Environmental Progress in China's Electric Power Sector

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In April, 2000, the installed electric generating capacity in China was 300 GW. This compares to a 1995 capacity of 215 GW (Figure 1). For the past 15 years, China's electric power supply growth has averaged 12 to 18 GW each year (equivalent to adding a new 565 MW power plant every two weeks). By 1995, China became the world's second largest consumer of electricity with a total consumption of about 1,000 terawatt-hours. However, on a per capita basis, 1995 consumption was 815 kwh, 1/3 of the world average and 1/13 that of the U.S.

Currently, in part because of the successful power generation construction program and Chinese government policies to improve energy efficiency, and in part because of the economic slowdown in Asia, electric power supply exceeds demand in many regions of China. As a result, government officials are focusing their efforts on reforming the power sector to make it more efficient and cost-effective. In doing so, they are also reducing the serious pollution associated with electric power production.

Currently, China's electric power sector is centralized. The Government owns and operates a large percentage of the electric power generators as well as all of the transmission and distribution systems. It sets prices, decides where subsidies should be provided, what new plants and transmission systems should be built, how plants should be dispatched, among other things. In short, it has had a hand in all aspects of the industry. As a result, the system suffers inefficiencies that a more competitive industry could avoid.

To create competition, reduce costs, and for other national purposes, the Chinese government has embarked upon broad-based economic and policy reforms. Recognizing the importance of electric power to sustained growth of China, the electric power sector has been designated as a priority sector for reform. If the reforms are successful, China expects to improve the reliability and performance of its power sector, while improving efficiency and competition. This, in turn, will reduce electricity prices, making it more affordable to a larger percentage of the population, including the poor. Reform will also result in an optimal use of China's energy and natural resources and could alleviate many environmental and social concerns.

The Chinese electric power industry is aggressively carrying out steps to comply with the government's reform mandate. It has developed projects with the World Bank and the Asian Development Bank to create road maps to systematically reform the sector. It has initiated pilot projects in six provinces -- Shandong, Zhejiang, Shanghai, Liaoning, Heilongjiang, and Jilin -- to demonstrate grid/generation separation strategies.

Reform of the industry in China will not proceed without confronting obstacles. The implementation issues confronting China as it moves forward in carrying out its pilot projects and expanding reform to other provinces can be categorized into the following three areas:

1) **Technical and management issues** such as organizing power plants and dispatch centers for competition, forecasting power plant load, creating dispatching plans at a

power plant level, developing and evaluating bid documents, structuring independent power producers so they can be competitive, developing and using technical support systems to assist in managing the power plant and grid operations, among others.

2) **Legal, regulatory and institutional issues** such as price and settlement regulation, addressing environmental, rural power development and other social issues, creating legally enforceable contracts for the sale of electricity, creating policy guidelines on addressing stranded assets and grid requirements, among others.

3) **Financial issues** such as determining the components of competitive price bids, quotation procedures, economic dispatching procedures, wires charges policy, use of financial incentives and price subsidies.

Recognizing the efficiency and economic improvements that can result from market-based economic systems, China's leaders have placed high priority on expediting formulation of a modern state enterprise system and establishing a socialist market system. Both China's 9th Five-Year Plan and the Fifth Plenary Session of the 14th Party Congress give high priority to creating a socialist market system. As part of this national reform movement, priority has been placed on reform of China's electric power sector. A four-step strategy to become market-based is currently being implemented (Figure 2):

