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ENERGY-EFFICIENT LIGHTING IN CHINA: PROBLEMS AND PROSPECTS*

ABSTRACT

China's choices of energy demand and supply technologies have a large impact on the world's energy market and the environment. Of its 920 billion kWh electric power production in 1993, it is estimated that 15% was used for lighting consumption (~120 billion kWh). This figure is likely to grow as the country develops, and so improving the energy efficiency of lighting in China could have a tremendous impact on China's energy consumption. This paper describes key components of the energy-efficient lighting industry from technology and marketing points of view. We identify a few key problem areas and their potentials for improvement.We identify a national savings potential of 40% by shifting to lamps with performance characteristics typical of current Western practice—but without changing the market share of various lamp types—and of 60% by adopting the best commercially available lamps in the West.

OVERVIEW

With the world's largest population and the fastest growing economy, meeting the growing demand for energy is one of the most important and difficult tasks for China [1]. Because of energy savings programs in the industrial sector during the last two decades, China is one of the few developing countries that has limited its energy demand growth to half of its GNP growth rate. However, energy production and use still impose significant economic and environmental costs

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on China. Given the ever growing economy, population, and standard of living, the current electricity demand and supply relationship cannot be sustained much longer.

This nation of 1.2 billion people has the third largest economy in the world after the United States and Japan. Lighting is responsible for about 15% of total Chinese electricity usage. The ~120 billion kWh is equivalent to the output of about one hundred 250-megawatt electric power plants. Despite the enormous energy demand, lighting energy use in China on average is less than 100 kWh/capita-year, versus about 2 000 kWh/capita each year in the United States. Additionally, recommended light levels promulgated by the Illuminating Engineering Society in China are only one-sixth to one-tenth of those in Japan and western industrialized countries (Table 1). For example, the standard is 75-100 lux in Chinese hospital examination rooms versus 500-1 000 lux in Germany. Increasingly, lighting designers are using the higher Western lighting levels. The combination of increased light levels and growth in population and building construction will cause lighting demand to grow quickly, probably faster than overall electricity demand. During the last five years, the average annual increase in lamp production was about 15% versus an 8 to 9% increase in electricity production.

Table 1. Comparison of illumination standards in different countries (lux)

	U.K.	Germany	Japan	Russia	USA	China
General office	500	500	300–750	300	300	100–200
Drafting	750	750	750–1500	500	750	200–500
Classroom		300	200–750	300	300	75–150
Hospital examination room	500	500–1000	200–500		540	75–100

THE NEED FOR ENERGY-EFFICIENT LIGHTING

The continuing shortfall between electricity demand and supply, the escalating cost of building new power plants and competing needs for investment capital are just some of the obvious reasons why China is ripe for improved energy efficiency in lighting and other end-use areas. Moreover, power shortages are attributable in part to peak demands caused by lighting and air conditioning in the major cities. Although electricity prices vary widely around China from 3 to 12 US cents/kWh, they are typically higher in fast-growing cities that have serious problems meeting peak electricity demand.

However, even with such indisputable market potential, energy-efficient lighting products have had their share of difficulties in the marketplace. Lack of clear direction and comprehensive policy from the central and local governments, lack of financial structure and incentives for energy-efficient products, and insufficiently advanced technology and materials to manufacture high-

quality, high-performance products are some of the factors limiting the growth of energy-efficient technologies. Because of high cost and short equipment lifetimes, typical consumers often view energy-efficient lighting as something that “saves energy but not money”. When buying cheaper but poorer quality products, some consumers lose all confidence in the technology.

The Chinese lighting energy savings potential has not been rigorously estimated. Based on the product characteristics discussed below, one notes a potential of 45% to 70% efficiency improvement simply by comparing the best-available lamp efficacies in China with those in the West. Luminaire and ballast technologies lag behind western standards, offering a similar degree of saving potential. Elevating product quality (as measured by lamp lifetime) to western standards would dramatically improve the cost-effectiveness of a given lighting measure, thus expanding the potential sphere of application. Similarly, as energy prices rise to western levels, the technical-economic potential also increases. A trend towards increased lighting levels and population growth counterbalances the savings potential to an unknown degree.

