New Equipment Efficiency Standards: An Opportunity to Achieve Substantial Energy Savings and Emission Reductions in China

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ABSTRACT

China's rapid economic growth in recent years has been accompanied by large increases in energy use and increasingly severe environmental problems. Implementation of energy efficiency standards is an effective means to improve energy efficiency and realize energy savings. Analysis of energy saving potential quantifies the potential costs and benefits of possible new standards. In those cases where the benefits are large, policy-makers are encouraged to pay more attention to the standards program. Such analyses also provide a scientific reference to help set priorities among candidate products. This paper introduces briefly the methodology and results of energy saving potential analysis for standards in China. The cogent findings indicate setting energy standards for major household appliances and office equipment not only saves energy but also saves more than Chinese RMB 100 billion Yuan (more than $10 billion U.S. dollars) and helps to mitigate climate change. It is urgent to develop mandatory energy efficiency standards for these products in the very near future to realize the substantial energy saving potential and the associated environmental and economic benefits.

Introduction

In the mid- and late-1980s, China drafted and promulgated a first batch of energy efficiency standards for household appliances covering domestic refrigerators, room air conditioners, household washing machines, and color TV sets. These standards were intended to eliminate products then considered high energy consuming/low efficiency, but fell short of this goal given the technical limitations at that time. This was in part due to the lack of rigorous technical and economic analysis during the preparation of these standards. Thus the implementation of these standards did not achieve the desired energy saving effects. In 1995, the China National Institute of Standardization (CNIS) began revision of the first batch of energy efficiency standards while simultaneously initiating new standards as well. Today, much progress has been made but the product coverage of standards is still relatively narrow with many major appliances used in residential and commercial buildings yet to be covered. Furthermore, the existing energy efficiency criteria including the "energy efficiency limiting value" (mandatory minimum-efficiency standard) and the "energy conservation evaluating value" (voluntary recommended efficiency level) are not very stringent by international standards. Thus the energy savings expected from these standards, while worthwhile, fall well short of the technical or economic potential.

The energy efficiency gains achieved in the past decade in China, despite the above limitations, suggest considerable energy saving potential is available by extending the standards programs to additional household appliances as well as increasing the stringency of existing

energy efficiency standards. With support from the China Sustainable Energy Program of the Energy Foundation (EF), and with help from the American Council for an Energy-Efficient Economy (ACEEE), CNIS conducted a national-scale analysis to estimate the overall energy saving potential from establishing efficiency standards for more than a dozen types of products and equipment. The research analyzed several metrics for savings including energy and economic savings and reductions in emissions and peak demand. This paper presents the analysis results for residential appliances, consumer electronics, and office equipment. The findings show that large energy, environmental, and economic benefits can be achieved through a new, more stringent energy standards programs. Hopefully these findings can be used as the basis to persuade the Chinese government to accelerate the development and extend the product coverage of these energy efficiency standards.

Product Coverage

Products covered by this study can be divided into two categories, specifically:

- Household appliances: TVs, room air conditioners, refrigerators, rice cookers, freezers, and washing machines
- Standby power for consumer electronics and office equipment: microwave ovens, laser printers, facsimile machines, copiers, and computer displays

The overall analysis also examined industrial equipment as well, but the industrial results are discussed in another paper (Liang 2003).

Methodology

The general methodology used for this study is based on an approach previously used in the U.S. (Kubo et al. 2001) but adapted for use in China. In the sections below we briefly summarize this methodology, as it was applied in China.

Setting a Baseline

The objective of this energy saving potential analysis was to calculate the prospective energy savings that could result from energy efficiency improvements by implementing new minimum energy performance standards. The analysis began with consideration of a baseline defined as the expected trend in energy efficiency level of new products in the absence of new or revised efficiency standards. For products that already had efficiency standards, a baseline model of energy efficiency approximately equal to the existing minimum-efficiency requirement was chosen. We also considered the current market share of products exceeding the current standard and incorporated this information into the baseline. For products without an existing efficiency standard, a baseline model was set according to current average energy efficiency levels estimated or determined from discussion with manufacturers, trade associations, institutes, testing laboratories, government agencies, and information organizations.

Proposing New Standards

After consultation with international and local experts on the market for and efficiency level of different products, a range of new proposed energy standards and their prospective dates for implementation were developed for each product taking into account: (1) international benchmarks of energy efficiency levels for equivalent products; (2) the best current Chinese products; (3) development and availability of new energy conservation technologies for these appliances and equipment; and (4) the capability of domestic manufacturers to produce high-efficiency products.

