Working Paper

Impact On Global Warming Of Development And Structural Changes In The Electricity Sector Of Guangdong Province, China

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I. Introduction

This paper examines the impact on global warming of development and structural changes in the electricity sector of Guangdong Province, China, together with the possible effect of international instruments such as are generated by the Kyoto Protocol on that impact. The purpose of the paper is three-fold: to examine and analyze the data available, to put that data into an explanatory economic and institutional framework, and to analyze the possible application of international instruments such as CDMs in that locality. Our plans are to supplement this work with similar work elsewhere in China.

Guangdong Province has led China in economic growth since the market reforms started in 1979. For more than a decade, this growth was constrained by a severe shortage of electricity. Following the central government's electricity sector policy change in the mid-1980s, Guangdong's utility sector expanded rapidly. Guangdong is now the richest Chinese province, with the most market-oriented economy, and the largest electricity industry judged by per capita installed capacity and per capita electricity consumption.

The development of new capacity has been accompanied by changes in the fuel structure and energy efficiency pattern. The new policy and sectoral reforms have also changed market mechanisms and institutional factors for the electricity sector. These changes represent a step towards reducing carbon emissions per unit electricity consumed, but the growth raises concerns about potential increase in total emissions in the future.

This research contributes to two groups of existing studies. First, several researchers have studied China's energy industry, including the utility sector, in the context of global greenhouse gas emissions and abatement policies. These studies either look at China's energy development and its global warming impact in large economic models (Garbaccio, et al., 1999; Ho, et al., 1998; Zhang, 1998; IAEE, 1999), or the utility sector at the highly aggregated national level (Zu, et al., 1999; Guo, et al., 1998; Holt, 1998; Andrew-Speed and Dow, 1998; Shao, et al., 1997; World Bank, 1994). Not much attention has been paid to the electricity sectoral development at the sub-national level and its regional differences. Yet, important decisions are taken and important constraints operate at the sub-national level.

Second, since the Kyoto Protocol provided for the Clean Development Mechanism (CDM) as a policy instrument to involve developing countries in carbon emissions abatement in 1997, a number of studies have focused on the operation of CDM (Heller, 1998; Chomitz, 1998; Meyers, 1999; Hargrave, et al. 1998; Kelly, 1999; Lazarus, et al., 1999). Applying CDM is challenging because its rule of additionality requires that a "baseline" estimate be made of what developing countries, including China, would do to reduce carbon emissions in the absence of CDM. Minimizing moral hazard and other incentive problems is a daunting task. The studies to date have focused on discussions of general embedded problems and desirable principles for applying the additionality rule.[1] However, how to identify baseline factors in specific economies and evaluate their impact on the energy sector decisions in terms of transaction or institutional costs remain unsettled questions (Heller, 1998).

This study is a first step towards filling that gap. By investigating Guangdong's electricity sector, we hope to highlight new characteristics of Guangdong's electricity market and institutions, which may have been neglected from large model and highly aggregated approaches. At the same time, by examining the economic and institutional features of the decision making process in Guangdong's electricity sector, we hope to get a better understanding of the factors affecting possible baselines and to draw some preliminary implications for CDM and other carbon abatement policy instruments. This study may also provide a reference for other regional analyses and permit some preliminary implications for baseline and abatement policy studies to be drawn.

The paper is organized as follows. Section II reviews electricity sector growth, fuel structure change and energy efficiency patterns in thermal power generation, as well as market structure and institutional changes in Guangdong Province between 1990 and 1998. In Section III, we first characterize qualitatively the emerging market mechanisms, and then link the new power supply arrangement as well as financial market and policy factors with changes in energy efficiency performance across three vintages of technologies. Section IV examines the global warming impact of the Guangdong electricity development, and the implications of our study for the application of CDM and similar international policy instruments. In particular, we discuss our disaggregated and vintage technology approach to baseline determination in the context of the baseline methodology debate, and the principle factors that are likely to affect the future baseline carbon emissions in Guangdong's electricity sector.

II. Guangdong's Electric Power Industry

Our description of Guangdong's electricity sector development in this section is mainly drawn from GETRC's (1999) studies. Readers are referred to these studies for more detailed information.[2] GETRC, the Guangdong Energy Techno-Economic Research Center, is an

[1] Two principal discussions relate to whether the baseline should be set at the project, sector, or higher level, and what are the institutional costs and how they should be incorporated in the baseline estimate. See, for example, Meyers (1999) for details.

[2] Zu, et al. (1999), Andrew-Speed and Dow (1998) and World Bank (1994) contain accounts of the reforms and development of the electricity industry at the national level.

organization under the Guangdong Provincial government charged with gathering and interpreting data on energy for the province, preparing the provincial input to the national Five-Year Plans, and collaborating with other institutions in making decisions on prices, sources of supply, and other factors affecting energy consumption. GETRC was under contract to us for the period August 1999–January 2000 in order to carry out their study.

1. Guangdong Provincial Economic Profile

Guangdong is a province in the southeastern part of China with an area of 178 thousand square kilometers and a population of 71.2 million. As one of the thirty-one provinces, autonomous regions and municipalities, it shared a similarly national economic development experience and yet showed its own uniqueness.[3] The economy of Guangdong underwent four development periods. Before 1979, the entire Chinese national economy was centrally planned. Most decisions concerning economic development were made by the central government. The provincial economy was a part of this highly planned economy. Between 1979 and the early 1990s, the economy of Guangdong was characterized by fast growth associated with the experimental economic reforms undertaken at the time. Peak economic growth was reached between 1991 and 1995 as a result of a new round of market reform endorsed by the Third Plenary Session of the Central Committee of the 14th Communist Party Congress.[4] During this period, the growth rate of the provincial GDP reached 19.2 percent per year. Since 1996, several macroeconomic factors have led to a sluggish domestic demand growth. Exports have also been hit by the Asian financial crisis. As a result, the economy has been undergoing a period of macroeconomic adjustment. Despite this, the Guangdong economy managed to grow 10.4 percent annually between 1996 and 1998. Over the entire twenty years of economic reforms, the provincial income growth averaged above 14 percent per year, almost five percentage points higher than the national average of 9.5 percent. As a result, Guangdong has changed from a poor province to the richest in China. In 1998, its GDP was valued at $ 95.63 billion. The per capita GDP reached $1,344 (see Table 1).[5]

Two factors are directly responsible for this exceptional performance. First, Guangdong was granted pilot province status by the central government in its market reform experiment. As a result, the Guangdong provincial government enjoyed greater economic decision power and more liberal policy constraints than other provinces. Second, Guangdong is geographically connected with Hong Kong and has a close tie to the overseas Chinese. Both provided Guangdong with badly needed foreign capital, technology, and export channels, as well as the example of market economies. A liberal economic policy and exposure to the international economy have made Guangdong's economy the most market-oriented in China today. The private economy now accounts for about 55 percent of the provincial industrial output, the largest share among the provincial economies (Yu, 1998). Even the large share

[3] Unless otherwise specified, for simplicity we shall take provinces to include also autonomous regions and directly administered municipalities.

[4] Wu (1998) contains a detailed account of the reform history.

[5] All dollar figures are quoted at current exchange rate, about 8.3 Yuan per dollar.

understates the actual degree of the market economy. Not only do Cantonese consumers and producers behave more like optimizers who make economic decisions in response to market signals, but policy makers and economic planners are also more inclined to take market conditions into their consideration than elsewhere in China.

Table 1. Guangdong Economic Profile

	Guangdong (1998)	China(1997)
Population (million)	71	1,236
Area (1,000 sq. km)	178	9561
GDP ($ billion)	95.63	900.87
GDP per capita ($)	1344	732
GDP growth rate (%)		
1980–1990	13.2	8.9
1991–1995	19.2	11.3
1996–1998	10.4	8.8
1980–1998	14.4	9.5
Energy consumption (million tons sce*)	83	1420
Energy consumption per capita (ton sce)	1.16	1.15
Energy consumption structure (%)		
Coal	45.4	73.5
Oil	38.5	18.6
Gas	6.3	2.2
Hydro, nuclear	9.8	5.7
Installed electricity capacity (GW)	29	271
Installed capacity per capita (kW)	0.4	0.2
Generation (TWh)	104	1,160
Electricity consumption per capita (kWh)	1388	1010

* standard coal equivalent

Source: China Statistical Yearbook 1998, State Bureau of Statistics, GETRC 1999a.

Nevertheless, despite growth of the market sector and of its influence, the province is still constrained by central government policies and institutional arrangements. Most changes should be characterized as within limits set by the central government and following the central government reforms with a lead-time over other provinces. As will become clear later, the effect of this institutional arrangement is especially prominent in such important industries as utilities.

Rapid economic growth resulted in a sharp rise in demand for energy. According to the Guangdong data, the total energy consumption of the province doubled between 1990 and 1998, from 41 million tons standard coal equivalent (sce) to 83 million tons.[6] The annual per capita energy and electricity consumption was 1.16 tons sce and 1388 kWh respectively. Seventy percent of the energy is consumed by the industrial sector. Consumption of the primary, tertiary and residential sectors accounts for 5.2 percent, 13.4 percent and 12.0%

[6] All tons in this article are metric tons.

percent, respectively, of the remaining 30 percent.

