Title

A light diet for a giant appetite: An assessment of China's proposed fluorescent lamp standard

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Abstract

Lighting has been one of the fastest growing electric end-uses in China over the last twenty years, with an average annual growth rate of 14%. Fluorescent lighting provides a significant portion of China's lighting need. In 1998, China produced 680 million fluorescent lamps, of which 420 million were linear fluorescent lamps of various diameters (T8 to T12). There are substantial variations both in energy efficiency and lighting performance among locally produced fluorescent lamps. Such variations present a perfect opportunity for policy intervention through efficiency standards to promote the adoption of more efficient fluorescent lamps in China. This paper analyzes China's proposed minimum efficiency standard for fluorescent lamps and presents an assessment of its likely impacts on China's lighting energy consumption and GHG emissions.

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1 Introduction

China's two-decade long economic expansion has led to tremendous growth in its energy consumption in general and in its electricity use in particular. Lighting has been one of the fastest growing electric end-uses in China over the last twenty years, with an average annual growth rate of 14%. Although incandescent light bulbs remain the largest light source in China, fluorescent lamps provide a significant portion of China's lighting need, particularly in non-residential sectors, where lighting energy use is higher than in the residential sector.

In 1998, China produced 680 million fluorescent lamps, of which 420 million were linear fluorescent lamps of various diameters (T8 to T12). There are substantial variations in energy efficiency and lighting performance among locally produced fluorescent lamps. Such variations present a perfect opportunity for policy intervention through efficiency standards to promote the adoption of more efficient fluorescent lamps in China.

In 1996, China initiated its comprehensive Green Lights Program to promote efficient lighting products through public education, consumer incentives, national product testing, and investments in research and development and in manufacturing capacity of efficient lighting technologies. The Chinese lighting industry has responded enthusiastically, and as a result, China is one of world's leading suppliers of various lighting products. The dramatic growth, however, came with its own growing pains. Product quality, although vastly improved over the last few years, remains uneven in China's fragmented lighting market due to inexperience with new lighting technologies, inadequacy in the quality of raw material and components, and lack of industry consensus in product performance standards. China's Green Lights Program has recognized these challenges and given standard development high priority in its new market transformation strategy, a program which has received strong support from the United Nations' Development Program and the Global Environmental Facility.

China currently has one of the most active energy efficiency standard and labeling programs in the developing world. Since 1989, China has issued minimum energy efficiency standards for nine appliance and lighting products, and has been rigorously expanding its standard development activities through international collaborations in the recent years. In 1999, China issued the minimum energy efficiency standard for fluorescent lamp ballasts, the first mandatory efficiency standard in China for lighting products. Most recently, China issued minimum energy efficiency standards for compact and linear fluorescent lamps (AQSIQ, 2003). This paper will focus on likely impact of the linear fluorescent standard.

The first section will survey China's fluorescent lighting market, followed by a life-cycle cost analysis of China's proposed minimum efficiency standard for fluorescent lamps, and finally an assessment of its likely impact on China's lighting energy consumption and GHG emissions will be presented..

2. Fluorescent Lamp Market in China

China has a long history of indigenous production of electric light sources, and an extensive lighting manufacturing infrastructure. As China's economy has grown, and the electricity services have been provided to an ever greater proportion of the Chinese population, the production of lighting equipment has increased steadily in China over the past few decades. The pace of such development has certainly accelerated since 1980 when China began its ambitious social and economic reform, which has led to a stunning economic revival that remains the envy of many aspiring developing nations.

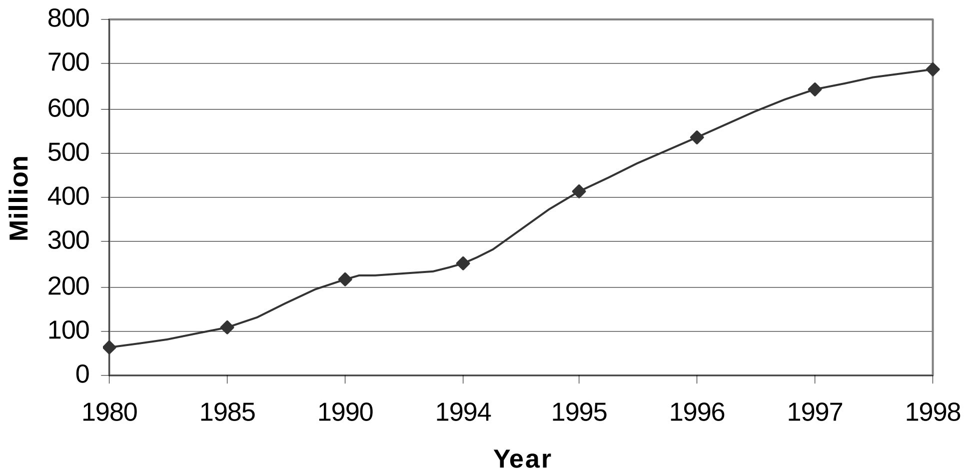
China's recent economic revival has clearly left its mark in the development of Chinese lighting industry. Over the last twenty years, production of lighting equipment has increased rapidly in China, making China one of the largest producers of lighting equipment in the world. In 1998, China produced roughly 4.6 billion units of lighting equipment, of which over 900 million units were exported to the global market.