Calculating National Energy Savings

Because the proposed energy efficiency standards are mandatory, all relevant products sold will, in theory, meet the new standard(s) and the energy savings during their lifetimes will be proportional to the increase in energy efficiency defined in the standard. In cases where new standards are not implemented, it is assumed that energy efficiency levels remain at baseline levels. Once the new standards are set, efficiency levels are assumed to rise to the specified level required by new standards and remain at this level for the remainder of the analysis period. In reality, product energy efficiency is likely to gradually increase, even in the absence of new efficiency standards. In addition, some products will be sold with higher energy efficiency than required by the new efficiency standards. Since this is an initial analysis, rather than attempt to quantify these trends, we implicitly assume these factors counterbalance each other.

The equations for end-use electricity savings and primary energy savings are as follows:

End-use electricity savings = per-unit electricity or coal savings × inventory
Primary energy savings = end-use electricity savings ÷ T&D loss factor × heat rate

Here the inventory of new efficient products means quantity of all equipment meeting new efficiency standards and not yet retired by the year in the forecast (i.e., 2010 or 2020). It should be noted that the savings from units installed during the forecast year will be equivalent to only half-year sales times annual savings per unit, to account for assumed uniform sales throughout the purchase year. For heat rates (primary energy input required to generate a unit of electricity, in grams of coal equivalent per kWh [gce/kWh]), we used 359.6 gce/kWh for 2010 and 334.8 gce/kWh for 2020. We used a loss factor of 0.925 to cover transmission and distribution (i.e., a 7.5% T&D loss). These estimates come from studies by the workgroup on statistical data of the China Electric Power Information Center (2001).

Calculating Emission Reductions and Economic Benefits

The equation for calculating carbon, nitrogen oxide, sulfur dioxide, and particulate emissions reductions is as follows:

Emission reductions = end-use electricity savings ÷ T&D loss factor × emission factors

The emissions factors for carbon, NOx, SOx, and PM10 are 0.267 kg/kWh, 4.07 g/kWh, 5.84 g/kWh, and 24.8 g/kWh, respectively. These estimates come from a statistical report by the

World Bank (Fridley 2000) and studies by the Chinese Research Academy of Environmental Sciences in 2000 (Wang 2002).

We determined the financial savings by multiplying current residential and commercial electricity rates by the energy savings, while we calculated financial costs by multiplying the per-unit incremental purchase cost for each product by the number of units sold. Present value (PV) calculations are discounted to 2000 using a 7.6% discount rate. This discount rate comes from a research report on the development of a lighting standard (Chen 2002). Net present value (NPV) of investment sums the present value of annual investments from the effective date of each standard through 2020. The NPV of savings sums the present value of annual utility bill savings. These include savings from products installed from the effective date of the standard up to the year 2020. The NPV also includes those savings that accrue beyond 2020 up to the time of their retirement for equipment sold up to 2020. NPV is calculated as:

$$NPV\ of\ investment = \Sigma\{PV(annual\ sales\ volume \times per\text{-}unit\ incremental\ cost)\}$$
$$NPV\ of\ savings = \Sigma\{PV(end\text{-}use\ energy\ savings \times energy\ price)\}$$

We used a residential electricity rate of RMB0.46Yuan/kWh (0.056US$/kWh) and a commercial electricity rate of RMB0.84Yuan/kWh (0.101US$/kWh), which are average figures for 2000 (Liu 2002). In all likelihood electricity prices will increase in China and therefore our estimates of financial savings are probably conservative.

Calculating Peak Demand Reductions

The utilization of some appliances (for example, air conditioners) correlates highly with summer peak load. Many areas of China are now experiencing summer system peak loads in part due to an increase in air conditioner ownership and use as well as rapid load growth in all sectors. This is driving investment in new electricity generation which requires substantial capital investment. Setting standards on these products will produce significant benefits from peak demand reductions. Peak demand reduction is calculated as:

$$Peak\ demand\ reductions = end\text{-}use\ electricity\ savings \div T\&D\ loss\ factor \times reserve\ factor \times peak\ factor$$

The peak factor for each appliance is the average coincident power demand of the appliance during peak periods divided by the annual electricity consumption of the appliance. Peak factors were estimated by project staff by taking estimated annual operating hours and allocating these to different seasons and times of the day based on available data and professional judgment. These estimates are subject to substantial uncertainty and peak savings results should be regarded as indicative only until field data on peak period electricity use by different products can be collected. In our calculations, we also used a 1.15 reserve factor (a 15% reserve margin).

