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How the People's Republic of China is Pursuing Energy Efficiency Initiatives: A Case Study

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Abstract

The Government of the People's Republic of China (PRC) has been paying increasing attention to enhancing energy efficiency, especially in the wake of rapid expansion of power-generating capacity in recent years. The existing even-load power generation scheduling regime, however, fails to contribute toward the objective of energy efficiency in power generation and is now regarded as a major cause of energy inefficiency and environmental problems. Since early 2007, the government has adopted unprecedented actions to reform the scheduling rule and has coupled it with equally strong actions to phase out inefficient power generating units. The initial outcomes indicate that the policy has been effective and successful. Over 500 inefficient small thermal generating units, with the combined generating capacity of 14.4 gigawatts, were decommissioned during the first year of implementation. This has resulted in significant reduction in coal consumption, greenhouse gas, and other pollutant emissions, and impressive improvement in energy efficiency.

Why is the policy successful and effective? What challenges lie ahead during further implementation? What lessons can one draw from the experience in the PRC? This paper attempts to address these questions, focusing on the key concern of implementation. Any program, no matter how meticulously designed, amounts to nothing if not implemented carefully.

CURRENCY EQUIVALENTS
(Mean value of exchange rate)
Currency Unit – yuan (CNY)

Effective 2001	CNY1.00 = $0.1208 $1.00 = CNY8.2774
Effective 2002	CNY1.00 = $0.1208 $1.00 = CNY8.2766
Effective 2004	CNY1.00 = $0.1208 $1.00 = CNY8.2767
Effective 29 December 2006	CNY1.00 = $0.1281 $1.00 = CNY7.8087
Effective 28 December 2007	CNY1.00 = $0.1369 $1.00 = CNY7.3046

ABBREVIATIONS

CHP	–	cogeneration of heat and power
CO_2e	–	carbon dioxide equivalent
GHG	–	greenhouse gas
LSS	–	large substitutes for small
NDRC	–	National Development and Reform Commission
PRC	–	People's Republic of China
AC	–	alternating current
DC	–	direct current

WEIGHTS AND MEASURES

gce	–	gram of coal equivalent
GW	–	gigawatt
GWh	–	gigawatt-hour
kV	–	kilovolt
kW	–	kilowatt
kWh	–	kilowatt-hour
Mt	–	million metric tons
Mtce	–	million tons of coal equivalent
$MtCO_2e$	–	million tons of carbon dioxide equivalent
MW	–	megawatt
MWh	–	megawatt-hour
t	–	ton
tCO_2e	–	tons of carbon dioxide equivalent
toe	–	tons of oil equivalent

NOTE
In this paper, "$" refers to US dollars.

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I. Introduction

The Government of the People's Republic of China (PRC) has been paying increasing attention to enhancing energy efficiency, especially in the wake of its rapid expansion of power generating capacity in recent years. The existing even-load power generation scheduling regime, however, fails to contribute toward the objective of energy efficiency in power generation and is now regarded as one of the major causes of energy inefficiency and environmental problems.

Beginning in early 2007, the government adopted unprecedented actions to reform the even-load power generation scheduling rule, and at the same time, introduced complementary and equally strong steps to phase out inefficient power generating units. The initial outcomes of these policies indicate that they are successful. Over 550 inefficient small thermal generating units—with the total generating capacity of 14.4 gigawatts (GW)—were decommissioned in the first year of implementation. This has resulted in significant reduction in coal consumption, greenhouse gas (GHG), and other pollutant emissions, as well as an impressive improvement in energy efficiency.

Why is the policy successful and effective? What challenges lie ahead during further implementation of the policies? What lessons can one draw from the experience in PRC? This paper attempts to address these questions, focusing on the key concern of implementation. Any program, no matter how meticulously designed, amounts to nothing if not implemented carefully. The next section gives an overview of the PRC energy and power sectors, highlighting why energy efficiency in power generation subsector has become a priority policy concern. The third section presents key elements of the policies that were introduced in early 2007 and highlights what has been accomplished during the first year of implementation. The fourth section provides a structured analysis of the implementation experience, focusing in particular on issues of timing, macro policy environment, organizing capacity, incentive and accountability, and complementary support. The fifth section discusses challenges ahead to scale up the policies and further measures required for energy efficiency improvement. Finally, the last section draws policy conclusions and discusses lessons learned.

All data used in this paper are collected from domestic and international public domains or through consultative discussions with relevant agencies. These data may have different degrees of accuracy and timelines and may not be fully consistent with each other. But the basic structure, trends, and policy implications can still be analyzed.

II. What is the Problem? Overview of Power Sector in the People's Republic of China

With a population of 1.3 billion and an economy growing at an average annual rate of over 10% in the past three decades, the PRC has become the largest energy producer, second largest energy consumer, and soon will be the largest GHG emitter in the world. The demand for electricity is expected to grow significantly in view of the current low level of consumption on a per capita basis. The PRC's energy need has been met basically from domestic resources, except when it became a net energy importer in the mid-1990s. The PRC's energy self-sufficiency ratio was very high at 94.2% in 2005 and indeed was the highest among all major energy consuming countries in the world (Table 1).

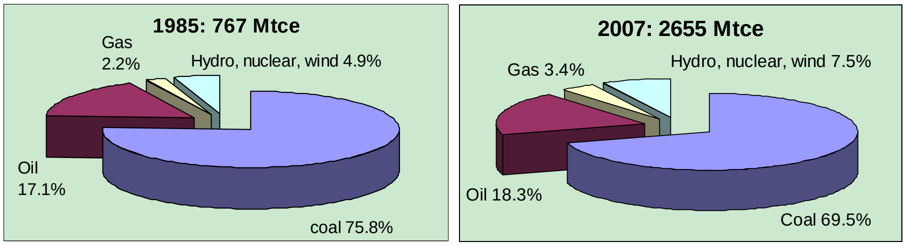
Table 1: Primary Energy Supply in Major Energy Consuming Countries, 2005

Country	TPES (Mtoe)	Domestic Production (Mtoe)	Net Import (Mtoe)	Self-Sufficiency	TPES per capita (toe)	CO_2 per capita (tCO_2e)
PRC	1,717.00	1,641.00	100.12	94.2%	1.32	3.9
US	2,340.29	1,630.68	734.87	68.6%	7.89	19.6
India	537.31	419.04	121.60	77.4%	0.49	1.1
Japan	530.46	99.77	438.98	17.2%	4.15	9.5
Germany	344.75	134.50	214.47	37.8%	4.18	9.9
France	275.97	136.89	143.30	48.1%	4.40	6.2
UK	233.93	204.30	32.26	86.2%	3.88	8.8
Republic of Korea	213.77	42.93	176.26	17.6%	4.43	9.3

CO_2 = carbon dioxide, Mtoe = million tons of oil equivalent, PRC = People's Republic of China, tCO_2e = tons of carbon dioxide equivalent, toe = tons of oil equivalent, TPES = total primary energy supply, UK = United Kingdom, USA = United States of America.
Source: International Energy Agency, *Key World Energy Statistics 2007*, Selected Indicators for 2005.