Trends in the mix of lamp types being produced in China suggest that by the year 2000 the ratio of fluorescent to incandescent lamps will increase from 1/9 to 1/4. Over this same time period, combined CFL, T8, and T10 production will increase from 10% of all light sources to 70%, and the share of HIDs will increase from 1% to 10%. These “structural” changes will in themselves lead to energy savings, even without efficiency improvements within a given lamp type. Advanced lighting control systems—currently little known in China—would add to the savings potential.

THE LAMP INDUSTRY

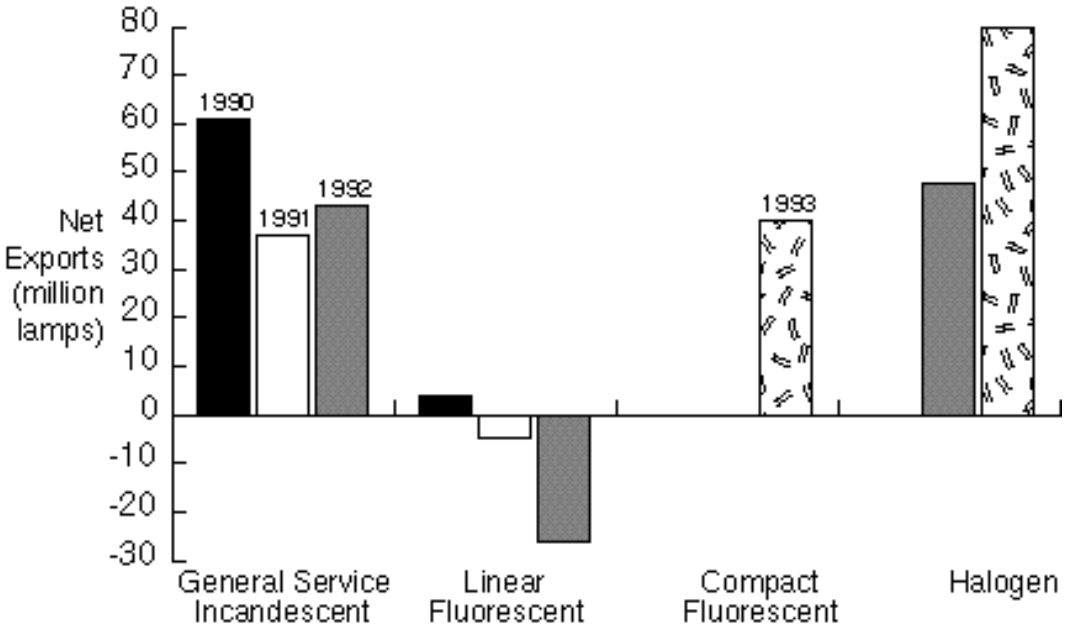
Electric light sources have been manufactured in China for more than 80 years. China produced 3.6 billion lamps in 1993, and annual growth in production has been 10% to 15% in recent years—compared to about 1% per year in the United States (Table 2). Only a small fraction of production—or growth in production—is attributable to net exports, which amounted to about 70 million lamps of all types in 1993 (Figure 1).

Table 2. Lamp production trends in China (millions)

	1988	1989	1990	1991	1992	1993
General Service Incandescent	1 303	1 437	1 747	1 993	2 264	2 217
(market share)	*74%*	*71%*	*71%*	*70%*	*68%*	*60%*
Halogen						100
(market share)						*3%*
Low-voltage			61	89	131	
(market share)			*2%*	*3%*	*4%*	
Linear Fluorescent	156	171	212	218	286	248
(market share)	*9%*	*8%*	*9%*	*8%*	*9%*	*7%*
Compact Fluorescent			10	11	18	38
(market share)			*0%*	*0%*	*1%*	*1%*
Other	302	413	445	518	648	1 083
(market share)	*17%*	*20%*	*18%*	*18%*	*19%*	*29%*
Total	1 761	2 021	2 476	2 828	3 340	3 586