Table 1 summarizes general assumptions used to estimate savings.

Table 1. General Assumptions across all Products

T&D loss factor:	0.925（7.5% loss）
Reserve factor:	1.15（15% reserve margin）
Residential electricity rate:	RMB 0.46Yuan /kWh
Commercial electricity rate:	RMB 0.84Yuan /kWh
Discount rate:	7.6%
Heat rate (2010):	359.6 gce/kWh
Heat rate (2020):	334.8 gce/kWh
Carbon emission factor:	267.27 g/kWh
NOx emission factor:	4.07 g/kWh
SO_2 emission factor:	5.84 g/kWh
PM10 emission factor:	24.80 g/kWh

Analysis Results

Baseline and Proposed New Standards

Table 2 summarizes the baseline and proposed new standards for these candidate products as included in the analysis.

Estimated Energy Savings and Economics of Proposed New Standards

Table 3 summarizes the potential for energy and economic savings from adopting national minimum-efficiency standards for the above products.

Estimated Summer Peak Load and Pollutant Reductions from New Standards

Table 4 shows the potential peak load and emission reductions from adopting these standards.

Conclusion

From the analysis above, we can see clearly that the energy saving potential from energy standards on residential appliances and consumer electronics/office equipment is approximately 39.2 TWh and 5.4 TWh, respectively, in 2010 and 65.9 TWh and 10.4 TWh, respectively, in 2020 (refer to Table 5 for details). According to the initial forecast of power departments, the growth rate of electricity demand in China in the next 10–15 years is forecast to be 6% per annum, and the proposed efficiency standards will slow the predicted increase in power demand by about 5.7% if they are implemented in the timetable proposed.

These standards will also save consumers a substantial amount of money. Over the forecast period, these standards will save RMB182 billion Yuan for products purchased over the period from standard effective date to 2020, which is 4.1 times greater than the estimated RMB 44 billion Yuan in increased equipment costs due to standards over this period. The net present value benefits of these standards will total RMB 138 billion Yuan over this period (see Table 5), which is equivalent to $16.7 billion U.S. dollars at current exchange rates.

Table 2. Baseline and Proposed New Standards

Product	2000 National Sales (million)	Annual Growth in Sales %	Baseline/ New Standard	Units	Basis for New Standard	Average Product Life (years)	Effective Date (year)
Residential							
TVs (active mode)	19.92	3.5	80/70	W	Based on Japan Top Runner	8	2004
Room AC	17.3	5.0	2.5/2.8	EER(W/W)	Min. LCC on previous analysis	8	2004
Refrigerator	9.26	3.2	1.10/0.7	kWh/24h	Min. LCC on previous analysis	11	2003
Rice cooker	12.978	6.0	76/86	Heat eff.(%)		5	2005
Freezer	3.84	3.5	1.50/1.20	kWh/24h	Min. LCC on previous analysis	11	2003
Washing machine							
Impeller	9.79	1.0	0.032/0.027	kWh/kg/cycle	GB12021.4	10	2004
Drum	1.32	2.0	0.35/0.31	kWh/kg/cycle	GB12021.4	10	2004
Standby Power							
TVs (standby mode)	19.92	3.5	8.1/3	W	Energy Star	8	2004
Microwave oven	2.00		2.7/1	W	IEA“1W”	8	2006
Laser printer (<10ppm)	0.59	15.0	20/10	W	Energy Star	5	2004
Facsimile machine (<10ppm)	1.96	15.0	6.8/3	W	IEA“1W”	3	2006
Copier (<20cpm)	1.56	14.0	12.0/5	W	Energy Star	8	2006
Computer display	8.68	13.0	5.43/2	W	Energy Star	5	2004

As an additional benefit, the proposed efficiency standards will have a significant impact on reducing summer peak load and helping to balance peaks and valleys. We estimate that the standards would save a total of about 16.65 GW of peak power in the year 2020. This is roughly equal to the generating capacity of 55 average power plants of 300 MW each. The peak load reduction would make some future new power plant construction unnecessary and improve electric system reliability. At recent power plant construction rates, the proposed new standards would offset about one year of new power plant additions.