Fluorescent light sources experienced substantial growth as well. In 1995, just over 400 million fluorescent lamps were produced in China, while by 1998, that number had increased to 642 million. The growth in the compact fluorescent lamps in China is particularly notable: 66 million were produced in 1995, and 180 million were produced in 1998, a tripling over three years. Although concern over the quality of compact fluorescent lamps made in China has persisted, China has supplied a large volume of high-quality compact fluorescent lamps to the US to meet the increased demand resulting from the electricity crisis of 2001 in selected regions of the United States.

This remarkable growth in China's compact fluorescent lamp production is quite unique, and in large part due to the success of China's Green Lights Project and the dynamic nature of China's lighting industry, among other factors. A detailed analysis of such a phenomenon, however, goes beyond the scope of this paper.

The spectacular rise of compact fluorescent lamps in China has to some extent over-shadowed the fact that linear fluorescent lamps remain the dominant fluorescent lighting source, and have witnessed substantial growth of their own as well.

Figure 1: Fluorescent lamp production in China



In 1980, total fluorescent lamp production in China was around 65 million, however, by 1998 that number had reached 642 million, representing a ten-fold increase in less than twenty years. The production of linear fluorescent lamps alone was about 462 million in 1998. In contrast to compact fluorescent lamps, a large portion of which is for export, almost all linear fluorescent lamps made in China are sold in China.

Despite its rapid growth over the last twenty years, China's lighting industry remains fragmented. In the linear fluorescent lamp segment, there are nine firms with an annual production of over 10 million lamps. The total production of these nine firms reached 234 million in 1998, representing roughly 55% of the market. The second tier has five firms with an annual production of 5 to 9 million lamps. The total production of these five firms reached 31.4 million lamps in 1998, representing only 7.5% of the market. There are numerous smaller firms spread around the country which compete only in local markets. The fragmented nature of the market combined with rapid growth in the Chinese lighting industry has to some extent contributed to the substantial variation in product performance and quality. Larger and more established firms and joint-ventures tend to produce the best quality products that serve the top end of the market, while smaller firms produce inferior products that are mostly intended for the lower end of the market.

Since the early 1980s, there have been significant changes in the product structure of linear fluorescent lamps in China as well. In 1980, most linear fluorescent lamps made in China were T12-types, with a tube diameter of 38 mm. Since then, several thinner and more efficient tube designs have been introduced. In addition to T8 lamps (with a tube diameter of 26 mm), Chinese manufacturers have also developed T9 and T10 fluorescent lamps as replacement products for T12 lamps. In recent years, T8 lamps have seen substantial growth as their benefits in energy and material cost savings become more apparent to Chinese manufacturers and consumers, and as Chinese manufacturers have become more competent at mastering the production of T8 lamps. In 1998, China produced 84 million T8 lamps, representing roughly 20% of the linear fluorescent lamp market. The trend seems to suggest that T12 lamps are gradually losing market share to other more efficient lamp types. A new generation of T5 lamps is also being made in China. However, their sales are relatively small in comparison with other lamp types.

Table 1: Output and export of electric light sources, China, 1995-1998（million）

		1995		1996		1997		1998	
		Output	Export	Output	Export	Output	Export	Output	Export
Total output		4,611.6	452.5	5,255.3	517.6	5,022.7	536.0	4,642.5	919.7
Ordinary bulb		2,900.0	150.0	3,412.8	141.8	3,052.7	97.8	2,623.9	423.0
Low voltage bulb		340.0		338.4		303.9		300.0	
FL	Total output	412.0	39.0	534.0	70.0	642.8	80.0	642.0	100.0
	T8	18.0		50.0		70.0		84.2	
	T9-12	328.0		364.0		422.8		377.8	
	CFL	66.0	39.0	120.0	70.0	150.0	80.0	180.0	100.0
Special bulb	Total	959.6	263.5	970.2	305.8	1,023.3	358.2	1,076.6	396.6
	Mercury lamps	11.0	3.0	15.0	5.0	17.0	7.0	19.2	11.1
	High-Pressure Sodium lamps	3.7	0.3	4.0	0.5	5.0	0.8	5.9	0.5
	Metal Halides lamps	0.9	0.2	1.2	0.3	1.3	0.4	1.5	0.3
	Halogen lamps	278.0	180.0	300.0	200.0	350.0	230.0	400.0	264.8
	Automobile lamps	666.0	80.0	650.0	100.0	650.0	120.0	650.0	120.0
Electronic ballast		10.0	2.0	15.0	5.0	20.0	8.0	25.0	10.0
Magnetic ballast		120.0	40.0	130.0	45.0	140.0	45.0	150.0	50.0
Source: China Illumination Association									

Typical Fluorescent Lamp Products in China

Fluorescent lamps in China can be grouped by their diameters, tube lengths and wattage ranges. Most T12 lamps have a wattage range from 20-125 watts, T10 lamps are from 18-65 watts, T9 lamps from 19-36 watts, T8 lamps from 15-58 watts, and T5 lamps from 4-13 watts. The most commonly used fluorescent lamps are listed in table 2.