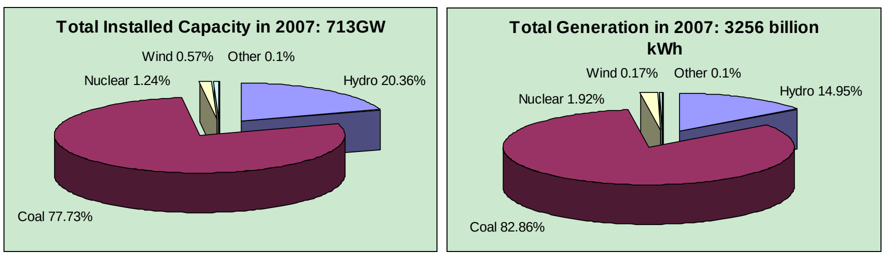
While the PRC has been taking steps to develop nuclear, hydro, wind, and other renewable energies, the country remains heavily dependent on coal as the primary energy and fuel for power generation (Figure 1). Indeed, coal is the most abundantly available indigenous energy resource. Coal accounted for 69.4% of the total primary energy consumption and 82.9% of power generation in 2007 (Figure 2), which are far above the world average of 26.2% and 40%, respectively (International Energy Agency 2007).

Figure 1: The PRC: Changes in Primary Energy Consumption



Mtce = million tons of coal equivalent.
Sources: *China Statistics Yearbook 2007*, Table 7.2 Total Energy Consumption and its Mix. Primary energy consumption in 2007 from Summary of Energy Data in National Statistics Report 2007. The sum of items is 98.7%, not 100%.

Figure 2: The PRC: Fuel Mix for Power Generation

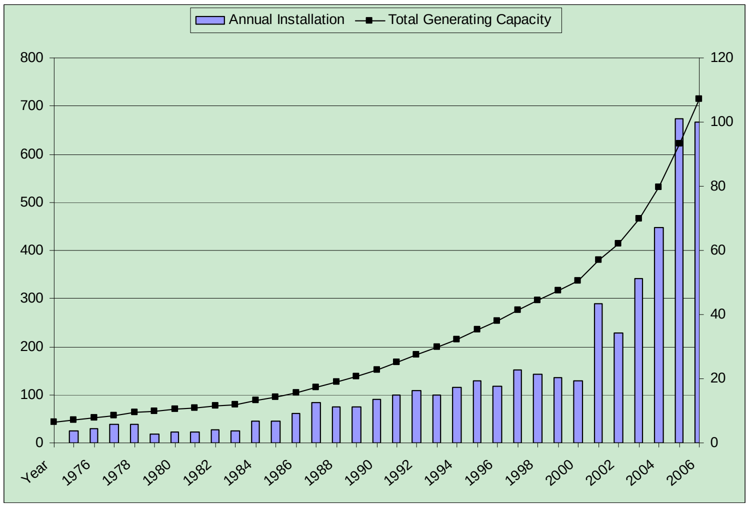


GW = gigawatt, kWh = kilowatt-hour.
Source: China Electricity Council, Express Report of National Electricity Industry 2007.

In the PRC, power generation accounted for more than half of the total coal use and was responsible for 53% of sulfur dioxide emissions. For this reason, the government has identified power generation as a priority sector to be targeted to improve energy efficiency and to reduce emissions.

Commercial power generation has had a long history in the PRC. The first commercial power generation with a 16 horsepower (11.67 kilowatt [kW]) machine was launched in 1882—over 125 years ago. For the first 70 years from this to the founding of the PRC in 1949, the PRC had built a total generation capacity of merely 1.85 GW nationwide. However, power generation capacity has recently been expanding at a fast speed, especially since the late 1970s when economic reforms and growth acceleration began (Figure 3). It took almost 30 years for the PRC to increase the total capacity to 57 GW, from 1949 to 1978; in contrast, the annual addition of generation capacity climbed from a few GWs in the 1980s to 10–20 GW in the 1990s.

Figure 3: Power Generation Capacity in the PRC (GW)



Source: China Electricity Statistics Year Report 2007, China Electricity Statistics.

Since 2000, energy demand has grown much faster, driven by accelerated urbanization and industrialization. In early 2002, the PRC experienced an unexpected reoccurrence of severe power shortages. In response, power generation capacity increased sharply. Table 2 shows that annual installation of the generation capacity has doubled every 2 years, and the annual addition reached 100 GW in 2006 and 2007.

Table 2: The PRC: Annual Addition of Power Generation Capacity (GW)

Year	2000	2001	2002	2003	2004	2005	2006	2007
Annual capacity addition	20.5	19.3	43.3	34.2	51.2	67.2	101.2	100.1
Total installed capacity	317.0	336.0	379.0	414.0	465.0	532.0	622.0	713.0

Sources: China Electricity Council, Electricity Statistics; *2007 Electricity Express Report*.

In the early 1980s, the country's economic growth was constrained by persistent and sometimes severe power shortages. The government opened this sector up to various investors, as it had been previously monopolized by the state. Key policy measures included reforming ownership structure, changing the financing regime, and adopting an even-load power generation scheduling rule on power grids.

Under the even-load scheduling rule, the grid load is evenly dispatched to all grid-connected power generating units, regardless of their efficiency in energy use and effectiveness in emission control. When the grid load is low during nights and weekends, all grid-connected generating units are required to reduce their power output evenly.