In addition, the reduction of energy consumption would reduce emissions of carbon dioxide, sulfur dioxide, nitrogen oxides, toxic gases, and particulates from coal combustion in power plants. From Table 6, we can see emissions reductions from the reduced energy consumption are significant. In the year 2020, 22.03, 0.34, 0.49, and 2.05 million tons of carbon, NOx, SO_2, and PM_{10} could be reduced, respectively, which would help mitigate environmental problems such as the greenhouse effect, photochemical smog, and acid rain. This would obviously be important for improving China’s environmental quality and improving the quality

of life. For example, the 2020 carbon emission reductions are equivalent to the annual carbon emissions from nearly one million average passenger cars.

Table 3. Estimated Energy Savings and Economics of Proposed New Standards

Products	Effective Year	Energy Savings in 2010		Cumulative Savings from Effective Year to 2010		Energy Savings in 2020		Cumulative Savings from Effective Year to 2020		Net Benefits (NPV Benefits - Costs) RMB Million Yuan	Benefit-Cost Ratio
		TWh	MTce	TWh	MTce	TWh	MTce	TWh	MTce		
Residential											
TV	2004	3.07	1.19	11.20	4.41	4.79	1.73	53.09	20.05	8946	5.8
Room AC	2004	13.39	5.21	47.82	18.82	20.04	7.25	229.40	86.63	30925	3.0
Refrigerator	2003	12.65	4.92	51.86	20.46	21.78	7.88	244.48	92.35	45729	9.1
Rice cooker	2005	4.69	1.82	16.58	6.51	8.41	3.04	82.15	30.96	12362	4.3
Freezer	2003	3.92	1.53	16.12	6.36	7.38	2.67	78.28	29.54	14017	6.8
Washing machine											
Impeller	2004	0.39	0.15	1.49	0.59	0.56	0.20	6.90	2.61	5148	2.4
Drum	2004	1.11	0.43	3.76	1.48	2.91	1.05	26.32	9.88	1893	1.4
Standby Power											
Color TV	2004	3.26	1.27	11.91	4.69	5.10	1.84	56.48	21.33	9173	5.0
Microwave oven	2006	0.46	0.18	1.20	0.47	1.46	0.53	11.92	4.46	1298	2.3
Laser printer (<10ppm)	2004	0.14	0.05	0.55	0.22	0.24	0.09	2.52	0.95	761	6.1
Facsimile machine (<10ppm)	2006	0.12	0.05	0.37	0.15	0.25	0.09	2.24	0.84	291	1.6
Copier (<20cpm)	2006	0.39	0.15	1.00	0.39	1.32	0.48	10.44	3.90	3145	7.2
Computer monitor	2004	1.05	0.41	4.29	1.69	2.04	0.74	20.11	7.58	4632	2.8

Notes: MTce are million metric tons coal equivalent; there are 29.27×10^{15} joules (27.75×10^{12} Btus) in a MTce. RMB is the Chinese currency. At current exchange rates, there are about RMB 8.28Yuan to the U.S. dollar.

These numbers reveal clearly the substantial energy conservation potential from China's major appliance and equipment standards program. It will be important to develop carefully targeted standards to realize these savings. We recommend to the Chinese government that:

1. Energy efficiency standards should be supported by relevant polices and funded as one of the most important energy saving instruments available.
2. Products covered by standards should be expanded wherever and whenever possible.
3. Research on "reach" standards (standards that provide aggressive long-term targets) should be emphasized to help improve the effectiveness of such energy efficiency policy instruments.

Since this research was first presented to the Chinese government, significant progress has been made in implementing these regulations. New efficiency standards have taken effect for

refrigerators; new standards for room air conditioners, motors, and TVs are under development; and standards for external power supplies and water heaters are being planned.