Fueling such an economic expansion has proved to be a challenge to Guangdong's energy sector. Guangdong is poorly endowed in energy resources, providing only 15% of its energy need from indigenous resources. The remaining 85% have to be imported from other provinces and from abroad. The major sources of domestic energy imports include coal from Shanxi and Inner Mongolia in the north, and hydropower from southwestern provinces. Northern coal has to be transported first by railroad and then by sea. It is subject to serious transportation limitations and added costs. In addition, the province also imports coal from Australia and Indonesia, and oil from international suppliers. A very small amount of liquefied petroleum gas is also imported.

Guangdong Province derives most of its energy from coal, though less than the average in China, and there has been further diversification recently. The share of coal in total energy consumption amounted to 53.8 percent in 1990 and declined to 45.4 percent in 1998. The decline was matched by an increase in oil consumption to 38.5 percent, with hydro and nuclear electricity providing 9.8 percent of total energy and LNG accounting for the remaining 6.3 percent of the 1998 consumption. Direct coal combustion by industry and households also declined from 36.4 percent in 1990 to 23.5 percent in 1998. The national average is 70 percent. Guangdong, because it lacks its own energy resources, has more options in choosing energy sources. Domestic coal is not as comparatively advantageous as it is in other provinces, because of transportation and associated costs.

Energy demand growth has slowed in the past few years due to the tempering off of the economic growth. Nevertheless, given the government's expansionary fiscal policy and the recovery of East Asian economies, it is generally expected in the province that the economy and energy demand will continue to grow. According to GETRC (1999a), Guangdong's economy is expected to grow at 8.5 percent a year between 1999 and 2000, 9 percent from 2001–2005 and 9.5 percent from 2006–2010. By 2010, GDP per capita is expected to rise to $2000 from $1,344 in 1998. To meet the continued increase in energy demand, the energy strategy designed by the provincial government emphasizes optimizing the energy structure, introducing cleaner energy sources, and promoting energy industry reform with a focus on the electricity development. Under this strategy, it is estimated energy consumption will reach 157 million tons sce by 2010, or 1.9 tons sce per capita.

2. Guangdong's Electricity Sector Development

Guangdong's electricity sector is a major component of the provincial energy industry, with electricity accounting for over 40 percent of primary energy. Many changes have occurred in the past twenty years, especially since the 1990s. They range from capacity and production expansion, to shifts in fuel structure and technologies leading to greater energy efficiency, to market structure and institutional changes. All the important changes, however, have occurred in the generation subsector. Transmission and distribution remain under government control, and have received very little attention as compared to generation. Accordingly, our discussion will focus primarily on generation. Assessing prospects for changes in transmission and distribution and their implications are to be the topic of future research.

As was the case with the overall energy sector, since the economic reforms in 1979, the electricity sector growth has gone through a cycle from demand-supply balance under central planning, to chronic shortage and rapid capacity building, and finally to excess supply. These changes are primarily associated with changes in income growth and electricity policy.

Before 1979, Guangdong's electricity sector was a part of the national electricity system. It was almost entirely controlled by the central government and operated according to the five-year economic plans. Through these plans, the central government determined the electricity needs of different regions as well as of the country as a whole, allocated resources to each region and sector, and organized the production of the targeted quantity. Like all provinces, Guangdong's electricity supply and demand were balanced each year in this fashion at the quantity commanded by the plan.

Entering the 1980s, Guangdong started to see a huge surge in its electricity demand driven by the early market reform and unprecedented economic growth. Meanwhile, however, the electricity production and supply was still organized by central planning. The central government kept monopolistic control over the electricity sector, which was deemed a crucial national industry, and did not start limited policy changes until the second half of the decade. The rise of demand and the stagnant supply led to an electricity shortage in Guangdong which would last for sixteen years. The shortage was particularly severe during 1983–84 and 1987–88 periods. Many factories had to be shut down four out of seven days a week due to the lack of electric power (GETRC, 1999a). The chronic electricity shortage became a bottleneck on economic development.

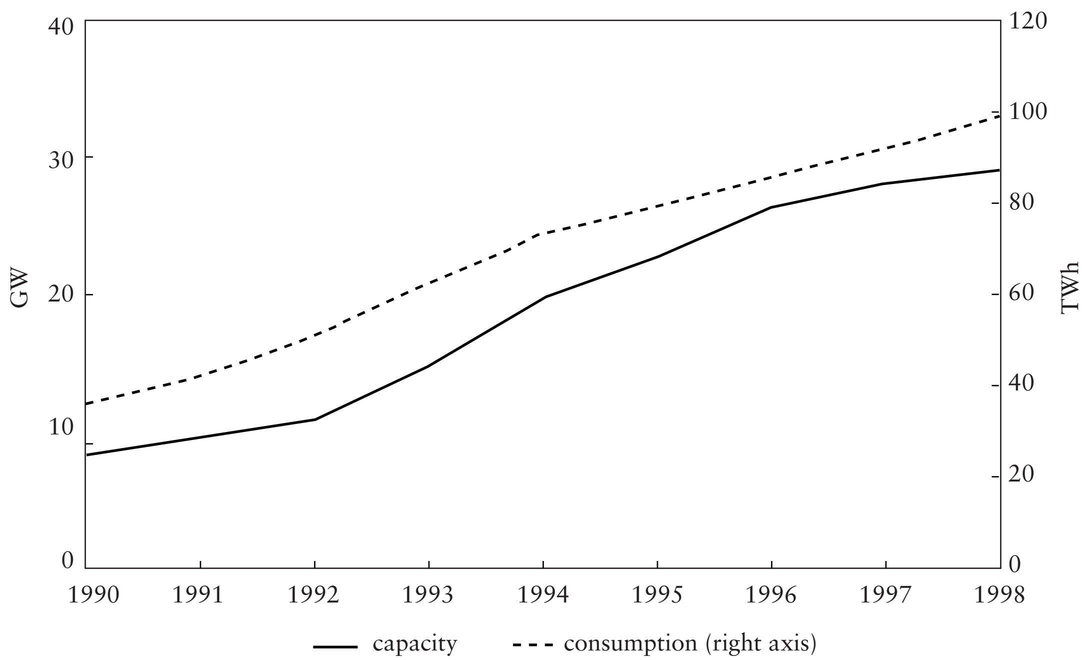
In an effort to eliminate the electricity constraint on economic growth, the central government finally abandoned its complete control over electricity supply and started to change its full-planning policy in 1985. The new national policy consisted of three elements. First, the central government opened the generation subsector to noncentral government investors and encouraged the local governments to raise their own money to build up generating capacity. Second, the central government raised electricity tariffs to encourage local investment and create an electricity construction fund. Particularly, on the generation side, a "cost + profit + tax" formula was adopted for the price paid to the generators. The policy guaranteed a comfortable profit margin and minimized the risks of the investment. On the end-user side, beginning in 1987 the government started to levy an electricity fee to provide revenue for the electricity construction fund.[7] The third element was a set of broader economic reforms, which entailed efforts to separate government functions from business activities and to decentralize central control in order to give more responsibilities to the provincial governments (Zu, et al. 1999). The purpose was to improve economic efficiency. The Guangdong provincial government started to adopt similar investment and tariff policies in 1987 (GTERC 1999a).

These policy changes dramatically altered the dynamics of Guangdong's electricity industry. Capacity building and electricity generation expanded in the 1990s (see Figure 1). Between 1990 and 1998, the provincial installed capacity increased from 8.3 GW to 29.1 GW, an average of annual growth of 17 percent. Power consumption grew 13.5 percent per year on average, from 35.9 TWh to 98.9 TWh. The growth was particularly strong between 1993 and 1995, when the province added an average of 4 GW capacity per year. By 1995, the per capita installed capacity, generation and consumption were 84 percent, 44 percent, and 34 percent higher than the respective national averages. The supply shortage disappeared and electricity rationing was finally lifted. Guangdong had emerged as the province with the leading electricity industry in the nation.

[7] Electricity pricing is a very complicated system under the government control. It will be further discussed in the next section.