1. Beginning in 1997, the Chinese government laid the foundation for reform by abolishing the Ministry of Electric Power and creating the State Power Corporation of China (SP). The SP manages state-owned electric power assets (almost ½ of the generating capacity) and runs the country's national transmission networks.
2. From 1998 to 2000, efforts are being placed on separating government functions from those of the electric enterprises and restructuring the industry. Major elements of this part of the strategy include:
   - Defining the roles and responsibilities of and relationships among the SP, provincial power corporations and power companies and reorganizing them as appropriate,
   - Organizing the functions of the SP to ensure they are properly linked and function well together,
   - Creating a national grid by completing the interconnections that are needed among the regional power grids,
   - Continuing to implement the government electric power reform policies to lay the framework for separation of electric power generators and transmission and distribution of power,
   - Improving the performance of power generators by shutting down small, inefficient systems and encouraging the use of new technologies,
   - Bringing electric power to regions of China currently without it, and
   - Encouraging foreign investment in the power sector, among other things.
3. From 2001 to 2010, realize a fully integrated national grid and a reformed power generation sector that is competitive, incentivized to use advanced technologies, and organizationally separated from transmission and distribution systems.
4. After 2010, to achieve efficiencies and the level of electric power reform equivalent to that of any country in the world.

As a result of recent restructuring of the Chinese government, management of the electric power sector has changed dramatically. Several organizations play important roles in

electric power.

Currently, the State Power owns and manages the sector's State assets including nearly 50% of the generating capacity and a large majority of its transmission and distribution systems. In addition to direct ownership and management of the State's electric power assets, the SP has many autonomous wholly owned subsidiaries that manage most of the remainder of the country's electric power assets.

Regional Power Groups are wholly owned subsidiaries of SP, that manage inter provincial power grids and exercise other functions designated by SP. Provincial Power Corporations are responsible for operation and management of the local power grid and are either under the control of the SP directly or reporting to the Regional Power Groups.

In addition, several Government agencies are important participants. They include:

- State Development Planning Commission who formulates plans for national economic development, develops the national investment plan and develops electricity tariff policy and approves the fixed tariff.
- State Economic and Trade Commission develops and implements macro-regulation of the Chinese economy, guides industrial policies and production activities for industry and local governments and serves as a promoter, coordinator and law enforcement body for the establishment of the electricity market.

But, aside from the technical and infrastructure issues facing China as it reforms its electric power industry, it must address the environmental issues dependence upon inefficient, coal-burning plants have caused. China now ranks as the world's second largest energy consumer. The country's heavy reliance on coal causes severe pollution in many regions. Acid rain affects up to 40% of China's land area and causes over $13 billion in damage to forests, farms and health each year. CO_2 emissions could surpass those of the U.S. within the next few decades (Figure 3).[1] Still, per capita energy use will remain far below that in more developed countries (Figure 4).

In 1997, the electric power sector consumed over one-third of the country's nearly 1.4 billion tons of coal. Seventy-five percent of all electricity produced in China was generated using coal. In contrast, hydroelectricity produced 23% and nuclear 1%.

Statistics indicate that, as a result of industrial production, 21 million tons of sulfur dioxide are emitted into the atmosphere in China each year, in addition to 14 million tons of smoke-filled dust and another 13 million tons of powder-like particulates. Industrial boilers and furnaces consume almost half of China's coal and are the largest single point sources of urban air pollution. However, coal-fired power plants also rank among the major sources of pollution in China. Table 1 shows the role of electric power in China's particulate matter and SO_2 emissions problems in 1994. In 1994, 28% of the country's particulate matter and 32% of its SO_2 were the result of emissions from electric power plants.

Despite the environmental problems, the electric power industry has made notable progress in environmental protection (Table 1). While installed capacity and coal use doubled from 1987 to 1994, emissions increased by a much smaller amount. This was due in large part from the implementation of laws and policies on environmental protection, increased

investment in pollution control and the development of advanced technologies.

Particulate emissions from thermal power production have been stabilized. The total installed capacity of coal-fired power plants over 6 MW in size was 55 GW in 1987 and particulate matter emissions totaled 3.9 million tons. By 1994, installed capacity had doubled to 108 GW yet particulate matter emissions increased by only 4% to 4 million tons. Stated another way, particulate emissions declined by over 20%, from 47,000 tons/GW in 1990 to 37,000 tons/GW in 1994. This was a result of increase in particulate removal rates from 92% to 95.6% primarily from the increased use of high-efficiency electrostatic precipitators on all new, expanded and renovated power plants (Table 2). In addition, according to SEPA's latest annual report, 1999 particulate emissions has been reduced by 20% from 1995 levels (to 3 million tons) by the end of 1999, in part because of the industrial slowdown.