Source: Chinese Lighting Industry Association

Figure 1. Chinese lamp export/import balance

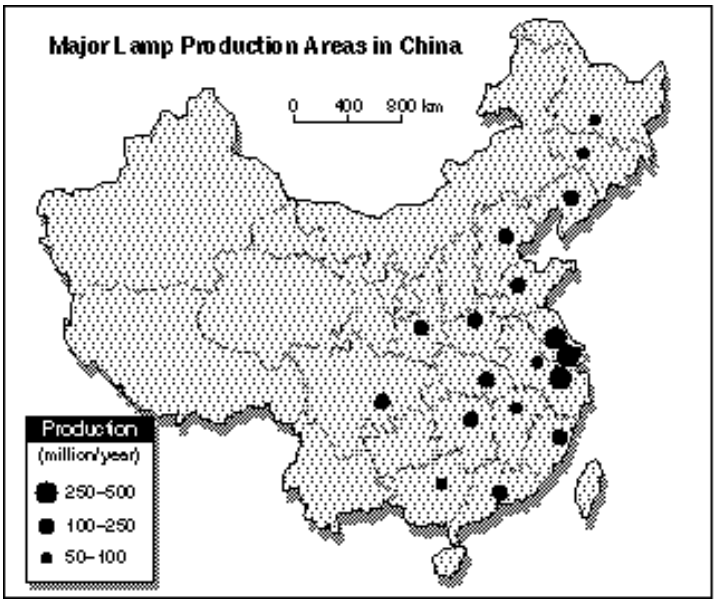


There are more than 600 lamp factories in China today, employing 250 000 workers. Most of this industry is in the eastern part of the country, especially around Shanghai, where nearly 40% of the national production occurs (Figure 2). A wide range of lamp types are produced in China, including incandescent, halogen, high-intensity discharge, linear fluorescent (including efficient 26 mm “T8” lamps), and compact fluorescent lamps. Approximately 10 million energy-efficient T8 lamps were made in China in 1993 (1 million with tri-phosphors). The largest manufacturer produces 400 million incandescent lamps annually.

As of 1994, attempts had been made to establish about 10 CFL production plants in China with equipment imported from Taiwan, the United Kingdom, and South Korea. Each of these projects

have been troubled with technical and marketing problems, and, as a result, production capacity exceeded the actual production level for several years. With most idle production lines finally put into service, 60 million CFLs were produced in China in 1994—exceeding the domestic consumption levels of any western country for that year. Production soared to 300 million by 1996.

Figure 2. Major lamp production areas in China



THE BALLAST INDUSTRY

The Chinese ballast industry is much smaller than the lamp industry, both in terms of the total production level and the size of a given factory. The industry is very decentralized, with only a few manufacturers producing more than one million units per year. The largest, located in Shanghai, is EBT (largely owned by Philips).

Most producers make the old inefficient magnetic ballast for linear fluorescent lamps. However, in recent years, electronic ballast production has grown rapidly to a level of about 10 million units per year in conjunction with the growth of CFLs, T8 and T10 straight fluorescent lamps. There are hundreds of CFL ballast producers in China. Most operate at a scale of 100-500 000 units per year. In the city of ShenZhen alone, there are more than 10 manufacturers of electronic ballasts for CFLs.

There is a continual trade off between higher-priced advanced technology and good quality versus the cheaper but lower quality products. Gradually, architecture and engineering companies, and public building owners are beginning to specify electronic ballasts. One manufacturer has

developed a high-performance CFL ballast with a hybrid chip. The electronic ballast export market is very promising, given China's highly competitive labor rates.

