variable-speed room air conditioner MEPS is smaller in this analysis because the market-average efficiency has increased significantly over the last decade, resulting in a relatively high 2010 baseline efficiency of 3.95 SEER versus the revised 2013 MEPS requirement of 4.41 SEER. The market transformation that has occurred for room air conditioner markets can be traced back to the impact of the high efficient room air conditioners subsidy program that was launched in June 2009. Corresponding to the duration of the subsidy program, the share the most efficient Grade 1 and efficient Grade 2 variable-speed room air conditioners of total models on the market increased from only 17.5% in 2008 to 59% in 2009 (CNIS 2010). Nevertheless, the expected increase market share of variable-speed room air conditioners coupled with large absolute sales still results in annual MEPS savings of 6 TWh in 2030 and cumulative savings of 64 TWh from 2010 to 2030.

Figure 2 compares the 2020 and 2030 annual electricity savings from the one-time adoption of the 23 new and revised MEPS compared to electricity supply-side options. In 2030, the annual electricity savings is equal to the electricity output of 28 typical 1-GW Chinese coal-fired power plants with 38% assumed generation efficiency and average capacity factor of 55%. The 2030 annual electricity savings is also equal to 1.3 times the annual output of the Three Gorges Dam with total installed capacity of 22.5 GW and average capacity factor of 50%.

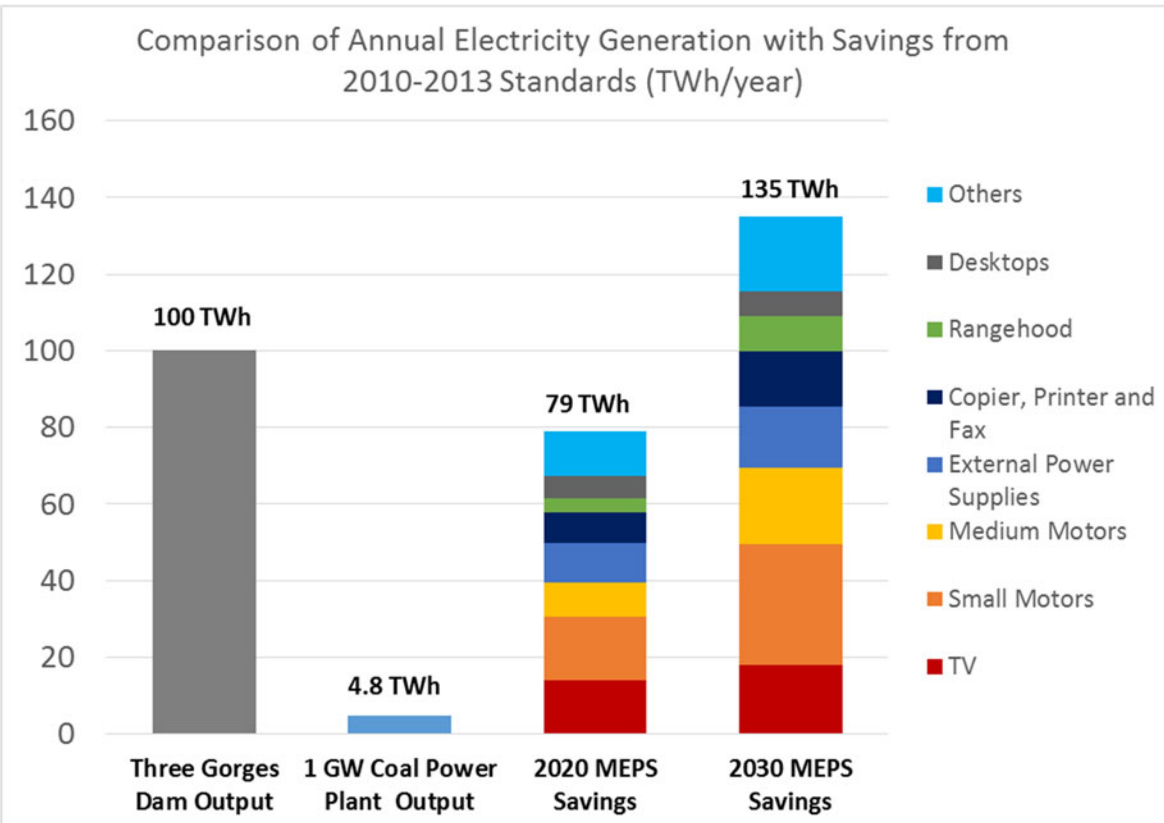


Figure 2. Comparison of 2020 and 2030 Annual Electricity Savings from 2010-2013 MEPS with Electricity Generation Supply Options