Reductions in emissions of sulfur dioxide (SO_2), in production of ash and slag and increases in ash and slag utilization also occurred between 1990 and 1994. However, even though significant increases in waste water production also occurred during between in this time period, waste water recovery increased dramatically from none in 1987 to 770 million tons (over 40%) by 1994. In 1987, only 60% of the water discharged from thermal power plants met national standards for water protection. At that time, almost no waste water was recovered. By 1994, 76% of the waste water produced met national standards for water protection.

Like particulate matter, SO_2 emissions are reported to have declined by 20% between 1995 and 1999 as a result of China's economic slowdown. Likely, waste water and ash and slag production have declined as well, although no information is available to confirm this.

China has begun to implement many other programs to decrease pollution from the electric power sector. These include:

- Reducing emissions of SO_2 in acid rain regions and SO_2 control areas. This would be accomplished by sorting and washing of high sulfur and high ash coals and using flue gas desulfurization equipment on some new and repowered power plants as required by China's recently enacted Air Pollution Control Law. Coal cleaning will improve the power industry's fuel quality, allowing it to be more available and reliable, while at the same time reducing sulfur dioxide and particulate matter emissions.
- Requiring control of NO_x from dry bottom and wet bottom boilers.
- Requiring control of particulate matter and capping particulate emissions in power plants at 1995 levels and requiring the use of high-efficiency electrostatic precipitators on all new, expanded and renovated power plants.
- Imposing emissions fees of 200 yuan/ton SO_2 for all emitting sources in the designated acid rain control and SO_2 pollution control regions.
- Government policies to promote increased utilization of ash and slag from power production. Ash and slag utilization increased from 11 million tons in 1987 to 37 million tons in 1994; this trend has continued to today.
- Improving the efficiency of power plants, primarily by completing the technological update of 7.5 to 8 million kW medium and low pressure condenser-tube generating units that have been in operation for at least 25 years. This will reduce the consumption of coal to produce 1 kW of electricity by 34

grams.

- Shutting down of approximately 30,000 MW of small generators in addition to the 10,000 MW already shut-in because they are very inefficient and costly to operate. In addition, limitations have been placed on the construction of new small capacity units to ensure that only high efficiency cogeneration plants and other clean, efficient and economic technologies are used. This, coupled with the closure of 33,000 small coal mines and hundreds of larger ones that were inefficient and not economic, and the economic slow-down in Asia have resulted in an 18% reduction (300 million tons) in total coal consumption from its peak in 1996. In 2000, another 19,000 small coal mines are planned to be shut down, decreasing coal production by another 120 million tons to 870 million tons.
- Requiring that new coal-fired power plants be of sufficient size to ensure that they are as efficient as state-of-the-art plants built anywhere in the world (Figure 5). In 1987, only 11 plants had a capacity of 1 GW or more for a total of 15 GW. By 1994, 38 power plants of 1 GW or more had a combined capacity of 87 GW or 1/3 of total Chinese generating capacity. In 1997, 95 GW of capacity, or 38%, was from units greater than 200 MW in size; 63% was from units greater than 100 MW.
- Significantly curtailing new conventional thermal power plants until 2002. The Tenth Five-Year Plan (guiding government activity from 2001 to 2005) emphasizes the expanded use of natural gas and the further development of renewable energy resources for power generation. Advanced clean technologies including gas, clean coal and renewable energy plants will be emphasized.
- Improvement/upgrading of transmission and distribution systems in parts of China. China's objective is to reduce transmission and distribution line losses to 3.5% from the mid-1990's level of 8%.
- Encouraging power plant performance improvements to improve their reliability, availability and heat rates. These actions will result in the need to build less generating capacity than would otherwise be required.
- Improving the efficiency of electricity end-users to reduce electricity demand.
- Increasing the use of nuclear energy to attain a market share of 4% of the electricity produced in China in 2020 and increasing the use of renewable energy.
- Introducing clean coal technologies into China's power sector. Emphasis will be placed on: (1) supercritical pulverized-coal, (2) circulating fluidized-bed combustion, (3) pressurized fluidized-bed combustion, and (4) integrated gasification combined-cycle systems.