THE LUMINAIRE INDUSTRY

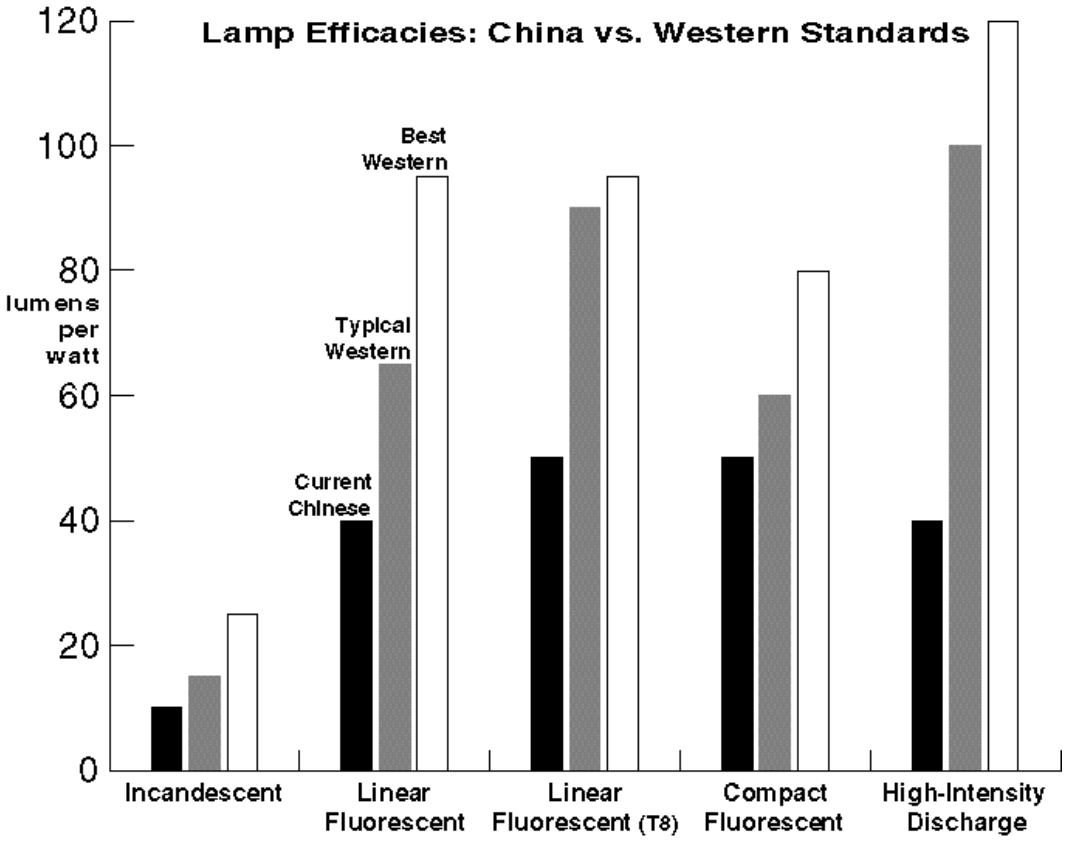
Until recently, little attention has been paid to light luminaire design or efficiency in China. Luminaires for outdoor applications (especially highway lighting or high-beam reflector flood systems for industry and commercial settings) are the most advanced. If luminaires are used at all, the main goal is to achieve a certain decorative effect without regard for efficiency. This is particularly true in the residential and commercial sectors. Luminaire production standards lag behind those used for lamps. For example, it is very difficult to find CFL-compatible luminaires in China.

Luminaire manufacturing occurs mostly in small factories (about 1 500 in total), with total production of 170 million units per year. With improved relations between mainland China and Taiwan, many Taiwanese and Hong Kong luminaire manufacturers are moving their production to mainland China (although much of the product is re-exported). This trend will bring improved technology, manufacturing quality control, and marketing expertise to the Chinese marketplace. The highest quality luminaires are typically exported to non-Chinese markets that will pay relatively high prices. Ironically, many new high-rise buildings in China install high quality imported luminaires. The luminaire market is perhaps the most underdeveloped market within the lighting industry.

IN PURSUIT OF QUALITY

Even given the great market potential for energy-efficient lighting, promoting efficient lighting products in China is still a very difficult task. A number of joint ventures between foreign companies and Chinese partners, and a number involving the Chinese government have had problems penetrating the market. Cutting corners on quality can have serious market consequences. For example, the national utility in Ireland purchased Chinese-made CFLs for a pilot rebate program—the CFLs had the best power quality characteristics of anything they could find on the international market. Unfortunately, the early failure rate was about 25% and the utility has rejected the CFLs until their quality can be brought up to Western standards.