## MEPS $CO_2$ Emissions Reductions

Over the period of 2010 through 2030, these electricity savings would result in cumulative $CO_2$ emissions reduction of over 1.5 billion tonnes assuming an increasingly decarbonized power supply. In 2030, annual $CO_2$ emissions could be reduced by 130 Mt $CO_2$ as a result of the electricity savings achieved by the one-time adoption of new or revised MEPS between 2010 and 2013 as seen in Figure 3. The relative contribution to $CO_2$ emissions reductions from MEPS by product follow closely to the electricity results, as all of the products analyzed used electricity.

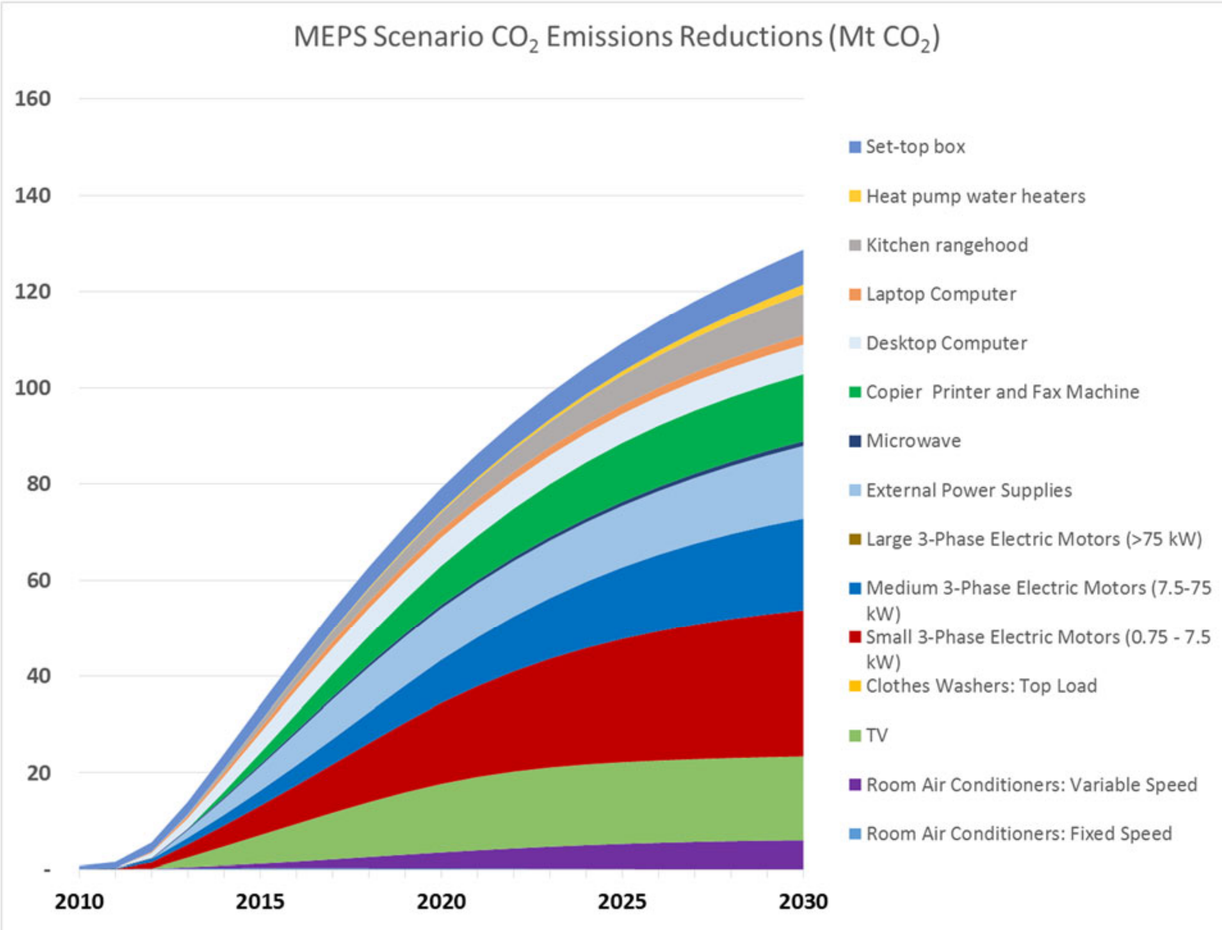


Figure 3. Annual CO2 Emissions Reduction by Product from One-time Adoption of New or Revised MEPS

## Conclusions and Policy Implications

The results of our analysis suggest that the full implementation of the 23 new or revised MEPS adopted by China between 2010 and 2013 have significant electricity savings and CO2 emissions reduction potential on the order of 135 TWh and 130 Mt $CO_2$ annually by 2030, but the savings potential vary significantly by product. Some products, such as televisions, external power supplies and industrial motors, have significant savings potential for different reasons. Motors have very large improvement potential because it is a very energy-intensive type of equipment used by all industrial subsectors where overall efficiency is still relatively low, but full realization of this savings potential will depend on full enforcement of the motors MEPS, which has been more difficult to achieve in China and internationally (Delaney 2015). In previous pilot check-testing conducted in 2009 and 2010, electric motors were found to have the lowest compliance levels amongst all products tested (Xia et al. 2012). The relatively large savings potential of the revised televisions and external power supplies MEPS can be traced back to the expected fast growing sales forecast for both consumer electronic products, as the incremental efficiency gain and UEC reduction is relatively small.

For other products including CFLs, front-load clothes washers, fixed-speed room air conditioners and distribution transformers, some revised MEPS actually had limited or no impact on energy savings and $CO_2$ emissions reduction. Both CFLs and clothes washers faced a long time lag of 9-10 years between MEPS revisions, during which the market uptake of more efficient products occurred quicker than expected as a result of the high efficiency lighting and appliances subsidies. Distribution transformers also had a 7 year interval between MEPS revisions and were not covered by efficiency subsidy programs, but the markets for both oil-filled and dry-type transformers also moved quickly towards efficiency levels at or beyond the revised MEPS requirements. One possible explanation for this is that electric utilities, unlike average residential consumers, have a greater financial incentive to invest in more efficient distribution transformers because the losses directly impact their electricity sales profits.