Since 1996 the electricity market disequilibrium reversed due to the continued supply increase and a concurrent slow-down in demand (See Figure 2). This reflected the situation in the national electricity industry. The excess supply has given rise to a fierce competition among different levels of governments and their power plants, and exposed the backwardness in the transmission and distribution system, especially in the rural areas. The problems are prompting further policy adjustment and sectoral reforms. The recently adopted provincial policy to address the problems includes both short-run and medium to long-run measures. Between 1999 and 2001, the provincial government will focus on further separating government from business and streamlining the rural electricity distribution management, which will eliminate all management layers below the county level. The measure is expected to lower the rural electricity cost to the level in the city and increase demand. A second step will be to separate power generation from transmission and encourage competition among the power suppliers. It is planned for Guangdong Electric Power Corporation, which operates the provincial power grid, to give up its power plants through stock transfers to newly created entities. Finally, the government also plans to separate distribution from transmission and promote direct supplier choice by end-users.[8]

Figure 1. Guangdong Electricity Capacity and Consumption



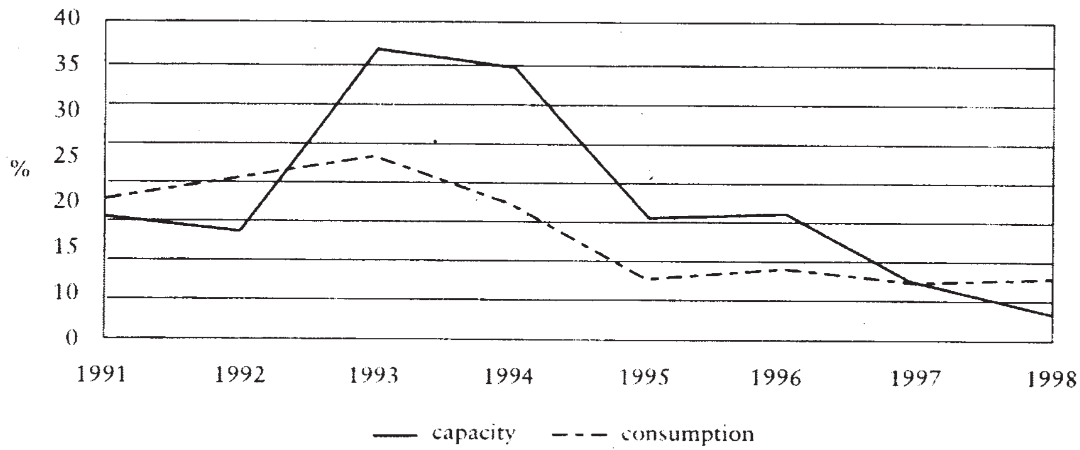
Source: GETRC, 1999a.

In the future, with the economy and electricity demand predicted to resume the fast growth,

[8] The new policy again mimics the recent policy change pronounced by the central government. See People's Daily (October 19, 1999) for the specifics of the central government policy.

the provincial capacity and power supply are expected to continue to grow. It is projected that by 2010 the capacity and generation will reach 49.93 GW and 217 TWh, respectively. Electricity consumption will reach 227.6 TWh, or 2842 kWh per capita (GETRC 1999a).

Figure 2. Guangdong Electricity Capacity and Consumption Growth Rate



Source: GETRC, 1999a.

3. Fuel Structure

Along with capacity building and generation growth, the fuel structure of the provincial electricity production has also experienced changes since the 1990s. In particular, fuel sources for the industry have become more diversified. The importance of coal has declined though it still remains the dominant fuel. Table 2 shows that in 1990 coal, hydro and oil constituted the entire electricity fuel source, accounting for 45.1 percent, 32.4 percent, and 22.5 percent of the installed capacity, and 53.6 percent, 22.4 percent, and 24.0 percent of generation. Since the mid-1990s, nuclear and wind powers have become new sources of fuel. By 1998, the share of coal reduced slightly to 41.8 percent of the installed capacity and 49.0 percent of generation. The share of oil increased to 32.9 percent of the installed capacity, though its relative importance in generation remained at the 1990 level. The three carbon clean fuels—hydro, nuclear and wind—together accounted for about a quarter of both installed capacity and generation.

Table 2. Guangdong Electricity Capacity and Generation

	1990		1998		2010*	
	GW	Percent	GW	Percent	GW	Percent
Installed Capacity	8.28	100.00	29.07	100.00	49.93	100.00
Hydro	2.68	32.37	5.51	18.95	9.38	18.79
Coal	3.74	45.11	12.16	41.83	25.60	51.27
Oil	1.87	22.52	9.56	32.89	4.10	8.22
Nuclear	0.00	0.00	1.80	6.19	5.80	11.62
Wind	0.00	0.00	0.04	0.14	0.16	0.32
Gas	0.00	0.00	0.00	0.00	4.89	9.79
	TWh	Percent	TWh	Percent	TWh	Percent
Generation	34.40	100.00	103.85	100.00	217.00	100.00
Hydro	7.72	22.44	15.28	14.71	20.90	9.63
Coal	18.43	53.58	50.85	48.96	128.00	58.99
Oil	8.25	23.98	24.70	23.78	10.30	4.75
Nuclear	0.00	0.00	12.94	12.46	34.80	16.04
Wind	0.00	0.00	0.08	0.08	3.40	1.57
Gas	0.00	0.00	0.00	0.00	19.60	9.03

* Projected
Source: GETRC 1999a.

In the next ten years, the province will seek to diversify the fuel structure of electricity generation further and plans to pay increased attention to reducing the industry's environmental impact. The most important development in this respect will be to add gas to the line of fuels. According to the current government plan, gas-fired power generation will grow from zero to about 10 percent of total electricity generation by 2010. Assisted by the central government, Guangdong will also increase hydropower imports from the Southwest. The annual import will amount to an equivalent of 2.9 GW installed capacity by 2010. Other clean fuels, hydro, nuclear, and wind, will continue to increase from their current levels so that they will maintain their relative joint share in the fuel structure. Nevertheless, in line with government policy, Guangdong's electricity sector will continue to depend predominantly on coal. Table 2 shows that coal will reverse its declining trend and increase to 51 percent of installed capacity and 59 percent of generation by 2010. The decision to rely on coal is based on the estimated high capital and/or fuel costs involved in noncoal power plants (World Bank, 1994; GETRC, 1999a). Although reducing the use of coal represents the best opportunity to reduce greenhouse gas emissions, it is currently not in Guangdong's electricity development plan. We shall discuss this issue further when we discuss the implications of these plans for baseline determination.

4. Efficiency of thermal power plants

Associated with, and in part owing to, the rapid capacity building, the technologies and the energy efficiency used in electricity generation have also undergone important changes. We use heat rate as the measure of these changes. Heat rate is defined as grams of standard coal equivalent (gsce) consumed per kWh electricity generated (gross heat rate) or supplied to the grid (net heat rate). It is a widely used indicator of the energy efficiency of power generation. The lower the heat rate, the more efficient is the plant.

The heat rate of a power plant is determined by two sets of factors. First, the plant's maximum energy efficiency is set by the technical design and embodied in the specific vintage of capital equipment. This level of efficiency is determined at the time a decision is made to adopt a specific technology and scale of capital equipment. These decisions determine the upper bound of the plant's energy efficiency for the lifetime of the capital equipment. It is the *ex-ante* energy efficiency. Second, the plant's real achieved efficiency is usually lower than the *ex-ante* efficiency. (The heat rate is higher.) There are a number of factors associated with the plant's ownership, management, operation practice, equipment wear and tear, quality of coal, etc. that can cause the plant's energy efficiency performance to fall below its maximum designed efficiency.

Several studies discuss and empirically test the effects of these factors on the energy performance of coal-fired power plants. For example, Joskow and Schmalensee's (1987) study of the energy efficiency of U.S. coal-fired plants and Khanna and Zilberman's (1999) investigation of the energy inefficiency and the global warming impact of the Indian power sector, contain detailed discussion of the heat rate determination and related empirical results.[9] Few such studies exist for China. Observations in Guangdong and elsewhere in China suggest that both inefficiencies exist. Further, *ex-ante* efficiency change may be the dominant factor behind the energy efficiency pattern shift of Guangdong's electricity supply because most of the provincial installed capacity has been built recently. Other studies of industrial energy efficiency changes in China make similar findings.[10]

The energy efficiency of Guangdong's electricity generating plants falls in the range from 300 gsce per kWh to 900 gsce per kWh for coal-fired plants and 300 to 550 gsce for oil-fired plants.[11] Figures 3 to 5 show the heat rate patterns and changes for both types of plants. Table 3 contains more detailed data on the heat rates of all provincial power plants. Figure 3 reveals three interesting changes in the heat rate distribution of the coal-fired plants. First, the province developed a bifurcate technology structure. A sizeable capacity of highly inefficient generating plants was built during the years of rapid development. The most efficient and the least efficient technologies coexisted and grew in parallel throughout the whole period. In particular, in 1990, electricity generated by the best technology and the worst technology were 4.1 and 4.0 TWh, respectively, or 24.5 pecent and 23.6 percent of the total coal-fired electricity supply. By 1998, they increased to 6.7 and 5.7 TWh though their shares declined to 14.1 percent and 12.1 percent. It is noteworthy that the capacity and generation representing the worst energy efficiency kept increasing despite a serious excess supply on the provincial electricity market in the past a few years.