Figure 3.Average Lamp Efficacies: China vs. Western Standards.



Lamp quality—both in terms of efficacy, color rendition, maintenance of initial light output, and and service life—is poorer in China than in many other parts of the world (Table 3). Only 20% to 30% of the lamps produced meet international quality standards. For example, standard linear fluorescent lamp lifetimes in China range from 3 000 to 5 000 hours, compared with 10 000 to 20 000 for their western-made equivalents. Efficiencies are 25 to 40 lumens/watt versus 40 to 100 lumens/watt in the West. Good phosphor sources are present in China, but are not well developed. The “soft lead glass” used today for CFLs loses ~20% of its transparency within the first 3 000 hours of operation. Most high quality lamps use “hard glass” and/or coating techniques which could cost twice as much for the Chinese makers.

Table 3. A comparison of Chinese & international lamp performance standard indicators

Lamp Type		*Wattage (W)*	*Efficacy (Lumens/W)*	*Life (hours)*
General Incandescent	China	15-1 000	7-18	100-1 000
	Int'l	10-1 500	5-25	100-2 000
Halogen	China	50-2 000	14-28	50-1 500
	Int'l	10-1 000	15-30	50-2 000
Linear Fluorescent	China	6-125	25-40	3 000-5 000
	Int'l	4-200	40-100	10 000-20 000
Compact Fluorescent	China	4-28	40-65	1 000-3 000
	Int'l	5-55	50-70	5 000-20 000
Metal Halide	China	150-1 500	70-80	3 000-8 000
	Int'l	30-2 000	50-125	2 000-10 000
High Pressure Sodium	China	35-1 000	60-100	4 000-12 000
	Int'l	30-1 000	50-150	10 000-25 000

At first glance, the problem seems to be a simple technical one. If the Chinese manufacturers use a higher quality glass, perhaps imported, and other better raw materials, they could make good lamps and save more energy in China. Indeed, many of those 20 to 30% lamps that meet international standards use better materials. However, the current "high-end" products are exported to U.S. and European markets that can absorb the additional costs of production. Only if the manufacturers can export the products and earn higher profits and hard currency can they justify the additional cost of production. If high-quality lamps are imported, duties of 42% apply on incandescent lamps and 30% on fluorescent lamps (including CFLs).

For typical households, the price of electricity is not high enough to justify the purchase of a 30 to 40 RMB (~US$ 5) CFL since the price of a CFL is about 1/4 to 1/6 of monthly family income (or about 5% for the relatively affluent urban households). Additionally, the often poor quality of domestic-made lamps makes it even harder to justify the economic benefits.

Most utility companies are subsidized or run by the government in ways that offer no incentive to promote energy efficiency or to change the electricity price to reflect true costs. This is a direct result of lack of appropriate energy policies. In a cost-driven mass market, lack of standards for quality and performance, and difficulty justifying cost-effectiveness lead to poor-quality, poor performance and cheap products flooding into the market that would not only undermine energy saving benefits, but ultimately destroy the consumer confidence and eventually the market itself.

THE FUTURE IS BRIGHT

The potential for energy savings within each lamp technology area is significant. As shown in Table 4, elevating lamp efficacies typical of China today to those typical in Western countries

would achieve savings of 15 to 60%, depending on the lamp type. Achieving efficacies representative of the best available in the West would achieve per-lamp savings of 45% to about 70%.