China's Law on the Prevention and Control of Air Pollution requires control of particulate matter, sulfur oxides and nitrogen oxides. These standards are shown in Table 3 and compared to U.S. and World Bank standards. Several provinces have imposed even more stringent requirements (e.g., Guangdong and Shanghai). In other attempts to reduce air pollution, China's national legislature is considering drastic changes to the Law on the Prevention and Control of Air Pollution, which was revised just three years ago. Suggested amendments include banning the discharge of air pollutants above a certain level, imposing heavy fines for violators of the law, and replacing coal combustion with clean energy resources such as "renewables" and natural gas.

On a regional level, China, South Korea and Japan have agreed to launch a five-year

project to control transboundary air pollutants.

In conclusion, although China's electric power sector still is a major source of pollution, many programs are in place, and many others will soon be implemented to reduce emissions considerably. China is to be congratulated for the progress it has made and encouraged to continue to improve the environmental performance of this sector of its economy.

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[1] China's Electric Power Options: An Analysis Of Economic And Environmental Costs, Batelle Memorial Institute, June 1998.

Figure 1: Total Electric Power Generation Capacity, by Fuel (1995-1997)

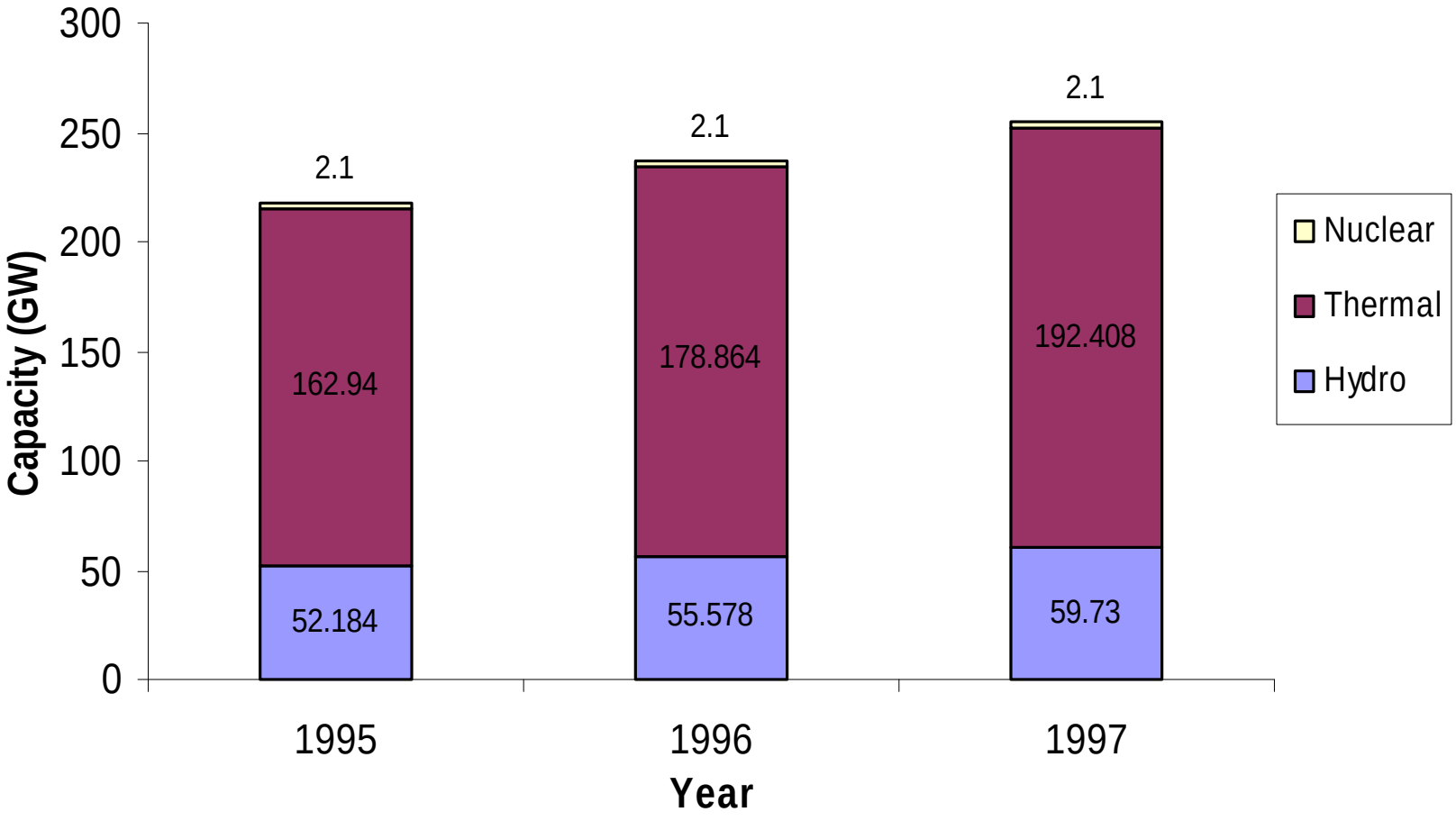
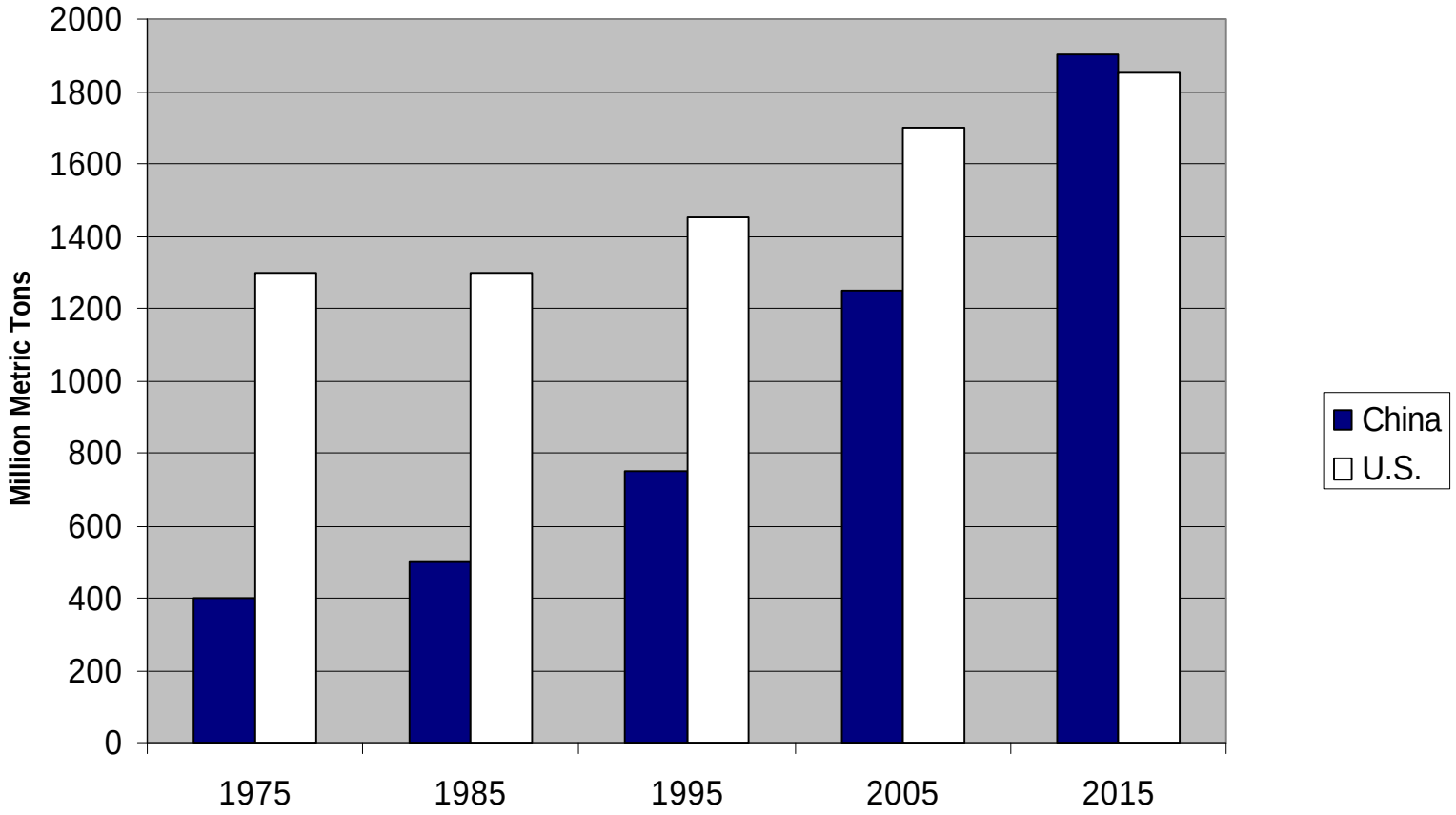