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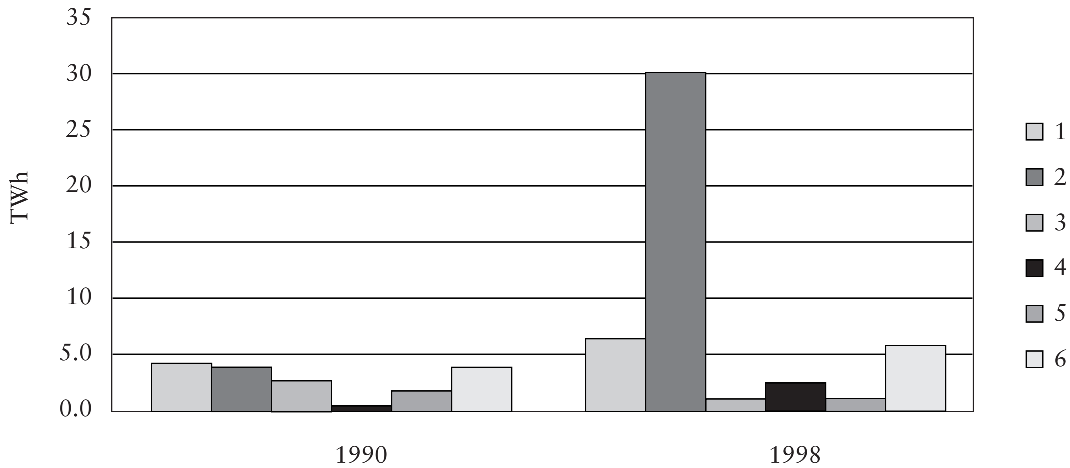
[9] Joskow and Schmalensee included in their regressions variables affecting both the choice of technology and energy performance of the generators. Khanna and Zilberman took the technology as given and studied the sources of *ex-post* inefficiency only.

[10] See, for example, Sinton's (1996) study of the Chinese cement industry and Fisher-Vanden's (1999) study of the Chinese steel industry. More generally, Sterner's (1990) study of the Mexican cement industry led him to conclude that (*ex-ante*) embodied technology advance is the most important source of energy efficiency improvement in developing countries.

[11] One gram of Chinese standard coal is 7000 calories Lower Heating Value basis.

Figure 3. Generation of Coal-fired Power Plants by Heat Rate



Source: GETRC, 1999c.

Second, since the 1990s, the second most advanced technology, with heat rates between 350-400 gsce/kWh, saw the most significant growth. Electricity generated by this type of technology increased from 4.0 TWh, less than that generated by the best technology, in 1990 to 30 TWh, or 63.7 percent of the power supplied by coal-fired plants in 1998. It has become the industry's standard generation technology.

Third, despite years of growth, Guangdong's coal-fired electricity generation is still characterized by poor energy efficiency performance. As indicated above, between 1990 and 1998, the share of the most efficient generation declined from 24.5 percent to 14.1 percent of the coal-fired electricity supply. Compared to the industrial countries' average of about 330 gsce/kWh, over 80 percent of Guangdong's coal-fired electricity generation is very inefficient.

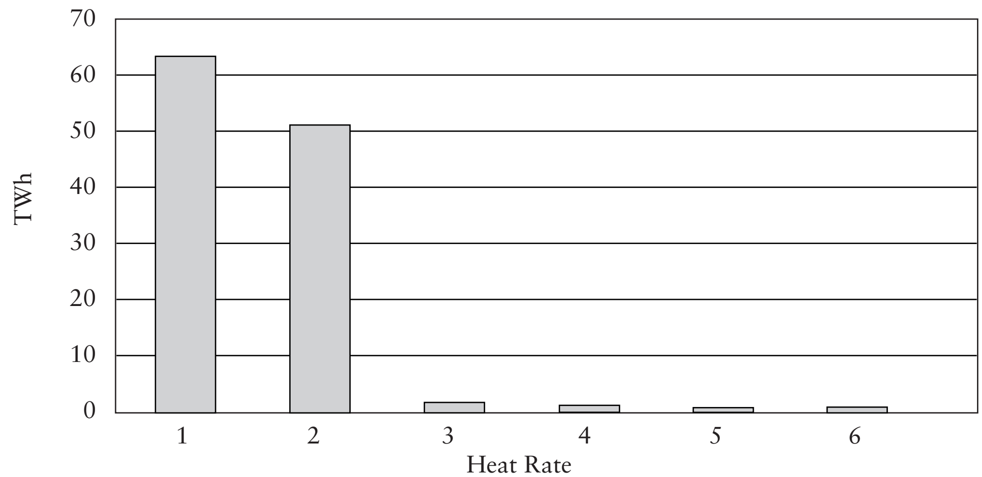
The data in Figure 4 suggest that future development of the sector will focus on the best coal technologies. It is projected that the generation technologies of 300–350 gsce/kWh and 350–400 gsce/kWh will increase by 86.3 percent and 68 percent, respectively between 1998 and 2010. Meanwhile, the electricity supplied at above 450 gsce/kWh will see a gradual decrease to 2–3 percent of the total power supply of the coal-fired plants. By 2010, the two top tier technologies will represent 53.8 percent and 42.3 percent of the generation. These technologies will become the benchmark of the provincial coal-fired generation technology. The projection implies a sectoral growth that is much friendlier to the global climate, though almost half of the generation technology will still be below the current standard of the western industrial countries.

Table 3. CO2 Abatement Cost Data

	Unit	Coal1	Coal2	Coal3	Coal4	Coal5	Coal6	Oil1	Oil2	Oil3	Oil4	Oil5	Hydro	Nuclear	Wind	Gas
Heat rate (std coal)	G/kWh	[300,350)	[350,400)	[400,450)	[450,500)	[500,550)	[550,1100)	[300,350)	[350,400)	[400,450)	[450,500)	[500,550)		386		
1990																
Electricity supplied	TWh	4.13	3.98	2.75	0.10	1.93	3.99	2.11	5.56	0	0.22		7.71			
Electricity unit cost	Yuan/kWh	0.28	0.26	0.23	0.26	0.27	0.31	0.32	0.30		0.33		0.14			
Fuel carbon content	%	70	70	70	70	70	70	75	75	75	75		0			
CO2 emissions	Mt(C)	0.96	1.07	0.80	0.03	0.71	1.62	0.35	1.07	0	0.057		0			
1998																
Electricity supplied	TWh	6.65	29.96	1.12	2.63	0.96	5.71	14.88	8.62	0.78	0	0.55	14.30	12.30	0.08	
Electricity unit cost	Yuan/kWh	0.38	0.42	0.42	0.43	0.45	0.47	0.42	0.41	0.40		0.42	0.18	0.50	0.30	
Fuel carbon content	%	70	70	70	70	70	70	75	75	75	75	75	0	0	0	
CO2 emissions	Mt(C)	1.57	7.47	0.35	0.88	0.36	2.32	2.45	1.59	0.16	0	0.14	0	0	0	
2010																
Electricity supplied	TWh	64.10	50.33	1.86	1.39	0.46	0.92	5.74	4.21				20.80	33.23	0.40	26.58
Electricity unit cost	Yuan/kWh	0.38	0.40	0.40	0.41	0.42	0.43	0.40	0.39				0.17	0.49	0.28	0.40
Fuel carbon content	%	70	70	70	70	70	70	75	75				0	0	0	66
CO2 emissions	Mt(C)	14.36	12.54	0.53	0.45	0.16	0.36	0.95	0.78				0	0	0	1.84

Source: GETRC, 1999c.

Figure 4. Generation of Coal-fired Power Plants by Heat Rate 2010

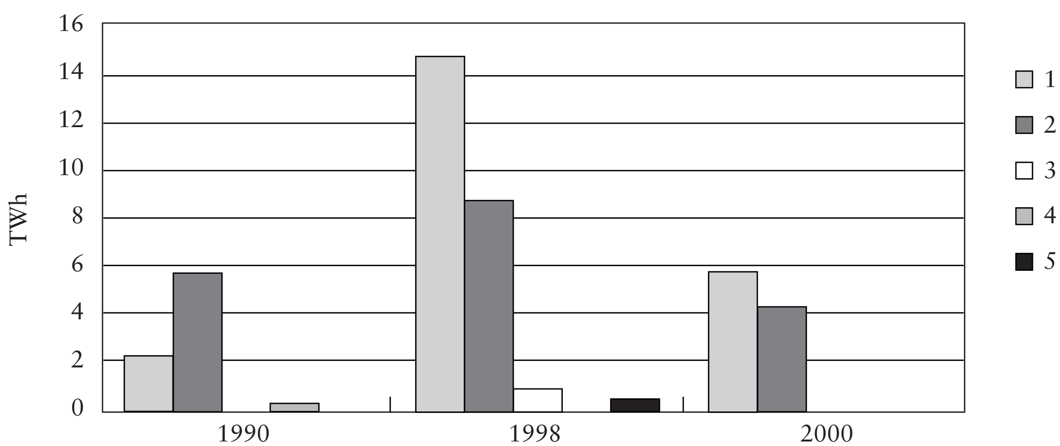


Source: GETRC, 1999c.

An interesting question raised by Figure 4 is whether efficient plants will actually be built and inefficient plants will be shut down. To answer the question, it is necessary to understand what prevented the adoption of the efficient technology and kept the inefficient in operation in the past. We discuss this in the next section.

Figure 5 displays the heat rate pattern of the oil-fired plants. It shows a different dynamic pattern from the coal-fired plants. Many recently built plants are very energy efficient. In general, the importance of oil-fired plants will be gradually declining over the next ten years. Particularly, the inefficient ones are said to be on the way to extinction.