Table 4. Derivation of savings factors applicable to the current Chinese lighting situation

Lamp Type	Current Chinese Lamp Efficacy (lumens/watt)	Typical Western Lamp Efficacy (lumens/watt)	Best Western Lamp Efficacy (lumens/watt)	Savings Factor (West Avg) [1993=1.00]	Savings Factor (West Best) [1993=1.00]
Incandescent	10	15	25	0.67	0.40
Linear Fluorescent	40	65	95	0.62	0.42
Linear Fluorescent (T8)	50	90	95	0.56	0.53
Compact Fluorescent	50	60	80	0.83	0.63
High-Intensity Discharge	40	100	120	0.40	0.33

The data assembled in this paper allow us to develop an estimate of the end-use breakdown of lighting energy in China and a projection of the energy savings potential, accounting for the current mix of light sources. Application of savings factors developed in Table 4 shows a total "overnight" savings potential of 40% by shifting to lamp performance typical of current Western practice—but without changing the market share of various lamp types—and of about 60% by adopting the best commercially available lamps in the West (Table 5). We have not estimated further savings from daylighting or lighting control and switching systems. Importantly, this savings potential does not include any structural changes, such as shifts from incandescent to fluorescent lamp types. By including changes from incandescent to compact fluorescent in 30% of all applications (approx. 50% of total incandescent lighting energy use) total savings grow to 70%.

Table 5. Bottom-up estimate of lighting energy use and savings potential in China (1993)

Lamp Type	Lamp Stock (millions)	Average Lamp Size (W)	Average Usage (hours/day)	Lamp Life (hours)	China Annual Electric Use (BkWh)	China Annual Electric Use at Western Ave. Performance (BkWh)	China Annual Electric Use at Western Best Performance (BkWh)
Incandescent	1063	40	4	700	62	41	25
Linear Fluorescent	500	30	5	4000	27	17	12
Linear Fluorescent (T8)	16	36	5	6000	1.1	0.6	0.6
Compact Fluorescent	38	13	4	2000	0.7	0.6	0.5
High-Intensity Discharge	30	350	8	5000	31	12	10
Total					122	72	48
Energy Savings						(41%)	(61%)

note: lamp stock derived using 1988 to 1993 sales statistics (Table 2), lamp usage, and lamp service lives.

Absolute savings in the future depend on other factors not included in Table 4. Some will tend to push lighting energy use up (such as changes in lighting levels, population and building stock growth) and others will push it down (such as structural shift towards a higher proportion of effi-

cient lamp types and improved control technologies).

If China is to become a competitive exporter of lighting products and save energy domestically, quality standards will have to be improved. The shift to a market economy is likely to accelerate the process of improving the economic benefits of energy-efficient lighting products. Following are some examples of preliminary efforts:

- To give consumers and exporters an easy way of assessing the quality of lighting products, China's National Center for Supervision and Inspection issues the "Great Wall Mark" certifying product safety. The organization also spot checks products already in the market. Work is underway to explore adoption of the IEC standards.

- The State Economic and Trade Commission (SETC) plans to launch a "Green Lights" program in China, loosely modeled after the successful US EPA's program. Several quality products produced by Chinese-owned factories and foreign joint ventures have been selected for utilization in the program. As currently conceived, the program would award special labels for products meeting a minimum efficiency threshold.

- As a form of reward, some city governments have given CFLs to the departments that have achieved energy savings. Today, some cities are considering rebate programs. More complex systems in which loans would be made to companies wishing to invest in efficient lighting retrofits are also under consideration. Loan payments would be indexed to energy savings.

- The SETC–sponsored Energy-Efficient Technology Investment Corporation is active in making loans and investment in energy-efficient technologies and products from co-generation to variable-speed motor drives and energy-efficient lighting.

- The Beijing Energy Efficiency Center, co-founded by the Chinese State Planning Commission, the US Department of Energy, and the US Environmental Protection Agency through Lawrence Berkeley Laboratory and Pacific Northwest Laboratory, is leading many projects in the area of Integrated Resource Planning (IRP) and Demand Side Management (DSM). ShenZhen, the first city to lead the way in running its own market-oriented utility, has already finished the first phase study of a IRP program proposal. It also has committed itself to carrying out several energy-efficient lighting demonstration projects using CFLs, electronic ballasts, and T8-lamps in ShenZhen and other cities. This project includes the development of a prototype light logger, for use in evaluating program impacts.