Figure 2: China's Electric Power Reform Strategy

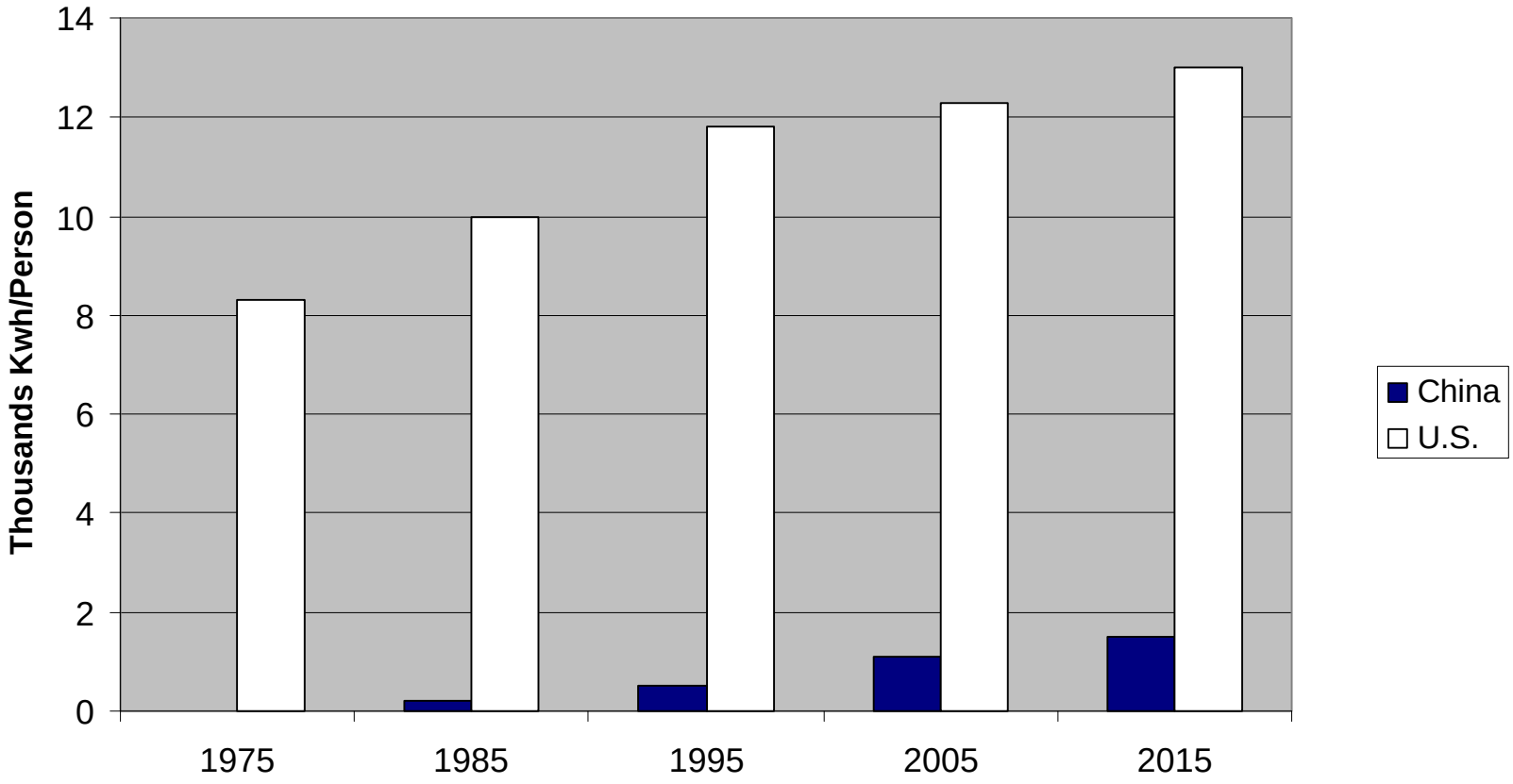
- 1997/1998 -- Abolish MOEP; Create State Power Corporation
- 1998-2000 -- Separate Government & Industry Functions
- 2001-2010 -- Realize Fully Integrated National Grid & Reformed & Competitive Generation Sector Separated From T&D
- >2010 -- Achieve Efficiencies & Reforms That are Best in Class