Figure 5. Generation of Oil-fired Plants by Heat Rate



Source: GETRC, 1999c.

5. Market Structure

The policy of opening the generation market to non-central government investors in the late 1980s and of transferring ownership from central to provincial government in the mid-1990s effectively changed the provincial electricity market structure. As mentioned earlier, the electricity had long been considered a core industry, vital to the national economy. It was traditionally monopolized by the central government. In the early 1980s, the Ministry of Electric Power owned the entire national electricity system.[12] The Guangdong Electricity Industry Bureau (GEIB) of the provincial government, representing the Ministry, owned and operated the provincial power plants and grid. Since 1987, various levels of local governments and foreign investors have increased their investment in the power plants.[13] Figure 6 shows that in 1990 Guangdong had a total of 8.3 GW of installed capacity. 3.4 GW, or 41 percent, belonged to the central or provincial government. The same number for local governments was 4.9 GW, or 59 percent.

By 1998, as Figure 7 reveals, the provincial government owned, through Guangdong Electric Power Corporation (GEPC), 8.6 GW, accounting for 30 percent of total installed capacity. GEPC was at the same time GEIB.[14] These numbers include both GEPC wholly-owned and GEPC-controlled power plants, but exclude power plants in which GEPC holds only a minor interest. In addition to GEPC, the central government, through various holding companies, controls 2.4 GW of generating capacity, including 1.8 GW of nuclear capacity. The South China Power Plant, also owned by the central government, controls 700 megawatt transmission of hydropower from southwest China. At the lower levels of governments, city and county governments have a combined installed capacity of 18.05 GW (62 percent). This included 0.9 GW that were self installed by twenty-five electricity consuming companies owned by the local governments. Also included was a 0.7 GW foreign build-operate-transfer (BOT) plant that was already transferred to the local government by 1998. Lastly, Hong Kong's China Light & Power Company supplies 500 megawatts electricity to Shenzhen and Shekou, two special economic zones, when a power shortage occurs in these areas. By way of comparison, the combined central and provincial government capacity increased 226 percent for the period between 1990 and 1998, while that of local governments rose by 268 percent.

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[12] The public ownership of means of production is a complicated issue. On paper, enterprises are owned either by the whole people (state-owned), or by the local people of administrative regions in which enterprises are situated (collectively-owned). In reality, the national and local governments and the government officials act as the owners as though they are fully trusted by the people. This arrangement is raising economic and legal questions as the economy is marketized, especially when these enterprises are involved in foreign financing and joint operations. In this paper, we shall refer to the government as the owner and discuss the questions associated with the ownership issue as they arise. A full discussion requires a separate study.

[13] The subprovincial level governments that have entered the electricity generation business mainly include municipal governments, municipal affiliated county governments, and rural county governments. The latter are mostly in remote mountainous areas. Town and village administrations sometimes own small power plants and are involved in local distribution operations.

[14] State and provincial power corporations were established under the 1996 Electricity Law. At the national level, the Ministry of Electric Power was abolished with its administrative responsibilities assigned to the State Economic and Trade Commission. In Guangdong, according to the restructure plan announced in February 2000, GEIB will be eliminated later this year, with its responsibilities assigned to the provincial Economic and Trade Commission. The discussion of GEIB in this paper refers to the current situation

GEPC is thus the dominant player on the electricity market. It not only owns 30 percent of generating capacity, but also owns and controls the entire transmission network (1,367 kilometers of 500 kV and 6,520 kilometers of 200 kV grid lines), the distribution systems in twenty-one large cities and twenty-six counties, and makes 80 percent of the sales of the provincial electricity market. The only area outside its control is the distribution in fifty-three remote mountainous counties. These counties are called "wholesale" counties in the sense that they trade electricity with the provincial grid in a wholesale fashion. The county governments, through their power agencies, own the small local distribution networks and manage the small local power plants, mostly hydro, connected to the system. They purchase electricity wholesale from the provincial grid and sell it to local end-users during dry seasons, and sell the surplus hydropower of the local generators to the provincial grid during high water seasons.

Figure 6. Guangdong Electricity Market Structure, 1990

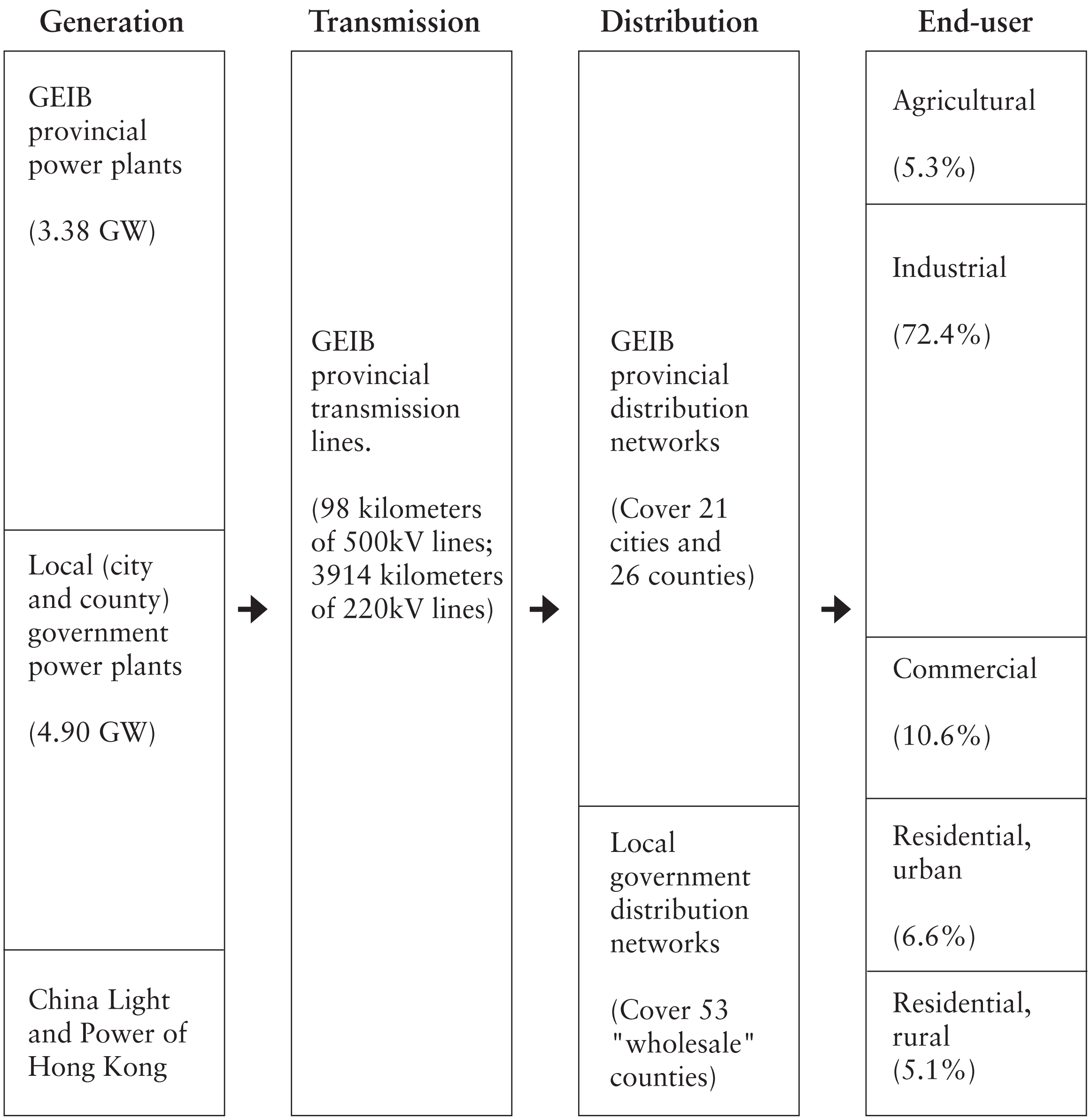
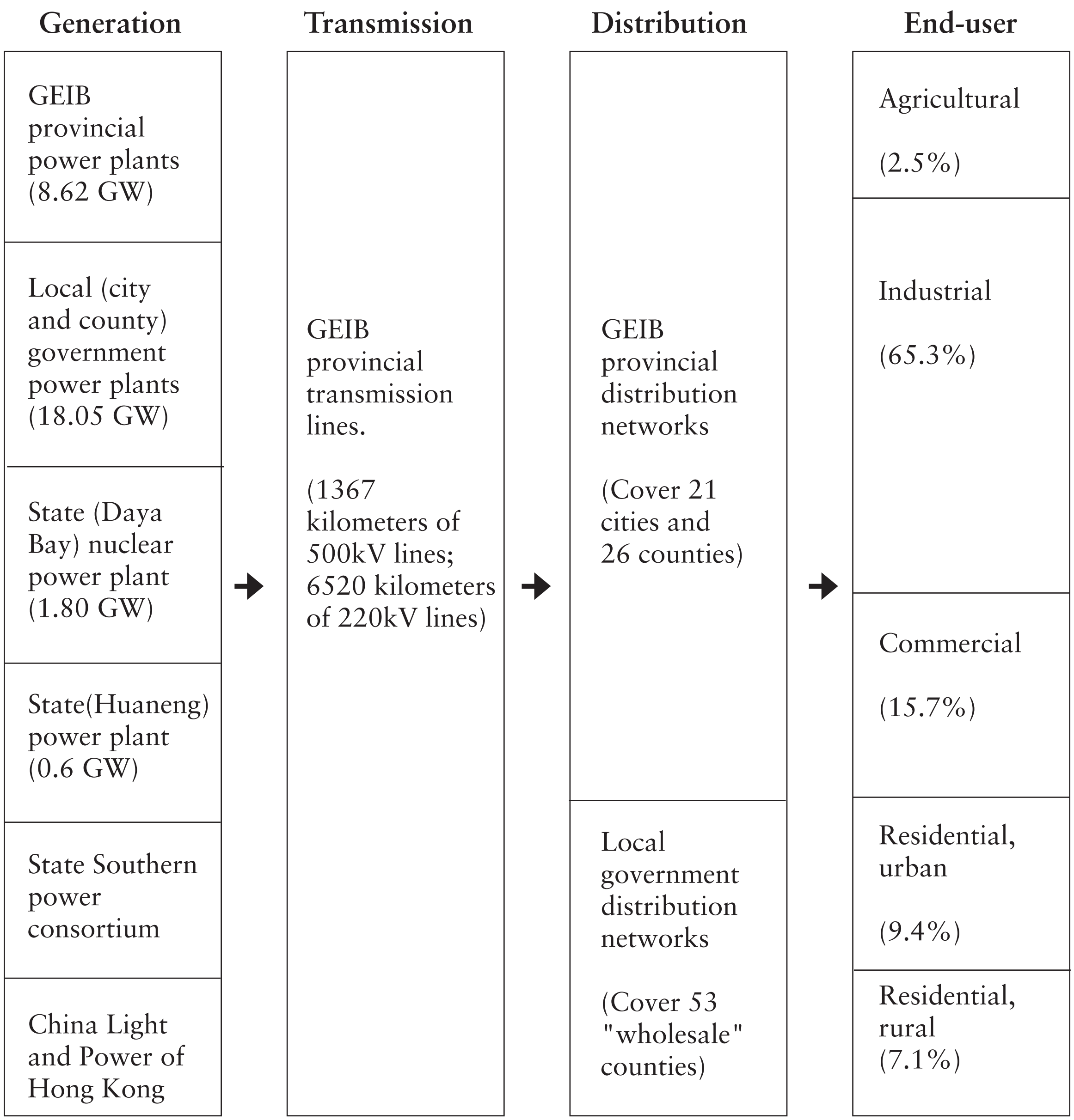