The even-load scheduling rule historically served a useful role by providing positive incentives to boost investment, thus contributing significantly to mitigating the country's power shortage. Over time and especially since 2000, however, this arrangement has increasingly led to unintended consequences—providing incentive to the survival and continued construction of inefficient small conventional power generating units. This has been viewed as a policy constraint to improving energy efficiency in the sector.

Table 3: Energy Efficiency of Different Power Generation Technologies in the PRC, 2006

Unit size		Net Heat Rate[a] (g/kWh)	Net Efficiency (%)	% of 300 MW
USC	1,000 MW	285.6	43.03	119.0
	600 MW	292.0	42.09	116.4
SC	600 MW	299.0	41.10	113.7
Subcritical	300 MW	340.0	36.15	100.0
	100 MW	410.0	29.98	82.9
	50 MW	440.0	27.93	77.3
	25 MW	500.0	24.58	68.0
	12 MW	550.0	22.35	61.8
	6 MW	600+	20.48	56.7
Average 2006		**367.0**	**33.49**	**92.6**
Average 2007		**357.0**	**34.43**	**95.2**

kWh = kilowatt-hour, MW = megawatt, SC = supercritical, USC = ultra-supercritical.

[a] Net heat rate is the amount of coal consumed by a power plant per kWh of power delivered. It equals the gross heat rate minus in-plant use of energy.

Source: National Development and Research Center (NDRC).

Small conventional thermal power generating units are defined as thermal power generating units with a capacity less than 100 MW (Table 3). Most small conventional thermal power generating units are condensing steam turbine generators. In general, they are energy inefficient as compared with larger and modern units. These small units consume much more fuel and emit more GHG and other pollutants to generate the same amount of electric power. As Table 3 shows, a 100 MW class unit consumes about 30% more coal than a 600 MW class unit.

Contrary to the intention to upgrade them, these inefficient small units were still being built during the latest investment boom and persistently account for around a quarter of the total installed thermal power capacity (Tables 4 and 5). In a country that is heavily dependent on coal as its dominant primary energy and fuel for power generation, continued existence and building of these inefficient small units is a critical problem and a major barrier to energy efficiency and emission reduction.

Table 4: The PRC: Small Conventional Thermal Power Generating Units in the Thermal Power Generator Sector

Year	Total Capacity of Thermal Power (GW)	Total Capacity of Small Units (GW)	Small Units in Total Thermal Power (%)
2000	237.5	67.4	28.4
2001	253.0	67.7	26.8
2002	265.6	66.5	25.0
2003	289.8	70.8	24.4
2004	329.5	84.8	25.7
2005	391.4	121.0	30.9
2006	483.8	114.0	23.6
2007	554.4	104.0	18.8

GW = gigawatt.
Source: National Development and Research Center.

Table 5: The PRC: Thermal Power Mix, as of end of 2006

Unit Size	Installed Capacity (GW)	% of Thermal Capacity
1,000 MW class	n/a	n/a
600 MW class	125.79	26.0
300 MW class	82.25	17.0
100–300 MW class	130.63	27.0
100 MW	113.99	23.6
50 MW	91.30	18.9
25 MW	51.60	10.7
6 MW	21.30	4.4

GW = gigawatt, MW = megawatt.
Source: National Development and Research Center.

III. What Needs to be Done? Key Policy Elements and Initial Results

Recognizing resources and the environment as major constraints to its further development, the PRC has committed a major shift of its development pattern from being resource intensive to being sustainable for the environment and resources—emphasizing efficiency, resource conservation, and environmental sustainability. In the 11th Five-Year Plan for Economic and Social Development (2006–2010), the government stipulated a target of 20% reduction in energy intensity and a 10% reduction in sulfur dioxide emissions. Efforts and investment have been devoted across all sectors in the PRC for improvement of energy efficiency.

In identifying small conventional thermal power generating units as the most inefficient element in the thermal power sector, the government prioritized a structural adjustment in its energy efficiency efforts by enforcing early retirement of these units and substituting them with efficient, modern, large ones. It is estimated that substitution of the existing 114 GW of small units with 300 MW class subcritical units (net heat rate 340 grams of coal equivalent [gce] per kWh or 36.15%) will reduce the burning of 90 million tons of coal equivalent (Mtce) and cut emissions by 1.8 million tons of sulfur dioxide and 220 million tons of carbon dioxide equivalent ($MtCO_2e$). The reduction would be higher if they are substituted with 600 MW or 1000 MW class units (net heat rate 299–285 gce/kWh or 41–43%), which are currently supplied in large scale and installed at a faster pace than the 300 MW subcritical units.

The government determined that early retirement of the small units and a ban on building new ones are necessary to facilitate energy efficiency enhancement in the PRC's power generation sector.

A. Program of Large Substituting Small

The government chose to introduce energy efficiency programs when the last power shortage eased in 2006. The two major programs are: (i) large substitutes for small (LSS), and (ii) energy conservation power generation scheduling. These programs intend to remove most of the existing 114 GW small units from operation. The LSS program is expected to decommission about 50% of existing small units in by 2010, with policy instruments that have economic incentives. The energy conservation scheduling will gradually phase out the surviving units of LSS program with policy instruments that focus on prioritized scheduling of power generation in favor of renewable, nuclear, efficient, and clean coal power plants.

While the energy conservation scheduling rule change is under intensive preparation due to its complexity in coordination, the government launched the LSS program at the beginning of 2007 to help meet the 2010 target. Toward a 20% reduction in energy intensity, 50 GW coal-based and 7–10 GW diesel-based small units will be decommissioned, including:

- (i) all conventional thermal power generating units of 50 MW class and below;
- (ii) all conventional thermal power generating units of 100 MW class and below with 20 plus years of service;
- (iii) all conventional thermal power generating units of 200 MW class and below with designed service life shorter than their actual periods of service;
- (iv) all coal-fired generating units with a net heat rate higher than the provincial average by 10% or greater than the national average by 15% or in 2005;
- (v) all generating units of all kinds not meeting environmental standards; and
- (vi) all generating units not complying with laws and regulations.