Joint ventures are also introducing the necessary technical expertise and capital or other financial arrangements with foreign companies to achieve western quality standards (Table 6). About 100 joint ventures for lighting have already been established in China. Most are small to mid-sized and involve Taiwanese and Hong Kong companies. Lighting giants such as GE Lighting, Philips, Osram, and several other Japanese lighting manufacturers have also established joint ventures in China. Many of them have started producing products for China's domestic market. For example, EBT Shanghai is starting the second phase of its operation in which it will produce and market electronic ballasts for China. Philips'joint ventures in Nanjing and Shanghai are producing CFLs and T8 lamps to supply Chinese market in addition to exporting in other parts of Asia.

Table 6. Examples of foreign investment in the Chinese lighting market

Product	***Foreign Company***	***Chinese Company***	***Location***
CFL	unknown (Taiwan)	unknown	Guangdong
T8 lamps	Philips (Netherlands)	Feidong	Nanjing
HID, CFLs	Philips (Netherlands)	Yaming	Shanghai
Electronic ballast	EBT* (USA)	none	Shanghai
Incandescent	General Electric (USA)	Jiabao Group	Shanghai
CFL	Panasonic (Japan)	Beijing Picture Tubes	Beijing
Halogen PAR	Litetronic Lighting Corporation (USA)	Sunlite	Shenzhen
Luminaires	Panasonic (Japan)	Stone	Beijing
CFL	Juifeng (Taiwan)	Nanchung	Jiangki
CFL	Quanneng (Hong Kong)	Auslite	Shanghai
CFL, linear fluorescent	Osram	Foshan	Guangdong
Electronic ballast	PRI (USA)	AME & Jantai	Jiangsu/Shandong

* owned by Philips North America

CONCLUSION

China is an immense lighting market with nearly one-quarter of the World's population and the world's fastest-growing economy. China has a hearty appetite for light and is already one of the world's largest producers and consumers of lighting products. Current growth in the lighting market will create an upward pressure on energy demand as well as associated costs and environmental impacts. Improving the efficiency and quality of its lighting products is one way China can offset its shortfall in electricity supply and fast-growing rate of demand.

Manufacturers recognize that the "market pull" for efficient lighting products is still weak in China. Government policies to promote energy-efficient lighting are a new feature on the Chinese landscape. Several fundamental problems remain:

(1) There is not enough emphasis on educating energy users and decisionmakers about efficiency options available to them.

(2) It is still difficult to obtain capital and justify the cost-effectiveness of energy efficiency projects.

(3) Primitive manufacturing process and poor quality raw materials are just some of the factors that contribute to the poor performance of most Chinese-made lighting products.

(4) There are strong incentives to export energy efficient products manufactured in China, with the result that domestic enrgy savings are not captured.

However, actions in the right direction have been taken in the last few years. Governments have been active in promoting energy efficiency, and higher performance and quality standards. Utilities around the country have started to work with local governments, manufacturers and end users to encourage more efficient products. Foreign companies and their joint ventures in the Chinese market have an opportunity to contribute to quality and performance improvements by providing technical expertise.

POSTSCRIPT

Since the time of writing, much has transpired in the Chinese lighting market. China's production of compact fluorescent lamps has soared from 60 million units per year in 1994 to approximately 300 million units in 1996. China is now responsible for about half of global production of these important energy-efficient light sources. The government has launched a broad energy-efficient lighting deployment effort loosely modeled after the U.S. Environmental Protection Agency's highly acclaimed Green Lights Program. The program may turn out to be even farther reaching, combining voluntary approaches with new mandatory efficiency standards. Lastly, torchiere floor lamps -- the fastest-selling household fixture in many western markets -- are now manufactured in very large volumes in China, most of which are exported. The extreme inefficiency of these 300- to 500-watt fixtures, combined with their rapid market penetration, has already overwhelmed the lighting energy savings that have been achieved in the residential sectors of some countries over the past decade. Adding insult to injury, the fixtures have also been responsible for a number of costly fires. Addressing this situation has become one of the most important emerging energy issues in the lighting area.

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ENDNOTES

[1] Presented at the *3rd European Conference on Energy-Efficient Lighting*, Newcastle upon Tyne, June 19-21, 1995