Table 2: Major linear fluorescent lamp product classes in China

Diameter	**Length (mm)**				
	600		**900**	**1200**	
T8	**18 watt**		**30 watt**	**36 watt**	
T9		**20 watt**	**30 watt**		**40 watt**
T10		**20 watt**	**30 watt**		**40 watt**
T12		**20 watt**	**30 watt**		**40 watt**

The proposed Chinese minimum energy efficiency standard would only regulate products that fall within the above product categories, because it is only cost-effective to target product segments that are likely to generate most of the intended energy savings.

Lamp Prices

Prices quoted in this paper were collected from lighting markets in Beijing in 2000. Prices are typically higher for T8, T9, and T10 lamps than for T12 lamps. For 40 watt T12 lamps, the typical retail price is about 8.8 yuan (at the current exchange rate, 8.27 yuan is equal to US $1). For the 36-40 watt group, T8, T9, and T10 lamps are 27%, 24%, and 19% more costly than T12 lamps, respectively. For the 30 watt group, T8, T9, and T10 lamps are 27%, 23%, and 19% more expensive than T12 lamps, respectively. And for the 18-20 watt group, prices for T8, T9, and T10 lamps are 28%, 23 %, and 20% higher than those of T12 lamps, respectively. This data suggests that there is a substantial price difference between T12 and other lamp types, on average of 25%. However, the prices of T8, T9, and T10 lamps do not differ greatly.

Table 3: Retail Prices of Chinese Fluorescent Lamps (RMB Yuan, 7.39 Yuan/Euro)

watt / Diameter	18W	20W	30W	36W	40W
T8	11.1		11.4	11.2	
T9		10.7	11.1		10.9
T10		10.4	10.7		10.5
T12		8.7	9.0		8.8

3. Efficiency of Chinese Fluorescent Lamps

China's lighting market is served by numerous firms, whose product quality and performance varies greatly. This characteristic makes the Chinese lighting market well-suited for the introduction of energy efficiency standards, which encourage competition between substitutable products and raise the average efficiency of the products on the market. Such a transformation of the market would also deliver to consumers a wider choice of higher efficiency products with similar performance characteristics.

China's National Performance Standard for Fluorescent Lamps

China currently has a product performance standard for linear fluorescent lamps, GB/T 10682, *Double-capped Fluorescent Lamp Performance Requirements*, which specifies requirements for lamp lifetime, initial lumens, lumen maintenance, and color rendering (table 4). These requirements are, in general, fairly lax in comparison with those of fluorescent lamps sold in more developed countries. Furthermore, compliance to the standard is set at 92% of the value indicated in the table below.

Table 4: Luminance parameter, lifetime and lumen maintenance of double-capped fluorescent lamps

<table>
<tr><th rowspan="2">Working type</th><th>Rated power</th><th colspan="3">Rated initial lumens (lm)</th><th rowspan="2">Rated CRI</th><th colspan="2">Lumen maintenance%</th><th rowspan="2">Rated life</th></tr>
<tr><th>W</th><th>RR，RZ</th><th>RR，RB</th><th>RN，RD</th><th>2000h</th><th>70% lifetime</th></tr>
<tr><td rowspan="19">AC, with starter, cathode preheat</td><td>4</td><td>110</td><td>130</td><td>130</td><td rowspan="23"></td><td rowspan="4">76</td><td rowspan="4">70</td><td rowspan="4">5000</td></tr>
<tr><td>6</td><td>210</td><td>260</td><td>260</td></tr>
<tr><td>8</td><td>310</td><td>280</td><td>380</td></tr>
<tr><td>13</td><td>650</td><td>800</td><td>800</td></tr>
<tr><td>15</td><td>560</td><td>610</td><td>630</td><td rowspan="4">83</td><td rowspan="15">75</td><td rowspan="4">7000</td></tr>
<tr><td>18</td><td rowspan="3">960</td><td rowspan="3">1110</td><td rowspan="3">2760</td></tr>
<tr><td>19</td></tr>
<tr><td>20</td></tr>
<tr><td>30</td><td>1720</td><td>2025</td><td>2100</td><td rowspan="7">87</td><td rowspan="8">8000</td></tr>
<tr><td>33</td><td>2050</td><td>2335</td><td>2432</td></tr>
<tr><td>36</td><td rowspan="3">2400</td><td rowspan="3">2600</td><td rowspan="3">2760</td></tr>
<tr><td>38</td></tr>
<tr><td>40</td></tr>
<tr><td>58</td><td rowspan="2">4080</td><td rowspan="2">4780</td><td rowspan="2">5000</td></tr>
<tr><td>65</td></tr>
<tr><td>80</td><td>4620</td><td>5440</td><td>5650</td><td rowspan="4">83</td></tr>
<tr><td>85</td><td>5110</td><td>6300</td><td>6525</td><td rowspan="3">7000</td></tr>
<tr><td>100</td><td>6010</td><td>7185</td><td>7380</td></tr>
<tr><td>125</td><td>7515</td><td>8700</td><td>8860</td></tr>
<tr><td rowspan="2">Fast start</td><td>20</td><td>760</td><td>885</td><td>920</td><td rowspan="4"></td><td rowspan="4">72</td><td rowspan="4">3000</td></tr>
<tr><td>40</td><td>2000</td><td>2120</td><td>2200</td></tr>
<tr><td rowspan="2">Instant start</td><td>20</td><td>760</td><td>885</td><td>920</td></tr>
<tr><td>40</td><td>2000</td><td>2120</td><td>2200</td></tr>
<tr><td rowspan="6">High frequency, cathode preheat</td><td>14</td><td rowspan="2">1050</td><td rowspan="2">1190</td><td rowspan="2">1220</td><td rowspan="6">82</td><td rowspan="3">85</td><td rowspan="6">75</td><td rowspan="3">8000</td></tr>
<tr><td>16</td></tr>
<tr><td>21</td><td>1800</td><td>2025</td><td>2100</td></tr>
<tr><td>28</td><td rowspan="2">2500</td><td rowspan="2">2600</td><td rowspan="2">2760</td><td rowspan="3">87</td><td rowspan="3">10000</td></tr>
<tr><td>32</td></tr>
<tr><td>35</td><td>3250</td><td>3350</td><td>3450</td></tr>
</table>