The program also requires parallel installation of flue gas desulphurization to all new coal-based power projects and accelerated desulphurization retrofitting to all coal-based generating units larger than 135 MW and not included in the LSS program.

B. Initial Accomplishments

The LSS program has been smoothly carried out during its first year of implementation. At the end of 2007:

(i) The decommissioning of 56 GW of inefficient units had been proposed by provinces and power producers to the National Development and Research Center (NDRC) for participation in the LSS program, already meeting the target of the 4-year program.

(ii) The government approved 82 substituting power projects of 57.3 GW under the LSS program, in addition to projects approved for normal growth.

(iii) With an average size of 26 MW, 553 small units of 14.38 GW had been decommissioned, 43% more than the annual target of 10 GW for the first year.

(iv) The national average net heat rate of thermal power generation was reduced by 10 grams per kWh in 2007, tripling the average annual reduction in the past decade. The national average net efficiency of thermal power generation was improved to 357 gce/kWh or 34.43%, from 367 gce/kWh or 33.49%.

(v) Were the reduced amount of power generation from small units substituted by more efficient large units, it would result in annual savings of 18.8 million tons of coal use and emission reduction of 37.6 MtCO_2e and 290,000 tons of sulfur dioxide, respectively.

(vi) Reemployment of current employees and benefit rearrangements for retirees involved in the first year decommissioning appeared to have been worked out properly. No social unrest incidents have been reported to date.

The government has set the annual decommission target for 2008 at 13 GW.

IV. How Has It Been Done? Factors for Effective Implementation

The implementation of a program as massive and sophisticated as this one needs to be well-designed, organized, coordinated, and executed. This section provides a structured analysis of salient factors that have contributed to effective implementation of the program.

A. Timing

Massive decommissioning of generating capacities would not have been possible if the power supply was in severe shortage. The government carefully assessed the timing of the program. As noted earlier, it was launched when the latest power shortage started to ease in early 2006 and after a rapid capacity increase starting in the second half of 2002. Spare capacities built in the past 5 years in both power generation and equipment manufacturing provided strong backup to prevent potential power shortages when several small units were decommissioned.

B. Implementation Measures

A set of measures was designed to enforce and encourage the program's implementation. Key implementation measures included the following.

1. Organizational Structure and Accountability System

The program implementation is headed at the national level by NDRC and supported by other government agencies including the State Electricity Regulatory Commission, State Assets Supervision and Administration Commission, State Environmental Protection Agency (renamed the Ministry of Environmental Protection in March 2008), Ministry of Land and Resources, Ministry of Water Resources, Ministry of Finance, as well as major grids. At provincial and local levels, a leading group for implementation was set up, usually headed by lieutenant governor of a province or vice mayor of a city. The group is composed of local development and reform commissions and other government agencies including representatives from economic and trade commissions; the departments of finance, labor and social security, and land and resources; State Assets Supervision and Administration Commission; State Environmental Protection Administration; State Administration for Industry & Commerce; price administration; and local utility companies.

The NDRC plays the policy oversight role in the implementation of energy conservation and emissions reduction programs. Acting on behalf of the central government, NDRC signs the binding memorandum of understanding with governors of provinces/municipalities and heads of major energy-intensive industrial enterprises to ensure the integrity and accountability of program implementation. In turn, the governors signed memorandum of accountability with chiefs of lower-level governments in their constituencies. The breakdown of the national target of energy conservation and emissions reduction is assigned along the chains of accountability to each city, county, and major local enterprise for compulsory implementation. At each level, the governments and companies are accountable by higher-level governments/companies for failure to accomplish the task assigned.

Provincial governments and major electricity companies were required to submit detailed implementation plans to NDRC before the end of March 2007. The plans include enforcing execution and addressing post-decommissioning issues such as reemployment and financial settlements.

2. Building Policy Environment

a. *Creating Policy Expectation.* The government has issued a regulative mandate to stop building condensing steam turbine-generator units smaller than 300 MW class in all grid-covered areas in the PRC. At the same time, the government's decision to adopt the energy conservation scheduling rule sent a clear message that only renewable energy and highly efficient and clean generating units are encouraged in the future, threatening the very survival of small units. Even before it is actually implemented, the forthcoming scheduling program has already had visible impact on the behavior of electricity producers and developers, as evidenced by the participation in and faster-than-planned implementation of the LSS program and the drastic increase of new power projects adopting large supercritical and ultra-supercritical units. It was also decided that during the transition period before the new scheduling rule becomes effective, differential scheduling will be applied to dispatch more generating hours to large units and to limit the generation of small units.

b. *Maintaining Market Pressure*. The PRC has purposely maintained a fast pace of capacity addition with a priority on large units with efficient and clean technologies (600 MW and 1000 MW supercritical and ultra-supercritical units). After the power shortages subsided 2 years ago, the PRC also maintained market pressure on inefficient small units. Although the PRC is likely to slow the pace of capacity addition after installing 100 GW for 2 consecutive years, a certain level of spare capacity is still regarded as an important and effective component in policy tools to force inefficient units from the market and to prevent them from resurgence.

c. *Increasing Operation Cost of Small Units.* In the increasingly intensified competition in the PRC power market, the survival of inefficient small units depends, to certain extent, on local subsidies. Many of these units were invested in by local governments or local state-owned enterprises. They are also important sources of local fiscal revenue and are job providers. Many small power plants, especially the captive power plants of industrial enterprises, have been offered higher prices on their power sales and are exempted from taxes and surcharges to which ordinary power plants are subjected. To remove this market distortion, the LSS program has taken measures to level the playing field, including (i) capping the power prices of captive power plants with regional average, (ii) forbidding local subsidies to purchase small units, (iii) removing regulated funds and surcharge exemption from captive power plants, (iv) banning the transfer of power plants from public utility to captive use, (v) enhancing supervision of environmental standards, and (vi) enforcing pollution fines to increase the cost of violating environmental standards. Previously exempted surcharges and funds over electricity generated by captive plants include:

(i) construction fund for the Three Gorges Project;
(ii) repayment fund for rural grids and distribution networks;
(iii) surcharge for urban public utilities;
(iv) surcharge for renewable energy;
(v) post-resettlement assistance fund for large- and medium-size reservoirs; and
(vi) spare capacity fee.