Figure 3: U.S. & China Carbon Emissions



Source: EIA, International Energy Outlook 1997

Figure 4: Net Electricity Consumption Per Capita: U.S. and China (1975-2015)



Source: EIA, International Energy Outlook 1997

Figure 5: Size Mix of Thermal Power Generating Units, 1997

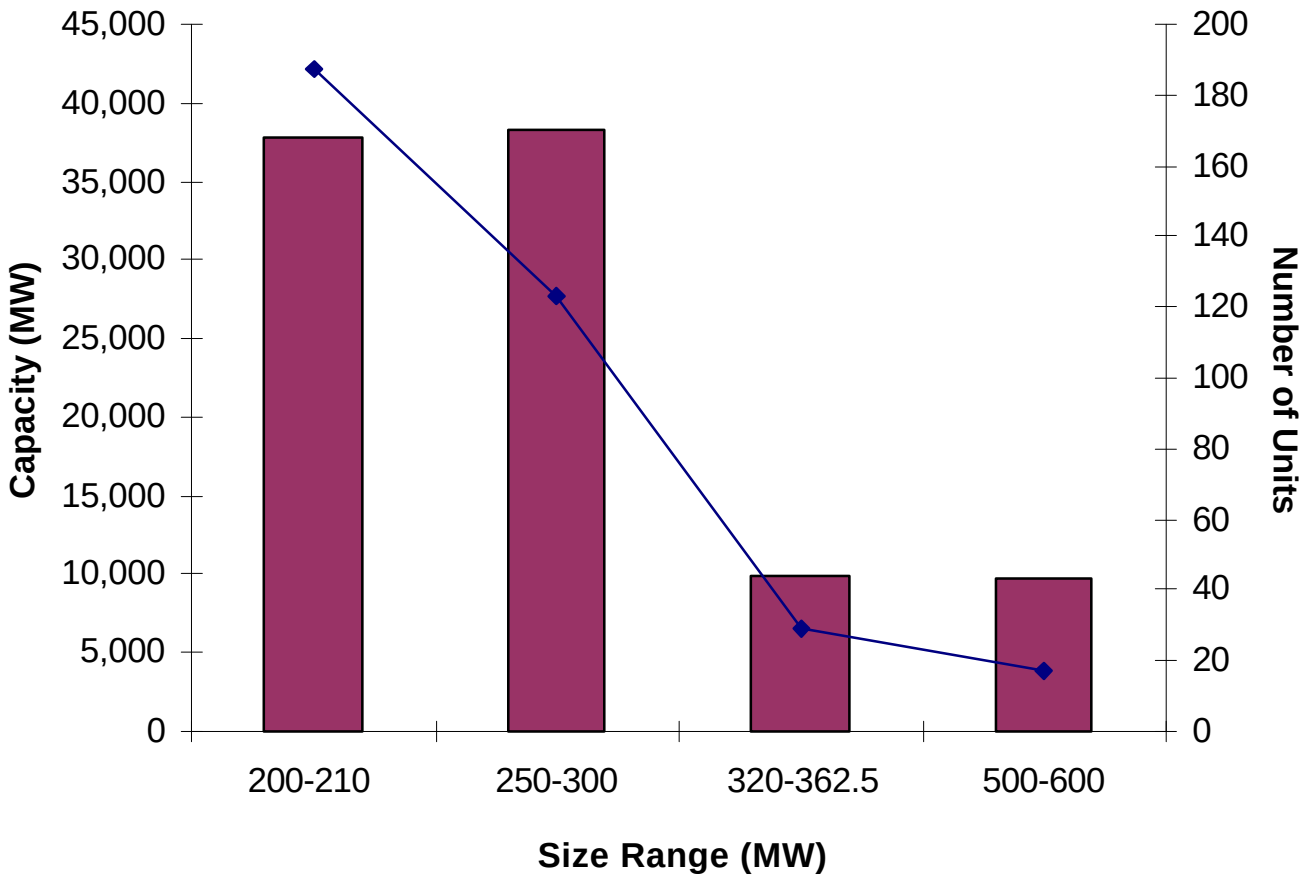


Table 1: Pollution From Coal-Fired Power Plants (Unit Capacity >6MW) (10^3 Tons/GW)

	1990	1992	1994
Particulate Emissions	47	43	37
SO_2 Emissions	55	54	54
Wastewater Production	11,000	N/A	17,000
Ash and Slag	880	880	840
Utilization of Ash & Slag	260	290	340

Table 2: Chinese Use of Ash Removal Equipment (%)

Type	1990	1992	1994	1997
Electrostatic Precipitator	33.2	41.7	53.5	64.7
Venturi Scrubber	30.1	28.4	23.9	19.5
Water Film Scrubber	17.2	14.2	11.9	7.9
Multi-Tubular Scrubber	5.9	5.2	3.5	2.1
Swirl Scrubber	4.7	3.2	1.8	1.1
Other Scrubber	0.4	0.3	0.4	0.2
None (Mostly Oil-Fired)	8.5	7.0	5.0	4.5

Source: World Bank

Table 3: Emission Standards for Thermal-Fired Power Plants (mg/NM^3)

Pollutant	China Phase III (new plants)	United States	World Bank
Total Suspended Particulates (TSP)	▫ 200 for cities [a] ▫ 500 for rural areas [a]	In most cases 50; new PM 2.5 standards are proposed by EPA	50
Sulfur Oxides (SO_2)	▫ 2,100 for coal w/ ≤1% sulfur ▫ 1,200 for coal w/ >1% sulfur	920 - 1,210	▫ For background air quality < 50 micro g/Nm^3, total SO_2 emission: 100 tons per day (tpd) ▫ For SO_2 air quality ≥ 50 micro g/Nm^3, total SO_2 emission: 100 tpd or 0.2 tpd/MW (whichever is lower)
Nitrogen Oxides	▫ 650 for dry bottom [b] ▫ 1,000 for wet bottom [b]	350 - 620	Coal: 750 Coal w/VM < 10%: 1,500 Oil: 460 Gas: 320 Combustion turbine units: Gas: 125 Diesel: 165 Fuel oil: 300

[a] Applies to boilers rated over 65 ton-steam/hour

[b] Applies to boilers rated over 1000 ton-steam/hour

Source: World Bank