This standard itself is voluntary and is only intended as a technical guideline for the industry. Chinese manufacturers only need to meet the standard if they indicate their compliance in their product and promotional literature. Data collected during this research suggest that performance varies greatly among available fluorescent lamps in China. A significant portion does not meet the current national product standard, as demonstrated in the next section.

Data Sources

Data used in the following sections principally come from two sources: the 1997 national sampling test conducted by the State Bureau of Technical Supervision, which includes products from 35 manufacturers; and tests performed on products purchased in Beijing lighting markets in 2000 by the Chinese standard development committee, which covers products from 24 manufacturers. Luminous efficacies are used as the measurement of efficiency, which is calculated as the ratio of initial lamp lumens over input power. The distributions of luminous efficacies observed in the sample are then plotted within each product class in the following figures.

In the 18-20 watt category, all lamps are separated into three groups by their luminous efficacy. The first threshold of 44.2 lumen/watt is determined by taking 92% of the specified initial lumen value in the Chinese lamp performance standard divided by the wattage of the baseline T12 product. The second threshold of 56 lumen/watt is determined by taking the average initial lumens of T8 lamps obtained in the sample divided by the lamp wattage.

Figure 2: Distributions of Lamp Efficacies, 18-20 Watt

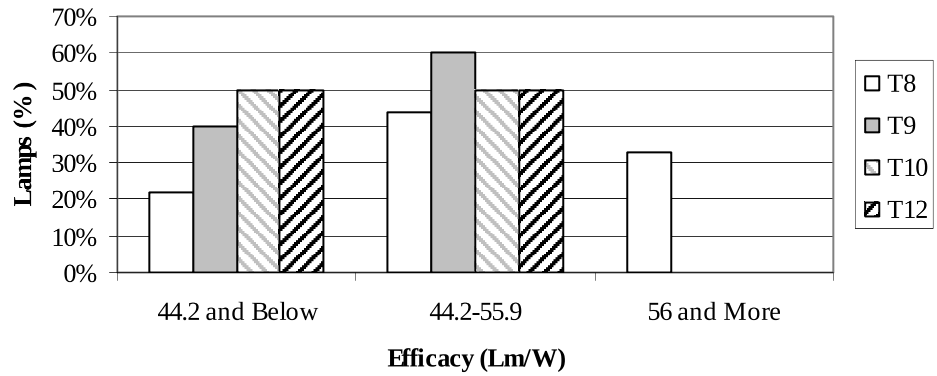
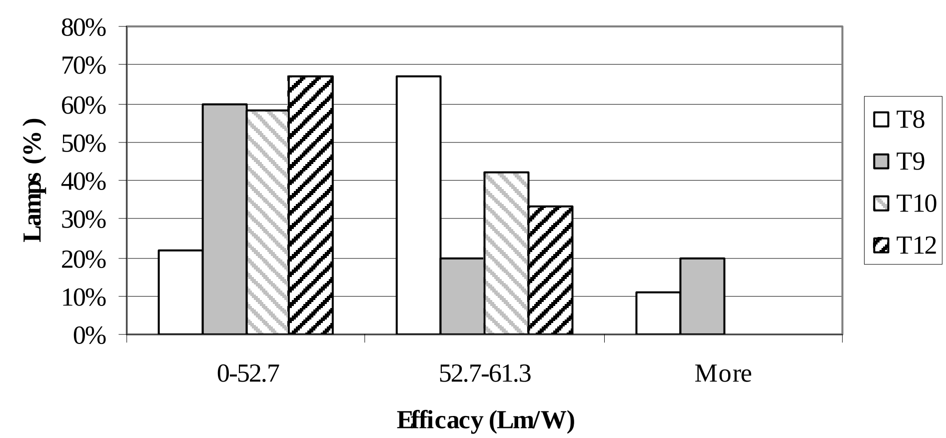