3. Incentives to Encourage Decommission of the Small

a. *Link between Decommissioning and Building*. Decommissioned capacity of inefficient small units is the key criteria of eligibility for substituting a new power project to be included in the national power development plan, which is the basis for the government’s approval of projects. For example, a power company must decommission 840 MW of inefficient small units to make itself eligible for a new project of two 600 MW class supercritical units approved by the NDRC (600 MW x 2 x 70% = 840 MW).

Table 7: Required Decommission of Small Units for Approval to Substitute New Project (as percentage of new project’s capacity)

Unit Capacity of New Project	Required Decommission as % of New Project Capacity
300 MW class	80
600 MW class	70
1000 MW class	60
200 MW + class cogeneration of heat and power	50

Source: National Development and Research Center.

For power generation, the principle of “build after decommission” is followed. If they substitute more decommissioned capacity and resettle employees involved in the decommission satisfactorily, new power projects can be prioritized in the national power development plan. The government will increase capacity in the plan for each province and municipality according to the capacity decommissioned. In case of interprovincial projects, capacity addition is retained by the province with decommissioned units, and the corresponding deduction in capacity is made to the neighboring province(s) where the corresponding new project is built.

b. *Economic Compensation*. Enterprises of decommissioned units will continue to be allocated quotas of scheduled generation hours, emissions, and water use for a certain period (typically 2 years with a 3 year maximum). They are allowed to trade these quotas with power producers of large units at negotiated prices. Therefore, the earlier the units are decommissioned, the longer and the more they enjoy the revenue from trading these quotas. The government allows grids and efficient power producers to offer discounted prices on electricity sold to enterprises with captive power plants that are decommissioned. The grids and efficient power producers, in general, would like to offer price discounts from their increased revenue resulting from the decommissioning of captive power plants to encourage more decommissionings. Twenty decommissioned power producers in Henan Province traded 1.36 billion kWh of scheduled generation quota for CNY80 million in 2006. Twenty-three decommissioned power producers in the same province traded 1.42 billion kWh for CNY90 million in the first half of 2007.

Since the decommission of inefficient units will clear room for increased generation of efficient units and will increase the overall efficiency and financial position of large generation companies with both efficient and inefficient capacities, major generation companies are expected to compensate their decommissioned units through internal cross subsidies.

Provincial governments and major power producers have the flexibility to take different approaches to reach their committed targets. For instance, large power companies are encouraged to acquire inefficient small units from local or private power producers and close these acquired inefficient units for approval of new efficient large units. To avoid the burden in merger, acquisition, and post-decommission issues with several geologically widespread small units, new power projects owners in Henan Province agreed to pay CNY200/kW of their new capacity, accounting to about 5% of the typical capital cost of thermal power plant in the PRC, to a special compensation fund. The provincial government will manage and use the fund to promote and compensate decommissioning in the province.

c. *Prevention of Policy Evasions*. Relatively new (i.e., less than 15 years of commission) power-generating units are encouraged to retrofit to biomass-based power plants or cogeneration of heat and power (CHPs) but subject to the government's approval with close supervision by provincial authorities. Priority is granted to large and medium CHPs in metropolitan areas, and the CHPs of back-pressure steam turbines and biomass-based plants in medium and small cities and towns. CHPs and units for comprehensive use of resources are subject to online monitoring and periodical verification by provincial governments. Those failing to meet regulations will be ordered to conduct efficiency retrofitting within a designated period. Failure to meet the retrofitting deadline or failure to meet regulations after retrofitting will lead to enforced decommission. These measures are designed to prevent policy evasions such as power generation projects of inefficient small units disguised as cogeneration or gangue and other waste fuel-based power plants. Power generation of CHPs is strictly subject to heat demand and is monitored closely. Excessive supply of power in heating seasons and power generation in nonheating seasons are subject to treatment of ordinary small units. Small units in public utility are also strictly forbidden to be transferred to captive power plants.

Supervision teams are sent by the government to conduct on-the-spot verification and registration for each inefficient small unit decommissioned. A list of decommissioned units is published online for public monitoring to ensure that these units are truly and permanently decommissioned.

d. *Safeguards against Supply Interruption*. Prudent coordination of supply is emphasized in the decommission or retrofit of in-service CHPs. The decommission of in-service CHPs, either for those that participated in the LSS program or those that fail to meet the efficiency standards in paragraph 20 after efficiency retrofitting, is required to be implemented under the principle of "decommission after construction of the new" or "decommission after retrofit." This is different from power generation projects in which a principle of "build new after decommission" is observed.

A CHP unit meeting the decommission criteria is allowed to postpone its decommission if it is

(i) the only heat supplier or more efficient than other heat suppliers available within a radius of 10 kilometers;
(ii) the primary electricity supplier or supporter of local grid safety at the end of a grid or within an independent grid; or
(iii) a Sino-foreign joint venture or cooperation project legally approved before the issuance of Notification of Decommission of Small-size Thermal Power Generation Units (State Council [1999] No. 44) with a unexpired contracted operations period. If verified by NDRC-accredited evaluation agencies, these units can be permitted to delay decommissioning but will be subject to an annual evaluation.

4. Addressing Post-Decommission Issues

a. *Reemployment and Retiree Accommodation.* Efficient modern power plants of large units need fewer employees than the inefficient small ones to operate. They also must replace the number of small units in the geological areas concerned. As universal coverage of social security networks independent to enterprises has yet to develop in the PRC, the benefits and pensions of retirees related to decommissioned power plants also must be addressed.

The LSS program’s first year of implementation involved reemployment of 90,000 current employees and benefits rearrangement of 30,000 pensioners, including those with decommissioned units and those in preparation for decommission. The number of employees and retirees involved in some cases was significant. For instance, the small power plants that the Fujian subsidiary of Guodian Group planned to decommission had 3,770 current employees and
1,057 retirees, accounting for well over 50% of the total of the provincial subsidiary company of the group. Yongan thermal power plant was the largest thermal power producer in Fujian, once accounting for 70% of the total thermal power generation of the province. Decommission of its small units would involve reemployment of 1,200 employees out of its current total of 1,600.