This study is a theoretical evaluation of the potential energy savings and CO2 emissions of China's 2010 to 2013 MEPS based on simplifying assumptions and do not explicitly account for rebound effects or autonomous efficiency gain in the baseline scenario. While additional data can help refine the estimates, the relatively order of magnitude of savings will unlikely change although the absolute energy savings estimates may be over-estimated or under-estimated to some degree. The limited or no impacts from the revised MEPS for CFLs, front-load clothes washers, fixed-speed room air conditioners, and distribution transformers suggest that understanding market dynamics are crucial to the development of effective and impactful MEPS. Properly characterizing the market dynamics related to MEPS development and revisions as well as other concurrent policy developments such as wide-ranging subsidy programs and emerging technological trends are needed when evaluating the market baseline and proposing new or revised MEPS efficiency thresholds. More real-time, up-to-date market data can help capture rapidly changing market trends and help set a more relevant market baseline, but this type of data is currently difficult to acquire given the constrained financial and human resources for MEPS development in China. New analytical tools and more in-depth analysis for specific products such as televisions may help, as well as methodologies to further refine impact evaluations that can differentiate the market transformation impacts of multiple programs including MEPS, labeling and subsidy programs.

Despite the market transformation that has occurred as a result of other policies such as subsidies, MEPS remains a very effective tool for significantly raising the market efficiency because it is a mandatory policy that affects all products on the market. Improving the stringency of future MEPS is still key to capturing greater electricity savings and $CO_2$ emissions reductions from efficiency improvements. This is particularly true for a country like China that revises its MEPS iteratively every few years versus the U.S. where MEPS are revised less frequently but with much greater incremental efficiency improvement. Therefore, MEPS continue to be a crucial tool for improving end-use product energy efficiency.

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