Figure 2 shows that in the 18-20 watt category, T8 and T9 lamps in the sample are generally more efficacious than T10 and T12 lamps, with T8 the most efficacious type. However, a substantial portion of linear fluorescent lamps in this category do not meet GB/T 10682 -- the existing Chinese national performance standard. T10 and T12 lamps are the worst in compliance rates, as only half of the T10 and T12 lamps meet the minimum initial lumen requirements in the current performance standard. The compliance rate for T9 lamps is slightly better at 60%. T8 lamps are the best in meeting the current performance standard; however, 22% of T8 lamps in the sample still do not comply with the current performance standard.

Lamps in the 30 watt category are divided into three groups by their efficacies as well. The first break of 52.7 is determined by taking the ratio of 92% of the initial lumen value specified in the current national performance standard over the input power of T12 lamps. And the second break of 61.3 is determined by taking the ratio of the average initial lumens of T8 lamps in the sample over lamp input power.

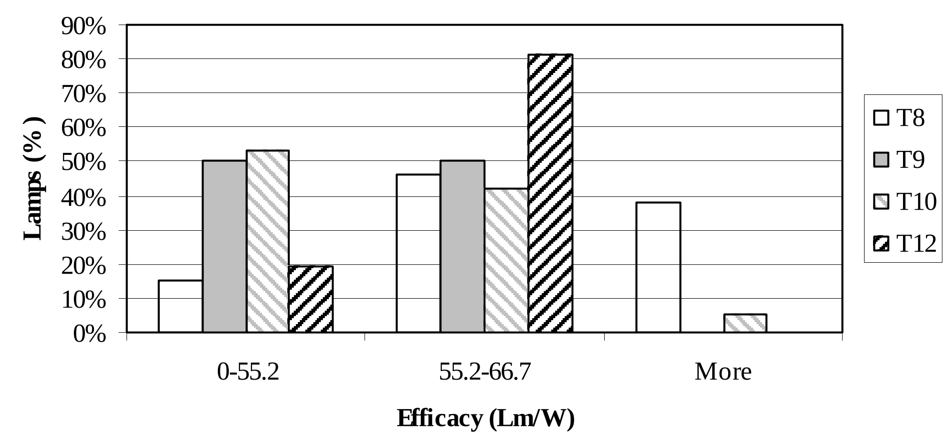
Figure 3: Distributions of Lamp Efficacies, 30 Watt



Data in figure 3 indicates that roughly 60% of T9, T10, and T12 lamps fail to meet the current performance standard, with T12's non-compliance rate the highest among all lamp types. While T8 lamps are most efficacious on average within this group, 22% of T8 lamps still fail to comply with the existing national performance standard for fluorescent lamps.

In the 36-40 watt category, lamps are also divided into three groups by their efficacies. The first breakpoint of 55.2 is determined by taking the ratio of 92% of the initial lumen value recommended in the national performance standard over T12 lamp input power. The second breakpoint of 66.7 is determined by taking the ratio of the average initial lumen of T8 lamps in the sample over lamp input power.

Figure 4: Distributions of Lamp Efficacies, 36-40 Watt



Efficacy distributions in figure 4 indicate that in the 36-40 watt category, T8 and T12 lamps have almost equally good compliance rates, while only half of T9 and T10 lamps meet the current requirements. Again, T8 lamps seem to be most efficacious of all lamp types; however, only 38% of T8 lamps have higher than average efficacy of all T8 lamps in the category.

4 Engineering Analysis

The purpose of engineering analysis in the development of the energy efficiency standards is to compare energy consumption characteristics of substitutable products within each product class, and to evaluate technical options that would improve the energy performance of the baseline product. Product classes are determined by the product features and market situations. In the current analysis, fluorescent lamps are classified into three distinct groups by their lengths (and associated wattage ranges): 600 mm (18-20 watt), 900 mm (30 watt), and 1200 mm (36-40 watt) lamps.

Technical Options

Within each product class, there are four products with similar features and energy performance characteristics, each representing a technical option for general lighting purposes. These products are distinguished and referenced by their tube diameters (T8, T9, T10, T12); typically the thinner lamps are more energy efficient.

To make the appropriate comparisons, T12 lamps are chosen as the baseline product within each product class. T10, T9, and T8 lamps represent sequentially more efficient technical options. Tables 5 to 7 present the input power and initial lumens of the baseline products (T12) and their options for each product class.