Figure 7. Guangdong Electricity Market Structure, 1998



(Capacity listed under each owner includes wholy-owned and controlled through majority shares holding. For example, Daya Bay nuclear power plant is 40 percent owned by the State Nuclear Industrial Corporation, 20 percent by the State Electric Power Corporation and 40 percent by GEPC, therefore, is listed under state ownership.)

6. Institutional Development

The Chinese economy is known for its network of horizontal and vertical relationships and hierarchic authority. Lieberthal (1997) contains a succinct and accurate description of this system. Reflecting this institutional feature, the set-up of the electricity industry administration in the Guangdong provincial government mirrors that of the central government. It includes commissions, bureaus, and agencies. Administratively, they are subordinate of the provincial government. Functionally, they carry out economic plans and orders vertically from the same line of administration in the central government. They play an important role of coordinating the national and provincial interests. In the same fashion, institutional arrangements in cities and counties are copies of the provincial institutional arrangements. The decentralization of economic management associated with economic reform has greatly weakened the vertical links and granted the local governments more independence. As a result, the system now may be described as a "matrioshka"—a set of look-alike dolls that are nested together and at the same time relatively self-contained.

Various provincial and local government offices are involved in the electricity sector management and regulation. *Guangdong Planning Commission* (GPC) oversees sector planning, new project development, and approval. After constructions are completed, the new power plants are then turned over to the *Guangdong Economic Commission* (GEC) which is in charge of the provincial electricity production, transmission and distribution, and other enterprise and market activities. This is the classic institutional specialization of the central planning system. The *Guangdong Electricity Industry Bureau* (GEIB) is responsible for making provincial electricity policy and regulations, setting technical standards and safety criteria, and enforcing electricity law and regulations. It is at the same time also GEPC, the electricity market monopoly. As a provincial enterprise, GEPC is responsible for proposing development plans and new projects, investing and carrying out the construction under the direction of GPC, and responsible for operating power plants, transmission, and distribution grids under the direction of GEC. The *Guangdong Price Bureau* is charged with approving and supervising the grid and end-user prices. The *Environment Protection Bureau* makes environmental evaluations of new projects and supervises pollution emissions of power plants according to the existing laws. The *Guangdong Hydropower Bureau* supervises hydropower generation and distribution in wholesale counties. The *Power Supply Bureaus* of cities and counties operate and maintain the distribution networks under the direction of GEPC. While these institutions have their areas of responsibilities, many decisions are a coordinated effort of multiple government agencies.

In terms of legal and regulatory framework, the national people's congress and the state council reserve the right to make laws and regulations for the electricity sector. The Guangdong provincial people's congress and government make local operating rules and regulations in accordance to national laws and regulations. GEIB is charged with the supervision and enforcement.

These government offices constitute an institutional framework that regulates the entire electricity supply process from making new investment decisions to production, pricing, and dispatching decisions of existing projects. Regarding new project investments, all proposals for new power plants have to go through GPC. The decision process consists of three steps. First, the project owner conducts a preliminary study. This includes demand projection, evaluation of location, scale, technology, project structure, and financing. The proposal has to be registered with GEIB and GPC. If a project is over 50 megawatts, it has to be reported to the State Development Planning Commission. A foreign investment project must also be reported to the State Economic and Trade Commission. Second, after the proposal is approved, the owner will study the economic feasibility of the project, start the bidding process for the equipment, secure the financing, and negotiate the electricity purchase agreement. The result from this stage will have to be resubmitted to the same offices for expert evaluation. The owner will make the final decision on the basis of the evaluation and report the decision to the administration. Third, upon final approval, the owner will then start the project design and construction. Compared with the past, there are two changes in this process. While GEPC's investment in the sector continues to enter GEC's provincial economic plan, the government assures that other investments conform to the plan only indirectly through its approval process. After a proposed project has been approved, the investor is now required to resort to the market to arrange for project financing, construction, equipment and fuel purchases, and off-taker contract. This is consistent with the market reform goal of making enterprises more cost sensitive.

Regarding electricity supply, GEC is still the main office responsible for all sectoral generation, dispatching, and distribution. GEC holds, in coordination with GPC and GEIB, annual and quarterly allocation meetings to distribute generation quotas among the electricity providers.[15] Because of the diversification of electricity providers, local governments now also participate in these meetings, making the allocation less authoritarian and more of a negotiated outcome. The power grid has a three-level dispatching system. The central dispatching office is in charge of large power plants and transmission. City dispatching offices manage low voltage (under 110kV) distribution system and local power plants that are connected to the system. County dispatching offices manage local distribution system and small power plants. The entire process follows very much along the line of the traditional economic planning.

III. Market Mechanism and Causes of Energy Efficiency Changes

The changes in Guangdong's electricity sector outlined in the previous section reflect the development of China's electricity industry as a whole. While a number of studies have described different aspects of this development, what seems lacking is an evaluation of the change in the market allocation mechanism imbedded in the observed sectoral growth. The experience of Guangdong's electricity sector suggests a slow departure of the sector away from the balancing mechanism of central planning. Interesting questions in this respect are what is evolving as the sectoral market allocation mechanism, especially the supply relationship and how it is associated with the observed pattern of technology adoptions and energy efficiency shifts. These questions are important because the answers to them will have implications for understanding future energy efficiency changes and the sectoral carbon emissions baseline. In this section, we first characterize qualitatively the emerging market mechanism, especially the new supply arrangement, and then discuss the causal relationship between the industry market evolution and the bifurcation of technology and energy efficiency development.

[15] In the case of electricity shortage, GEC also determines the consumption quotas.

1. Demand and Supply Arrangement

The development of Guangdong's electricity sector has brought about two obvious changes in the power demand and supply relationship. On the demand side, the economy-wide reform has effectively changed the electricity market from supply-driven under the central planning to demand-driven. The sixteen years of electricity shortage prior to 1995 were a direct consequence of a demand surge that exceeded the electricity available from the planned electricity system. Similarly, the excess supply since 1996 is caused by a slow-down in demand growth that was unexpected by the electricity producers. On the supply side, the traditional way of organizing electricity production at the plan-specified amount and allocating it to different business and residential end-users by the monopolistic central government has been greatly weakened. Many noncentral government investors are now participating in supplying power to the market. However, what is perhaps not so obvious is what supply arrangements are emerging to replace the old planning system.