Table 4. Estimated Summer Peak Load and Pollutant Reductions from Proposed New Standards

Products	Summer Peak Load Reduction		Pollutant Reduction (In 2020)				Cumulative Pollutant Reduction (from Effective Year to 2020)			
	in 2010 GW	in 2020 GW	C MT	NOx 1000T	SO_2 1000T	PM10 1000T	C MT	NOx 1000T	SO_2 1000T	PM10 1000T
Residential										
TV	0.25	0.39	1.38	21.08	30.25	128.46	15.34	233.60	335.20	1,423.43
Room AC	5.91	8.84	5.79	88.19	126.55	537.39	66.28	1,009.38	1,448.35	6,150.52
Refrigerator	1.88	3.25	6.29	95.85	137.53	584.03	70.64	1,075.71	1,543.52	6,554.67
Rice cooker	0.80	1.43	2.43	36.98	53.07	225.35	23.74	361.48	518.68	2,202.63
Freezer	0.58	1.10	2.13	32.46	46.57	197.77	22.62	344.42	494.20	2,098.68
Washing machine										
Impeller	-	-	0.16	2.47	3.54	15.04	1.99	30.35	43.55	184.93
Drum	-	-	0.84	12.81	18.39	78.07	7.61	115.81	166.17	705.67
Standby Power										
Color TV	0.26	0.41	1.47	22.43	32.18	136.65	16.32	248.49	356.56	1,514.17
Microwave oven	0.07	0.21	0.42	6.44	9.24	39.24	3.44	52.44	75.24	319.53
Laser printer (<10ppm)	0.04	0.06	0.07	1.08	1.54	6.55	0.73	11.07	15.89	67.48
Facsimile machine (<10ppm)	-	-	0.07	1.10	1.57	6.68	0.65	9.85	14.13	60.02
Copier (<20cpm)	0.10	0.34	0.38	5.79	8.31	35.31	3.02	45.91	65.88	279.77
Computer monitor	0.32	0.62	0.59	8.97	12.88	54.69	5.81	88.48	126.96	539.15

Table 5. Summary of Energy Savings and Economics of Proposed New Energy Standards

	Energy Savings				**Net Benefits RMB Billion Yuan**	**Benefit-Cost Ratio**
	2010		**2020**			
	Electricity TWh	**Primary energy Mtce**	**Electricity TWh**	**Primary energy Mtce**		
Residential products	39.22	15.25	65.87	23.82	119.02	4.2
Standby power	5.42	2.11	10.41	3.77	19.30	3.7
Total	44.64	17.36	76.28	27.59	138.32	4.1

Notes: RMB is the Chinese currency. At current exchange rates, there are about RMB 8.28Yuan to the U.S. dollar.

Table 6. Summary of Peak Load and Emissions Reductions from Proposed New Energy Standards

	Summer Peak Load Reductions (GW)		**Emission Reductions in 2020 (MMT)**			
	2010	2020	Carbon	NOx	SOx	PM10
Residential products	9.42	15.01	19.02	0.29	0.42	1.77
Standby power	0.79	1.64	3.01	0.05	0.07	0.28
Total	10.21	16.65	22.03	0.34	0.49	2.05

References

Chen Haihong. 2002. *Technical Supporting Report for China Energy Efficiency Standard of Self-ballast Fluorescent Lamps*. Available online: www.efchina.org. Beijing: China National Institute of Standardization.

China Electric Power Information Center. 2001. *Power Statistics 1952-2001*. Available online: http://www.sp.com.cn/zgdl/dltj/d0105.htm. Beijing: State Power Corporation of China.

Fridley, David (Lawrence Berkeley National Laboratory). 2000. Personal communication.

[IEA] International Energy Agency. 2000. *Energy Labels and Standards*. Available online: www.iea.org. Paris: OECD.

———. 2001. *Things That Go Blip in the Night – Standby Power and How to Limit It*. Available online: www.iea.org. Paris: OECD.

Kubo, Toru, Harvey Sachs, and Steven Nadel. 2001. *Opportunities for New Appliance and Equipment Efficiency Standards: Energy and Economic Savings beyond Current Standards Program.* Report number A016. Washington, D.C.: American Council for an Energy-Efficient Economy.

Liang Xiuying. 2003. "Energy Saving Potential from New Industrial Equipment Efficiency Standards in China." In *Proceedings of the ACEEE 2003 Summer Study in Industry*, 3:111–122. Washington, D.C.: American Council for an Energy-Efficient Economy.

Liu Wei. 2002. *Technical Supporting Report for China Energy Efficiency Standard of Double-capped Fluorescent Lamps*. Available online: www.efchina.org. Beijing: China National Institute of Standardization.

Wang Qingyi (Chinese Research Academy of Environmental Sciences). 2002. Personal communication describing their 2000 research report *Coal Combustion and Air Pollutant in Northeast Asia*.