Table 5: Technical options for 18-20W lamps

	Technical options	**Input power W**	**Initial lumens lm**	**Length Mm**
Baseline product	**T12 (YZ20RR38)**	20	883	600
Technical option 1	**T10 (YZ20RR32)**	20	992	600
Technical option 2	**T9 (YZ20RR29)**	20	1028	600
Technical option 3	**T8 (YZ18RR25)**	18	1006	600

Table 6: Technical options for 30W lamps

	Technical options	**Input power W**	**Initial lumens lm**	**Length Mm**
Baseline product	**T12 (YZ30RR38)**	30	1582	900
Technical option 1	**T10 (YZ30RR32)**	30	1704	900
Technical option 2	**T9 (YZ30RR29)**	30	1757	900
Technical option 3	**T8 (YZ18RR25)**	30	1839	900

Table 7: Technical options for 36-40W lamps

	Technical options	Input power W	Initial lumens lm	Length Mm
Baseline product	**T12 (YZ40RR38)**	40	2208	1200
Technical option 1	**T10 (YZ40RR32)**	40	2398	1200
Technical option 2	**T9 (YZ40RR29)**	40	2489	1200
Technical option 3	**T8 (YZ36RR25)**	36	2400	1200

Initial lumens for the baseline products (T12) are chosen as 92% of the value recommended in China's current product performance standard. Initial lumens for T8, T9, and T10 lamps are the average lumens of the lamp sample described earlier.

Lighting Energy Consumption

Lighting energy consumption is a function of both lamp input watts and lighting hours. To make appropriate comparisons of energy consumption between baseline products and their more efficient options, however, a few assumptions and adjustments need to be made.

Lighting hours vary by application. For example, lights are on for a longer period of time in commercial buildings than in residential buildings in general. Lighting energy consumption was calculated under a variety of situations, but results are only presented for the commercial buildings where lighting hours are estimated to be 4320 hours per year on average.

Given that the four types of lamps have different lumen outputs, their wattages need to be adjusted to account for these differences, so that their energy consumptions can be compared based on equal lumen outputs. Otherwise, more efficient lamps may be perceived as consuming the same amount of energy as the baseline products do, despite the fact that they also deliver more light. Normalized wattage is introduced here to correct such a bias. It is defined as follows:

Normalized Wattage = Rated Wattage X Lumen(baseline**) / Lumen(**option**)**

With corrected wattage and estimated lighting hours, energy consumption can be calculated for all lamps in each product class. Tables 8, 9, and 10 present the results of energy consumption comparison in commercial buildings for each product class, respectively.

Table 8: Annual energy consumption for 18-20W lamps

		Rated wattage W	Mean lumens lm	Normalized wattage W	Lighting hours h/y	Lighting energy kWh/y	Energy differential kWh/y
Baseline product	**T12**	20	883	20.0	4320	86.4	
Technical option 1	**T10**	20	992	17.8	4320	76.9	9.5
Technical option 2	**T9**	20	1028	17.2	4320	74.2	12.2
Technical option 3	**T8**	18	1006	15.8	4320	68.3	18.1

Table 9: Annual energy consumption for 30W lamps

		Rated wattage W	Mean lumens lm	Normalized wattage W	Lighting hours h/y	Lighting energy kWh/y	Energy differential kWh/y
Baseline product	**T12**	30	1582	30.0	4320	129.6	
Technical option 1	**T10**	30	1704	27.9	4320	120.4	9.2
Technical option 2	**T9**	30	1757	27.0	4320	116.8	12.8
Technical option 3	**T8**	30	1839	25.8	4320	111.5	18.1

Table 10: Annual energy consumption for 36-40W lamps

		Rated wattage W	Mean lumens lm	Normalized wattage W	Lighting hours h/y	Lighting energy kWh/y	Energy differential kWh/y
Baseline product	**T12**	40	2208	40.0	4320	172.8	
Technical option 1	**T10**	40	2398	36.8	4320	159.1	13.7
Technical option 2	**T9**	40	2489	35.5	4320	153.3	19.5
Technical option 3	**T8**	36	2400	33.1	4320	143.1	29.7

The results show that for 36-40 watt lamps, a T8 lamp would consume almost 30 kWh less a year than a T12 lamp, representing a 17% reduction; such annual energy use differentials between T8 and T12 lamps are about 18 kWh per year for 18-20 and 30 watt lamps, representing a savings of 17% and 14%, respectively.

The electricity saved by replacing T12 lamps with more efficient lamps would clearly reduce the operating cost. However, whether such operation cost savings would overcome the price differentials between various lamps can only be determined by comparing their life-cycle costs.