Reemployment of current employees and benefits rearrangement of retirees are the first priority for all compensation funds appropriated or raised under the LSS program by central, provincial, and local government and relevant companies, including the use of revenue generated through quota trading. Some provinces encourage local authorities to recover and reuse the land of decommissioned units, based on local urban planning, to increase the value of the land concerned. Part of the increased land value could be used as a funding source for compensation. The government and companies are also urged to explore additional sources of funding to address the employee issue.

As a principle, the employees who are laid off from the decommissioned units under the LSS program have priority to be reemployed by all new power projects. They are encouraged to be hired as close to their residence as possible to reduce the resettlement cost. Large generation companies are responsible for employing as many as possible laid-off employees in their new projects and other business branches. Various power plant service companies are also established to employ their expertise while providing jobs. Laid-off employees who cannot be absorbed by power companies locally can be employed by power projects in other areas. Those who fail to be employed locally and do not wish to find jobs in other areas will be included in local job training, reemployment in security systems and other industries, or to start their own businesses.

b. *Asset and Debt Treatment.* Treatment of asset and debt of decommissioned units are based on existing relevant laws. Owners and debt obligators of the decommissioned units are responsible for repayment of the debt involved. Companies that decommissioned all their units are allowed to settle their remaining financial obligations by liquidation or bankruptcy. Uninstalled equipment from decommissioned units must find markets somewhere else or are sent to metallurgical industries since there is a national regulative ban on building inefficient small units in the country. Also, few developers of new power projects in the PRC would be still interested in buying inefficient second-hand units in expectation of the imminent implementation of the new energy conversation scheduling rule.

5. Complementary Drivers

Some other factors and market signals that made the smooth implementation of the program possible also deserve attention.

a. High Fuel Prices. The removal of government price control (guiding price) over coal in 2002 coincided with the full recovery of economic growth from the Asian financial crisis and the start of an investment boom of fast urbanization and heavy industrialization in the PRC. Coal prices have increased rapidly ever since. The average thermal coal prices have climbed from CNY200/t ($24) 2002 to over CNY500/t ($64) in 2006 and grew 10% more in 2007. Major coal reserves in the PRC are concentrated in several provinces, far away from major load centers. The railway system, the dominant conveyor of coal in the country, also has difficulties handling the drastic increase of coal freight, attributing to the increase of thermal coal prices. Thermal coal prices in major load centers increased CNY30–40/t in 2007 alone. In major load centers, thermal coal prices have reached CNY580 in Shanghai ($79.40) and CNY650/t ($89.00) in Guangzhou. This price increase would add about CNY42 billion ($5.75 billion) to power producers' costs.

Soaring fuel prices have provided a much stronger incentive for power producers to improve energy efficiency then it did 5 years ago, when efficiency improvement did not make much difference in financial returns, especially when the electricity tariff was still regulated.

b. Public Awareness and Social Consensus. All humans desire clean air, clean water, scenic views, spacious accommodation, and convenient transport. However, inadequate environmental investments are often observed in poorer countries.

In the PRC, general public awareness and common willingness to pay for environment quality surfaced in 1993 in Guangdong, the richest and fastest growing province. The Guangdong government proposed environmental protection instead of gross domestic product growth as their number one priority in their provincial 9th Five-Year Plan for 1995–2000. Similar public awareness and willingness to invest soon gathered strength along the comparatively more developed coastal areas and then gradually spread to central and western parts of the PRC. Major flooding in 1998 triggered a drastic change in public attitude toward the environment and the sustainability of economic development, resulting in major policy changes and increased investment. This coincided with the need in the PRC to fight weak domestic demand in the shadow of the Asian financial crisis.

Today, a social consensus on the importance of a sustainable economic development that is harmonious with the environment has reached the majority of the population. Evasion of environment codes can no longer occur in an open manner although there are still incidences. This common recognition of the significance of the environment and sustainability of development is the foundation for the ambitious energy conservation and emission reduction programs that have been successfully implemented in the PRC. It also feasible public sector actions of internalizing the cost of externalities and introducing market play into this traditional area of market failure, such as lifting prices of water and other scarce resources, charging higher fees for environment treatment, and penalizing and enforcing close downs of polluters.

c. Low Investment Risk in the Power Sector. The PRC's economy is in the process of accelerated urbanization and industrialization. Expecting a migration of 300–400 million rural residents into urban economies in the coming decades, demand for electricity and other infrastructure is expected to grow steadily with little uncertainty. While certainty on future demand for electricity provides power developers with huge business opportunities of stable return and very low risk, it also makes the government's project approval process for entry into this sector an effective tool for industrial reorganization and structural adjustment. This was not the case some 20 years ago when the government had to offer incentives to attract every possible investor to help pull the country out of a severe power shortage.

The link between building new efficient power projects and decommissioning inefficient small units provides incentives to both regional governments and power producers to participate in the LSS program. On demand side, local (i.e., provincial, municipal, and city) governments actively promote decommissioning to secure adequate addition of new generation capacity to support local economic growth. On supply side, the sooner and the more a company closes down its inefficient small units, the sooner and the more of their new projects can be approved and constructed, resulting in a bigger market share and more profit from the stable and high returns on low risk investments. The prosperous future of the PRC's economy—and therefore a sustained strong demand—has enhanced the government's ability to restructure the power sector.

d. Adequate Domestic Supply of Equipment at Competitive Cost. Deployment of new and clean technologies is feasible only if an adequate supply of equipment is available and the cost barrier is effectively addressed—actions that do not easily occur in developing member countries. When the domestic manufacturing sector is weak and lags behind in technology, developing countries must depend on usually expensive imported equipment for their industries. Affordability and availability are typical barriers for large-scale deployment of new technologies in these countries.

When the PRC was founded in 1949, its manufacturing sector was able to produce few things more sophisticated than bicycles. It has taken 50 plus years for the PRC to develop a comprehensive and competitive manufacturing system with increasing technological capability and manufacturing capacity to meet the needs in its electricity sector.