A closer look at the electricity sector development in Guangdong province discussed in the last section suggests that the highly centralized and unified electricity supply system has been replaced by disaggregated and layered regional operations. The new supply relationship has three prominent characteristics. The first characteristic is that the electricity sector is still dominated by public suppliers though they are now local governments. The electricity sector however is still considered a core industry, vital to the economy. Though the central as well as the provincial governments no longer have enough resources to meet the market demand and have to encourage outside investors, they make sure the industry remains predominantly a public operation. Provincial, municipal, and county governments make market-sharing arrangements based on their economic power and political authorities. When the market is in supply shortage, local government investments become an important supplement of central and provincial government investments. When the market is in excess supply, local governments negotiate and fight with the central and provincial governments to maintain their share of the market.

It has been suggested by some researchers that the government policy to encourage investment in power generation led to the fast growth of independent power producers (IPP) (Zu, et al. 1999, p. 7; GETRC, 1999b). It should be pointed out that while local power plants are not owned by the grid, they are mostly owned by various levels of local governments even though some are labeled as collectively owned (see footnote 11). They bear significant differences from the IPPs familiar to western readers, which make their own independent business decisions, survive and prosper on the basis of their economic strengths. They often have the local government as an investor or fund raiser, go under the local government name for project approval, rely on the government power in securing market share, and sometimes serve government financial purposes in addition to their normal tax obligations.

Several recent studies of Chinese economic reforms have generally concluded that enterprises and the government often formed special relationships in which the former are subject to government control in various ways. In particular, the murky assignment of property rights and political appointment system of important personnel continue to cause the imposition of government administrative authority over enterprise decisions (Yu, 1998; Wu, 1998, chapter 4; Zhou, 1998; Gore, 1998; Zhou, 1996). Despite the reform effort to separate the government from business and corporatize public enterprises, enterprises still have very limited power in making important supply decisions. Table 4 presents data from a 1992 World Bank survey on the decision right of Chinese enterprises.[16]

It indicates that the percentage of enterprises that can make their own decisions with respect to setting production plans and product prices, making investments, and appointing managers is actually small, and especially so for state-owned enterprises. The right to make these decisions lies in the hands of the government. This situation can be expected to be especially prominent in the utility industry given its position in the economy.

Domestic individual and foreign companies have also been the investors in Guangdong's electricity industry. Domestic investors are in most cases minority stockholders and have no influence over power plant supply decisions. While foreign investors make their investment decisions, their projects have to go through the approval process and must agree with the government economic objectives. In addition, they only account for a very limited share of the industry.

A second important feature of the supply mechanism is that the electricity sector institution, which was originally set up to run the centrally planned economy, behaves like an inertial system. Under this system, electricity market is basically divided along geographic and administrative lines just as the sector was under central planning, and power supply is organized according to the traditional planning principle of general balance (*zong he ping heng*) (GETRC, 1999c, p. 13). Following the principle, municipal as well as county governments organize their own power supply to "self balance" the end-users demand in their respective administrative jurisdictions. If the market is not balanced for a local government, it should seek help and balance at the higher level of administration. The reforms needed to make this institution compatible with a market-oriented economy have been very slow, and sometimes nominal. For example, the attempt to separate the GEIB, which is a government administrative entity, from the GEPC, which is a public electricity generating business, ended up only in adding a second GEPC plate to the same building. The government is more familiar with its role in the planned economy than about its position in a new economy, and therefore continues to play the former role.

[16] It is reproduced from Jefferson, et al. (1999).

Table 4. Decision Right Ranking by Decisions

	No Right	Partial Right	Right
SOE (n=915-930)			
Appoint leaders	80.9	17.9	1.1
Set wage differentials	43.6	19.8	43.6
Make investment decisions	28.6	57.1	14.4
Set production plans	27.6	43.6	28.8
Recruit employees	27.4	50.0	22.6
Set prices	26.3	54.1	19.6
Set bonus levels	18.9	18.2	62.8
Dismiss employees	10.8	26.4	62.8
Choose customers	5.0	19.8	75.1
Choose suppliers	4.2	24.6	71.3
Set bonus differentials	2.3	4.4	93.3
COE (n=246-296)			
	No Right	Partial Right	Right
Appoint leaders	75.9	18.8	6.1
Set production plans	30.4	37.5	32.1
Set bonus differentials	30.3	19.7	50.0
Set bonus levels	16.3	23.1	60.5
Make investment decisions	14.5	48.4	37.1
Recruit employees	14.3	44.9	40.8
Set prices	11.7	41.7	46.5
Dismiss employees	10.6	34.6	54.8
Choose suppliers	3.4	10.4	86.2
Set wage differentials	3.4	3.1	93.5
Choose customers	2.4	7.6	90.0
TVE (n=282-285)			
	No Right	Partial Right	Right
Appoint leaders	60.0	24.2	15.8
Set production plans	21.8	20.4	57.7
Set bonus levels	18.6	27.0	54.4
Make investment decisions	16.0	59.6	24.5
Set prices	10.1	23.3	66.6
Set wage differentials	9.2	11.7	79.2
Set bonus differentials	5.0	8.2	86.9
Choose customers	4.9	4.9	90.2
Dismiss employees	4.2	23.6	72.2
Recruit employees	3.5	29.8	66.7
Choose suppliers	3.5	6.3	90.2

The third characteristic is that the power companies, though largely still government-controlled, now operate more like economic agents than before. This is a result of the economy-wide market reform and represents a considerable change from their traditional role in the central planning system. Under that old system, companies were no more than production units. The government provided them with capital through budgetary allocations, fuel, and other production materials according to the plan. They in turn executed the production plan and turned in all receipts to the government. They had no incentives and made no decisions. Now, subject to the provision that the projects conform with the government electricity development plan, the companies, under market reforms, are more sensitive to costs in making business decisions on fuel and equipment purchase, arranging for financing, and operating the plants. They also face pressure to increase productivity and reduce labor costs. If these pressures were not strong during the years of the electricity shortage, they certainly have become stronger since the market developed an excess supply in 1996. Plant visits in Guangdong and interviews with the plant managers by the authors confirm this.[17]

In brief, what we see in Guangdong's electricity sector is a local government controlled, "matrioshka" type of supply arrangement. Although it represents a departure from the traditional centrally-planned supply arrangement, it is also significantly different from the regulated electricity market found in many countries. It sees some market elements growing at the power plant level, but displays more characteristics of central planning institutional wise.

2. The role of price

The Guangdong electricity price structure is very complicated and under tight government control. It is determined in several steps. First of all, the central government sets the principle of a "cost + profit + tax" formula for the grid price that power plants receive. The Guangdong provincial government then verifies and supervises the implementation of that formula. The cost includes capital cost, depreciation, and fuel and operating costs. Second, the grid separates the end-users into three categories according to their geographic locations: cities, city-administrated counties, and wholesale counties. Different levels of governments and distribution management then add to the grid price various taxes and fees according to the geographic locations. The resulting end user price is highest in wholesale counties and lowest in cities. The difference can be as large as 0.66 Yuan per kWh for city residents and 5 Yuan for wholesale county residents. Third, the government also categorizes the end-users by industries and provides electricity at a subsidized price to such important economic activities as irrigation, fertilizer production, schools, and hospitals.[18]

The government has been using the price of electricity to adjust market demand and supply. For example, the "cost + profit + tax" formula that effectively raises the price received by power plants was designed to encourage investment and raise supply. Recently, to encourage consumption the government has decided to reduce the electricity fee that is a part of the end-user tariff. This obviously differs from an endogenous price determined in a market-clearing process. It also embraces various problems as a government policy tool.

[17] Trip reports that contain more information are available upon request.

[18] GETRC 1999a contains an example of the differences among various actual prices.

Instead of being sensitive to demand and supply differences in a timely way, changes in government price policy tend to have significant time lags. As a policy instrument, government often uses it to deal with one particular problem while neglecting the overall and long term impact of a tariff change. The "cost + profit + tax" tariff policy is a ready example. White the policy has encouraged investments in electricity generation, it has also enabled inefficient power plants to operate. In addition, government-set prices are also subject to political abuse. In this respect, one important reason for high rural electricity prices is that local governments set up intermediate distribution "toll booths" to collect revenue. These problems seriously hamper using price as a market equilibrating tool. Guangdong's electricity market is likely to remain subject to consumption limits during supply shortages and generation quota at times of excess supply. It must be noted that Guangdong province and China are by no means unique in facing problems stemming from government-managed electricity prices, but the problems are made sharper by relatively large fluctuations in demand growth and a lack up to recently in standby capacity.

3. Causes of fuel efficiency changes

The development of the bifurcate energy efficiency pattern shown in Figure 3 of the last section comes from two sources: construction of high efficiency and low efficiency plants at the same time since the late 1980s, and continued dispatching of electricity from low efficiency plants despite the excess supply in the late 1990s. Both of these sources are associated with the changes in the market mechanism described.