Life-Cycle Cost Calculation

A product's life-cycle cost takes into account all costs associated with the use of the product over its lifetime, including both the purchase price and the operating cost. In the case of fluorescent lamps, the operating cost is just the electricity cost. Since electricity use occurs over time, electricity costs are typically discounted to obtain their present values, which are then added together to the lamp price to arrive at the life-cycle cost of a lamp, as expressed in the following formula:

$$LCC = PC + \frac{OC}{r}\left[1 - \frac{1}{(1+r)^N}\right] \qquad (4)$$

where LCC stands for life-cycle cost, PC for purchase cost, OC for operating cost, r for discount rate, and N for lifetime in calendar years. Here OC is equal to the product of the annual electricity consumption and the electricity tariff, while N is the ratio of lifetime in hours over the annual lighting hours. A product with a lower life-cycle cost is a better choice for consumers, since the overall cost of utilizing the product over its lifetime is lower.

Calculating a lamp's life-cycle cost thus requires input variables of lamp price, annual electricity consumption, electricity price, discount rate, and lifetime. The first two inputs are listed in table 3 and table 8-10, respectively, while the remaining is listed table 11 below.

Table 11: Assumptions used in life-cycle cost calculation

	Elec. Tariff	Annual lighting hour	Discount rate
	RMB Yuan/kWh	hour	
Commercial buildings	0.84	4320[1]	10%

Table 12: Results of Life-cycle cost analysis for Chinese fluorescent lamps

Lamp group	Options	AEC kWh/year	AEC difference kWh/year	Lifetime year	Elec. price ￥/kWh	Elec. Cost ￥/year	Elec. Cost difference ￥/year	LCC ￥	△ LCC ￥	Payback year
18 and 20 watt	T12	86.4		1.62	0.84	72.64		113		
	T10	76.9	9.5	1.62	0.84	64.65	*7.99*	103	*9.73*	0.21
	T9	74.2	12.19	1.62	0.84	62.39	*10.25*	100	*12.63*	0.2
	T8	68.3	18.11	1.62	0.84	57.42	*15.22*	93	*19.41*	0.16
30 watt	T12	129.6		1.85	0.84	108.96		185		
	T10	120.4	9.25	1.85	0.84	101.19	*7.78*	174	*10.88*	0.22
	T9	116.8	12.85	1.85	0.84	98.16	*10.8*	170	*15.44*	0.19
	T8	111.5	18.11	1.85	0.84	93.74	*15.23*	163	*22.26*	0.16
36 and 40 watt	T12	172.8		1.85	0.84	145.29		244		
	T10	159.1	13.66	1.85	0.84	133.8	*11.49*	227	*16.89*	0.15
	T9	153.3	19.52	1.85	0.84	128.88	*16.41*	219	*24.51*	0.12
	T8	143.1	29.74	1.85	0.84	120.28	*25.01*	206	*38.08*	0.1

Table 12 presents the results of life-cycle costs in commercial buildings for three groups of fluorescent lamps analyzed here. For the 18-20 watt group, T12 lamps have the highest life-cycle cost of 113 yuan, T8 lamps have the lowest life-cycle cost of 93 yuan, while the life-cycle costs of T10 and T9 fall in-between. The cost savings of using the thinner lamps seem to outweigh their price premium as evidenced by their short payback periods, typically less than three months.

Same patterns hold true for 30 watt and 36-40 watt lamps as well. Typical payback periods for using thinner lamps over the baseline T12 lamps are all less than three months.

The Proposed Chinese Minimum Energy Efficiency Standard for Fluorescent Lamps

It is based on above results of life-cycle cost analysis that China has proposed two levels of efficacy requirements for the fluorescent lamps (table 13). The first sets the minimum efficacies which are mandatory, and the second sets the efficacy requirements for qualifying China's energy conservation product label which is voluntary. These requirements are generally lower than those observed in other countries. However, if implemented these

[1] The average lighting hour over sectors is estimated at 3360 hours per year.

requirements would eliminate a significant proportion of fluorescent lamps in each of the lamp groups, and help accelerate the shift from T12 toward more efficient T8 lamps.

Table 13: The efficacy requirements in China's proposed standard for linear fluorescent lamps

Length (mm)	600	900	1200
Power (W)	18, 20	30	36, 40
Minimum efficacy (lm/W)	44.2	52.7	55.2
Efficacy for energy conservation certification (lm/W)	55.9	61.3	66.7

5 Impacts on National Electricity and GHG Emission

Despite its modest efficacy requirements, China's proposed energy efficiency standard for fluorescent lamps could, if implemented, lead to substantial reductions in electricity use and associated GHG emissions, given the size of China's fluorescent lighting market and the dominant role of coal in China's electricity generation.

To estimate these savings, future lamp sales and electricity prices are projected. These data are then combined with energy consumption data in the last section to estimate lighting energy uses under both business-as-usual (BAU) and standard implementation (Standard) scenarios. The differences between the scenarios represent energy savings that can be attributed to the implementation of the standard.

Figure 5: Fluorescent lamp production in China, 18-40 watt.