Through economy of scale and international technological cooperation, the PRC's manufacturing sector has been able to supply its power sector with many clean technologies at costs significantly lower than imported counterparts. Domestic production of 1000 MW class and 600 MW class ultra-supercritical units has lowered their costs through an increased production scale, together with ongoing mass production of 300 MW class subcritical and 600 MW class supercritical units. The actual capital cost of the thermal power project on average was reduced from CNY4,800/kW ($580) in 2001 to CNY3,600/kW ($435) in 2004, according to the State Electricity Regulatory Commission. The capital cost of power projects equipped with 300 MW class subcritical, 600 MW class supercritical, and 1,000 MW class ultra-supercritical units in 2007 was in a range of CNY3,500–4,000 ($480–548), taking into account increased currency appreciation and inflation.

Table 9: Domestic Supply of Power Generation Equipment in the PRC

Year	Annual Installation of Generating Capacity (GW)	Annual Domestic Production of Generating Equipment (GW)
1998	22.81	16.08
1999	21.45	13.69
2000	20.49	12.49
2001	19.26	13.40
2002	43.33	21.21
2003	34.21	37.01
2004	51.17	71.38
2005	67.23	92.00
2006	101.17	110.00
2007	100.09	129.91

GW = gigawatt.
Source: China Statistics Yearbook 1999–2007, *China Statistics Report 2008*.

Lower cost has made it possible to deploy new technologies on larger scales with less financial resources. This, in turn, allows more resources to be allocated to the more expensive renewable energy subsectors without adding heat to the already booming investment demand. This is happening because the electricity of each generating unit is priced at the government-based cost and average capital return. By the end of 2007, seven of 1000 MW class and two of 600 MW class ultra-supercritical units have been commissioned, in addition to 226 of 600 MW supercritical units and 580 of 30 MW class subcritical units, totaling 326 GW. These efficient units account for 58.9% of the 554.42 GW total thermal generation capacity in the PRC. The ratio of efficient units is increasing along with the implementation of the LSS program. Further improvement is expected when the energy conversation scheduling program becomes effective.

Table 10: New Technologies Deployed in the PRC, End of 2007

Technologies	No of Units	Net Heat Rate (g/kWh)	Net Efficiency (%)
1000 MW class USC	7	285.6	43.03
600 MW class USC	2	292.0	42.09
600 MW class SC	226	299.0	41.10
300 MW class subcritical	580+	340.0	36.15

Source: National Development and Research Center.

New and more efficient technologies are being introduced in a much shorter period along with the development of technological capability and manufacturing capacity in domestic industries. The 1000 MW and 600 MW ultra-supercritical, 250–400MW class integrated gasification combined cycle, 600 MW class circulating fluidized bed reactor, 800 kilovolt (kV) DC (direct current) and 1000 kV AC (alternating current) transmissions are current priorities in technological development, local manufacturing, and deployment in the 11th Five-Year Plan. These new units, in addition to 600 MW supercritical units, are expected to dominate the PRC thermal power subsector by 2010 as the country accelerates its deployment and stops building generating units smaller than 300 MW. The first 800 kV DC (direct current) transmission line[2] and the first pilot project of carbon capture and storage[3] started construction in December 2007. Four integrated gasification combined cycle (IGCC) projects of 250–400 MW classes as the first package of this technology are scheduled to start construction in 2008 and will be commissioned in 2010. Two (250 MW class) are based on domestically developed technologies.

[2] The National Grid began construction on the first project of 800 kV DC transmission line between Sichuan Province and Shanghai on 21 December 2007 and will be commissioned in 2010. The 2000-kilometer line is designed for annual transmission of 30.5 billion kWh of power, resulting in reduction of 15 Mtce used and 25 $MtCO_2e$ emissions per year.

[3] The Huaneng Group began construction on the first PRC-Australia cooperative pilot project of 3000 tons/year of carbon capture and storage at its Beijing CHP plant on 26 December 2007. It is expected to be put into operation before the 2008 Beijing Olympics.

V. Challenges Ahead and Further Reform Measures

A. Continuing with the LSS Program

As stated previously, major challenges in implementation of the energy efficiency programs are derived reemployment and compensation of financial losses incurred from decommissioning. More laid-off employees and retirees are expected in decommissioning the rest of the 36 GW units in the next 3 years. At the same time, many of the small units subject to decommissioning are still operational and profitable. Some are actually new, having built in the past 5–10 years. Advance decommissioning would incur significant financial losses to the investors and owners. The original investment of the existing 114 GW inefficient small generation units cost the PRC more than CNY 456 billion ($62.4 billion) even at average investment cost in 2005 of CNY 4000/kW ($548/kW) in the PRC, though there is no aggregate cost estimate for the programs available.

The program's first year implementation reflected different levels of progress, revealing different abilities in various areas, companies, and ownerships to absorb impact on employment and financial losses.

The state-owned sector, e.g., the five major power producers, local state-owned investment companies, and other local state-owned enterprises, decommissioned 256 units of 10.52 GW of the 553 small units of 14.38 GW in 2007, accounting for 73.1%. The private sector, including domestic and foreign-owned subsidiaries, decommissioned the remaining 297 units of 3.86 GW, accounting for 26.9%.

The five largest power producers in the PRC, e.g., Datang, Huaneng, ZDT, Huadian, and Guodian, demonstrated stronger ability by decommissioning 2.6 GW, 1.95 GW, 1.54 GW, 1.47 GW and 1.22 GW small units respectively, accounting for 61.06% of the total capacity decommissioned in 2007. With diversified assets and business branches after the major reform in this sector in 2002, these companies are more able to reemploy the laid-off employees in their expanding efficient energy divisions and other businesses. As decommissioning of their inefficient divisions cleared room for increased generation by their efficient divisions, company-wide fuel efficiency and financial position are improved, making the companies more able to balance the financial losses incurred from decommission. Intensified competition for the market share as introduced by major sector reform in 2002 also provided strong incentives to these companies to expand efficient capacities that can be done only by decommissioning more inefficient small units and doing it faster as designed in the implementation measures of the program.

However, decommissioning has proved to be a much tougher challenge for smaller and single business power producers. These companies usually have fewer in-house job opportunities for reemployment and less financial sources to cross-subsidize the financial losses incurred.

Developed areas and areas with greater potential for further expansion of power capacity have also shown a stronger ability to absorb the impact by providing job opportunities for the laid-off workers and financial compensation for retirees located in their administered areas. The five leading provinces of Shandong, Henan, Guangdong, Jiangsu, and Shanxi decommissioned 1.717 GW, 1.543 GW, 1.294 GW, 1.139 GW, and 1.007 GW, respectively.