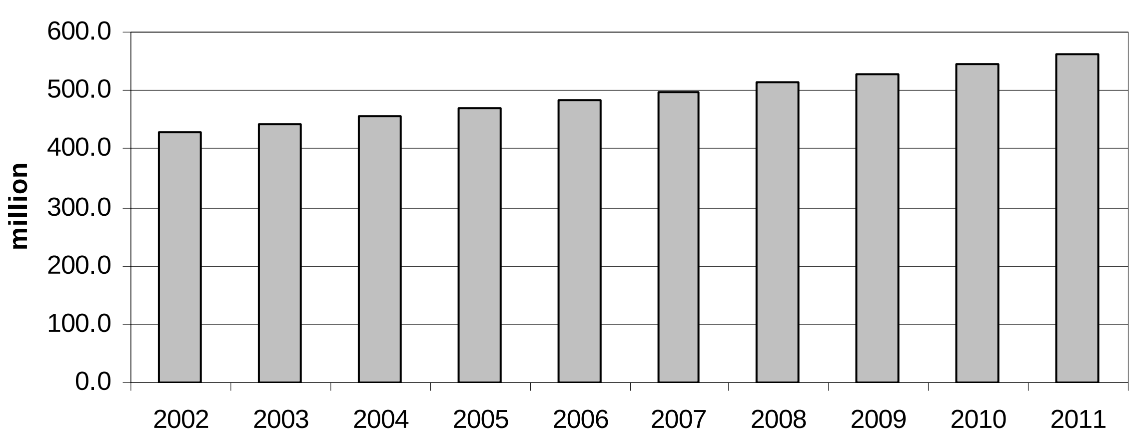


Figure 5 presents the projected fluorescent lamp growth for the 18-40 watt group in China.[1] Even with a modest growth rate of 3% in the next ten years, production of fluorescent lamps in this group is likely to be around 560 millions by 2011.

Electricity prices vary substantially by regions and sectors. Rates are highest in the commercial sectors and in coastal regions, and lowest in the residential sector and in inland provinces. Average rates based on rates collected from various sectors and regions are approximately 0.67 Yuan/kWh in 2001. Although electricity prices have increased steadily in the 1990s, prices were little changed in 1999 and 2000. In the current analysis, annual growth rate of electricity prices is assumed to be 2% from 2001 to 2011, which is probably conservative. Average price is estimated to be 0.82 Yuan/kWh in 2011.[2]

Table 14: Average electricity price by sector, 1999（Yuan/kWh, 7.39 Yuan/Euro）

	Residential	**public**	**Commercial**	**Industrial**
Average price	0.46	0.59	0.84	0.53

The results of the national saving calculation indicate (table 15) that the implementation of the proposed minimum energy efficiency standard for fluorescent lamps would lead to a reduction of lighting electricity use by 80 TWh over the next ten years in China, with a corresponding reduction of CO2 emissions by almost 100 million tons.[3] These reductions would also bring substantial economic benefits to the end users, totaling 36 billion yuan over the same period.[4]

Table 15: National Impacts on energy savings and reduced CO2 emissions, 2002-2011	
Electricity savings	**80** *TWh*
NPV	**36** *Billion Yuan*
CO_2 Emission Reduction	**99** *million tons*

These results suggest that the modest efficiency improvements proposed in China's fluorescent lamp minimum energy efficiency standard would translate into large reductions in China's lighting energy use and could make a significant impact on China's growing emissions of greenhouse gases. It is also illuminating that such measures are extremely cost-effective, and highly beneficial to the national economic welfare.

6 Discussion

China's growing lighting market presents an excellent opportunity for reducing energy use and associated GHG emissions, due to its size and uneven energy performance of the lighting products on the market. Minimum energy efficiency standards are a proven tool that is well suited to address this potential by stimulating market competition toward higher efficiency segments. Modest improvements in efficiency in a large market still lead to large aggregate reductions. In the case of China's proposed minimum energy efficiency standard for fluorescent lamps, these reductions add up to 80 TWh in electricity consumption and almost 100 million tons in CO2 emissions. These results highlight a large potential energy savings through efficiency improvements both in the lighting sector and in other end-use sectors.

Minimum energy efficiency standards are a very cost-effective tool to raise product efficiency. However, the effectiveness of the minimum energy efficiency standard is largely dependent on strict implementation. China's large and fragmented lighting market presents a significant challenge for Chinese policy makers. Given the large environmental and economic benefits that could be brought by successful implementation of the standard, it behooves the relevant Chinese agencies to devote adequate resources to build an effective implementation and enforcement mechanism to ensure that China enjoys the full benefits of its standard program.

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[1] The annual growth rate is assumed to be 3% for the period, considerably lower than that observed between 1995 and 2000, which is roughly 6%. In addition, 18-40 watt lamps are assumed to be 90% of all linear fluorescent lamps.
[2] The conservative assumption of the electricity prices tends to underestimate the cost saving figures, and thus the economic benefits of the standard.
[3] CO2 emission coefficient of 1.24 kg/kWh is taken from the World Bank report, *China: Issues and Options in Greenhouse Gas Control.*
[4] The net economic benefit is calculated as the difference between expected electricity cost savings and increased lamp costs, and is discounted back to 2001 with a discount rate of 7.6%.