Similar to smaller power producers, poorer areas with weaker public finance and less dynamic local economies find that the implementation is harder to carry out. These challenges are expected to intensify in the following years after comparatively easier jobs have been completed in the earlier years of the implementation.

The program's first year of implementation also found that slow progress in some areas resulted from weak commitment and poor coordination of relevant local authorities and weak enforcement of implementation measures, such as differential distribution of generation hours and quota trading. These failures also resulted in less survival pressure over inefficient small units.

These findings have helped the government fine-tune implementation measures, emphasizing the further worsening business environment of the inefficient small units. The government comprehensively used taxes, surcharges, funds, subsidies, and transfers of payment to form an exit mechanism for inefficient small units, as well as a detailed and concrete arrangement for the employees involved.

B. New Energy Conservation Scheduling Rule Program

Complementary to the LSS program, the energy conservation scheduling program is about to be launched in the latter half of 2008 to weed out the remaining inefficient generating capacity if they survived the LSS program. The program intends to recreate a market mechanism by substituting the current even-load power generation scheduling rule on the grids with an energy efficiency based one in favor of low carbon energy. Under the new rule:

(i) All grid-connected generating units are classified into the following priority categories:
- (a) unadjustable wind power, solar power, oceanic power, and hydropower;
- (b) adjustable hydro, biomass, geothermal power, and solid waste-fired units;
- (c) nuclear power;
- (d) coal-fired cogeneration units and units of comprehensive use of resources, including those using residual heat, residual gas, residual pressure, coal gangue, coal bed/coal mine methane, etc.;
- (e) natural gas and coal gasification based;
- (f) other coal-fired generating units including cogeneration without heat load; and
- (g) oil-based and oil product-based generating units.

(ii) Within each category, units are ranked according to their energy efficiency. Units with same energy efficiency are ranked according to their emission levels and water usage.
(iii) Units are scheduled for generation only when all units in upper categories and ranks are operating in full capacity.

The program's expected impact includes the following:

(i) Based on current and projected market structure in the PRC, all grid-connected renewable, nuclear-, and gas- (including coal bed/mine methane) fired units can be running in full capacity and have adequate room for further expansion.
(ii) Diesel-fired or other oil products–fired units will be out of the base load market with few exceptions, such as emergency backup units.
(iii) The current boundary would be located between 110–130 MW class coal-fired units, and units with capacity below this boundary are likely to be forced out of the market. Since peak load demand will be the only chance for majority of small thermal units below the boundary to sell their power, it is expected that most would have to quit the market because hundreds of generation hours per year would hardly generate adequate revenue for any power producer to survive.
(iv) Imminent implementation of this scheduling rule will provide powerful incentives to power producers to react to the LSS program.
(v) Rational power developers, under this new rule, would choose large and efficient generating units in their new projects to stay away from the ascending boundary. This, in turn, would accelerate the ascendance of the boundary, mutually reinforcing an energy efficiency ascending spiral in the sector. It is expected, if the LSS program removes about 50% of existing inefficient small units by 2010, the new scheduling rule would gradually drive most of the remaining half out of the market.

Four central government agencies headed by the NDRC jointly issued the new rules in August 2007. Experiments have been ongoing since December 2007 in the five provinces of Guizhou, Jiangsu, Sichuan, Henan, and Guangdong and are expected to be completed in mid 2008. Detailed implementation measures and working plans have been under development based on extensive planning and coordination by grids and local authorities and will be fine-tuned based on lessons learned. The new power generation scheduling rule is expected to become effective nationwide in the latter half of 2008.

VI. Conclusion and Implications

Successful implementation of public policies is based largely on effective planning. To succeed in implementation, the plan must be feasible and practical, contextualized solidly in local conditions, and have available resources. The PRC experience elicits several success factors, in particular, that an effective organizational structure, decision-making processes, and an accountability system along the chain of command are essential to efficient and successful implementation of public policies. It is also important to have careful coordination of interests between different levels of governments and different interest groups.

More broadly, the successful implementation of major energy efficiency programs in the PRC's power generation sector shows what developing countries can do in the global drive against climate change. It provides valuable experience to share with other countries in their future actions.

The PRC experience shows that developing countries see the virtue of tackling GHG emissions, without the legally binding quantitative commitment to GHG emission reduction. The PRC has taken concrete unilateral actions in energy efficiency, emission reduction, and low carbon energy development at a scale rarely seen in the rest of the world. Such actions taken by developing countries should be especially encouraged and supported, while recognizing the developed economies' historic and current responsibilities of global GHG concentration. Significant energy efficiency improvements in developing countries would help to address not only issues that concern developed countries like climate change and energy security, but also efficient use of scarce financial and natural resources to meet growing energy demands and to address local pollution, creating a win-win situation for all partners concerned.

The cost barrier needs to be addressed for new technologies to have global or regional impact. While seeking lower cost financing is important to overcome the initial cost barrier, development of domestic manufacturing capacity and technological capabilities are more fundamental, though more challenging and time-consuming.

The practice in the PRC demonstrates that development and mass production of new technologies in developing countries is a cost effective way in the global joint effort against climate change, especially in the areas of energy efficiency improvement, emission reduction, and renewable energy development. Developed countries could therefore best spend their resources by contributing to the global effort on climate change by promoting and facilitating technology transfer and providing finance to buy down the initial cost of new technologies for their application on a large scale.

The PRC experience further demonstrates that the public sector has a pivotal role to play in climate change mitigation by providing public goods for energy efficiency improvement and emission reduction. In these areas of market failure, private sector operations need to be encouraged, attracted, and supported by active, effective, and comprehensive uses of public policy tools like taxes, surcharges, subsidies, and transfers of payments, in addition to changes in legal and regulatory frameworks as necessary.

The Asian Development Bank has actively and persistently been a strong supporter of low carbon energy, clean technology, and the global campaign against climate change. Equipped with innovative policy tools and funding resources, the Asian Development Bank can and should serve as a significant contributor and a loyal partner to the efforts of its developing member countries in fighting climate change and improving energy efficiency.

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