The multi-layered market supply with dominant local government investments is the foremost cause of the bifurcation of technology and energy efficiency. The traditional central planning practice divides the economy according to administrative jurisdictions. City, county, prefectural, and provincial governments are responsible for the economies of their respective jurisdictions. Market reforms and decentralization have given these governments tremendous political pressure and economic incentive to improve local economic performance and protect local markets. The new electricity policy of the 1980s and the principle of regional general- or self-balance have further made them responsible for building their own capacity to meet the local electricity demand, or to blame for the shortage.

This institutional framework, on the one hand, severely limits the economic scale and planning horizon of power projects of lower level administrations. The data of the Guangdong electricity industry clearly show that the size of plants and level of technology are positively associated with hierarchy of governments who own them. Specifically, Table 5 shows that seven provincial and central government plants account for 5.8 GW installed capacity, or 40 percent of coal-fired capacity. The smallest is Yunfu power plants with two 125 MW units. Among local plants, most are small operations except for three big ones including one fully foreign-funded BOT.[19] These include 1.88 GW among twenty-one plants with plant size above 6 MW, and 2.18 GW among plants with plant size below 6 MW. On the other hand, it makes the elimination of energy inefficient operations extremely difficult when supply is plentiful. Since local investment, employment, economic performance, and particularly budgetary revenue are all at stake, the governments seriously resist shutting down their power plants and fight for generation quotas at the provincial electricity allocation meetings (GETRC, 1999a). They can even use administrative authority to order local end-users to only take

[19] Their plant sizes range from 0.7 to 1.2 GW. The unit sizes are between 300 and 350 MW.

electricity from the local power plants when the grid is uncompromising (People's Daily, May 13, 1999).[20]

The inadequacy of financial markets represents another serious cause of the existence of low tech and small scale generation facilities in Guangdong. Financial markets are vital for utility industry because electric power projects typically require large initial capital investments and a long payback period. Three connections can be established between the inadequate financial market and the expansion of the low energy efficient capacity in Guangdong. The limited availability of financing constrains investors' choice and adversely affects the size and level of the technology of the new power plants. After all, it is the lack of financial resources that forced the central and provincial governments to open the sector to small investors. The bias of the financial system towards large state-owned enterprises also often makes inefficient technologies and small scale operations the only viable investment choice for local governments. Moreover, although equity and bond markets have been developed recently, the structure of the financial market remains bank-loan dominated. The high interest rate and short payback period of bank loans make large investment extremely costly, giving local government and power plants incentive to adopt small projects and cheap technologies.[21] In general, backward financial markets are an often-cited problem in China's economic development, and is certainly so in Guangdong's utility industry growth.

Finally, government utility policy also provides incentives for the locals to go for small energy inefficient power plants. In particular, the project approval process assigns the right to approve large projects to the central government and leaves the right to approve small projects with the provincial government. Since the approval process for large projects often lasts five, seven, or more years, there is an incentive for local governments to bypass this process by choosing smaller projects. Similarly, tariff policy measures such as "cost + profit + tax" and fuel cost subsidies to generators promise a comfortable profit margin even to projects that are economically not viable. Many small and fuel-inefficient power plants have been built in response to the policy in Guangdong as well as nationwide, even to the extent that they crowded out generation from large thermal and hydro power plants (Shao, 1998).

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[20] The news article discusses a case in Chongqing, Sichuan Province, in which local governments build small coal-fired power plants and local distribution system all the time while the central government forbids their construction. To generate local revenue, governments often use administrative power to order industrial and residential end-users within its jurisdiction to only use the electricity from these small power plants, causing larger more energy efficient power plants to run idle. The case bears very similar institutional characteristics as the situation in Guangdong.

[21] According to GETRC (1999b), the major sources of financing for central government projects are from central government holding companies. Provincial government (GEPC) projects are financed through corporate retained earnings, provincial electricity development fund with the electricity construction fee and tax rebate as its source of revenue, bank loans, issuance of equities, etc. Local government projects are financed by local governments and their enterprises. Foreign investors are responsible for their own projects. Some projects also raise money by selling to the users the right to future power from the projects. Investors sometimes hold minor invests in each other's projects.

Table 5. Coal-Fired Power Plants (1998)

	Heat Rate					
	300-349	350-399	400-449	450-499	500-549	550-999
1990						
Total Capacity (GW)	0.70	0.60	0.80	0.02	0.50	1.11
Average plant size (GW)	0.70	0.60	0.40	0.02	0.25	0.06
Average unit size (MW)	350	200	267	10	39	17
Ownership	P*	P	P	L**	L	L
1998						
Total Capacity (GW)	1.98	7.15	0.24	0.77	0.24	1.78
Average plant size (GW)	1.98	0.60	0.08	0.13	0.08	0.04
Average unit size (MW)	660	193	40	45	14	11
Ownership	P	P	P, L	P, L	L	L

* Provincial government ownership. **Local government ownership
Source: Derived from GETRC 1999c.

More fundamentally, the observed bifurcation of energy efficiency distribution is associated with the fluctuations in income and electricity demand coupled with inadequate capacity build-up. The demand fluctuations, as noted earlier, aggravate the problems of a government-directed, fragmented supply arrangement that is ill suited to accommodate demand changes.

Changes in these factors and in the market mechanism will have continued impact on Guangdong's energy efficiency performance. Future carbon emission baseline predictions involving energy efficiency changes cannot be satisfactorily obtained without the consideration of the future trajectory of these factors. We discuss these factors below.

IV. Global Warming Impact of Guangdong's Electricity Development

Section II shows that Guangdong's electricity development was accompanied by fuel structural change and energy efficiency pattern shift. Guangdong projects that future fuel structure will stay the same and energy efficiency will be greatly improved. Section 3 linked these changes to economic and institutional factors. This section discusses the implications of these analyses for carbon emissions reduction costs and baseline determination.

Carbon Reduction Cost

The data obtained from the Guangdong Energy Techno-Economic Research Center (GETRC) permit, in principle, establishing a relation between carbon emission per kilowatt-hour and the cost per kilowatt-hour, leading to an estimate of the cost of abating a ton of carbon. In practice, however, the uncertainties in the data prevent making an accurate estimate. Nevertheless, it may be useful to go through the pertinent calculations in order to see more precisely how uncertainties in local data may affect policy-relevant inputs.

Approach

We adopt a simplified approach to using the data based on estimating the direct cost to producers of substituting one electricity generation technology for another with different carbon emissions per net kilowatt-hour (kWh) generated. Direct substitution costs to producers do not of course reflect total cost to the economy. For one thing, they do not take into account changes in demand for electricity. For another, they leave out general equilibrium effects. The latter are probably small given that the total electricity cost is under 5 percent of the provincial GDP. As to the former, estimating the lower demand for electricity would entail relating generation cost differentials with price differentials. Such a relation cannot be established with any confidence at present. The electricity pricing structure, discussed elsewhere in this article, is determined by agencies of the provincial government on the basis of social and political factors in addition to the cost of electricity. These factors, as well as the method by which capital costs are underwritten (often by central government appropriations), obscure the relationship between cost and price of electricity. This situation is changing, but, at present, direct cost differentials provide the best handle on carbon abatement costs. Even so, as we shall see, only qualitative conclusions can be drawn.

Using our approach, if the costs of supplying electricity that meet given specifications in a certain region at a certain time from two technologies with different carbon emissions are x_0 and x_1 ¢ (U.S. cents) or Yu (yuan) per kWh, the heat rates associated with those technologies are h_0 and h_1 grams per kWh, and the carbon emitted per gram of that fuel are c_0 and c_1 grams of carbon per gram fuel burned, then the cost y of abating one ton of carbon by switching from technology 0 to technology 1 is:

$$y = \{(x_1 - x_0) / (h_0c_0 - h_1c_1)\} * 10^4 \text{ \$ per ton of carbon abated}$$
$$= \{fx / (h_0c_0 - h_1c_1)\} * 10^4 \text{ where } fx \text{ is the cost differential.}$$

If, for example[22], the technology is coal in both cases with a 65 percent carbon content, the present (subscript 0) heat rate is 412 g/kWh corresponding to the 1995 average PRC pulverized coal plant, and the future (subscript 1) heat rate is 332 g/kWh corresponding to the average in developed countries, then we get the figures on the top three rows below for y as a function of various assumed values for dx:

Fuel	*f*x = assumed US ¢ per kWh differential	y = $ per ton carbon abated
Coal	0.5	96
Coal	1.0	192
Coal	1.5	288
Gas	0.5	30
Gas	1.0	60
Gas	1.5	90
Nuclear	1.0	37
Nuclear	1.5	56

[22] The authors are indebted to Neville Holt of the Electric Power Research Institute for much of the information on coal.

For a conventional (54 percent efficient) combined-cycle gas turbine, emitting about 100 g C/kWh, then, even with a higher cost differential, the dollars per ton carbon abated go down (next three rows). That is true as well of nuclear-generated electricity if it can replace present coal-generated electricity at 1 or 1.5 cents per kWh differential.

This approach may be used to give some idea of the carbon abatement cost associated with moving from one technology to different technologies if an estimate can be made of levelized costs of electricity for both technologies.

Data and Results

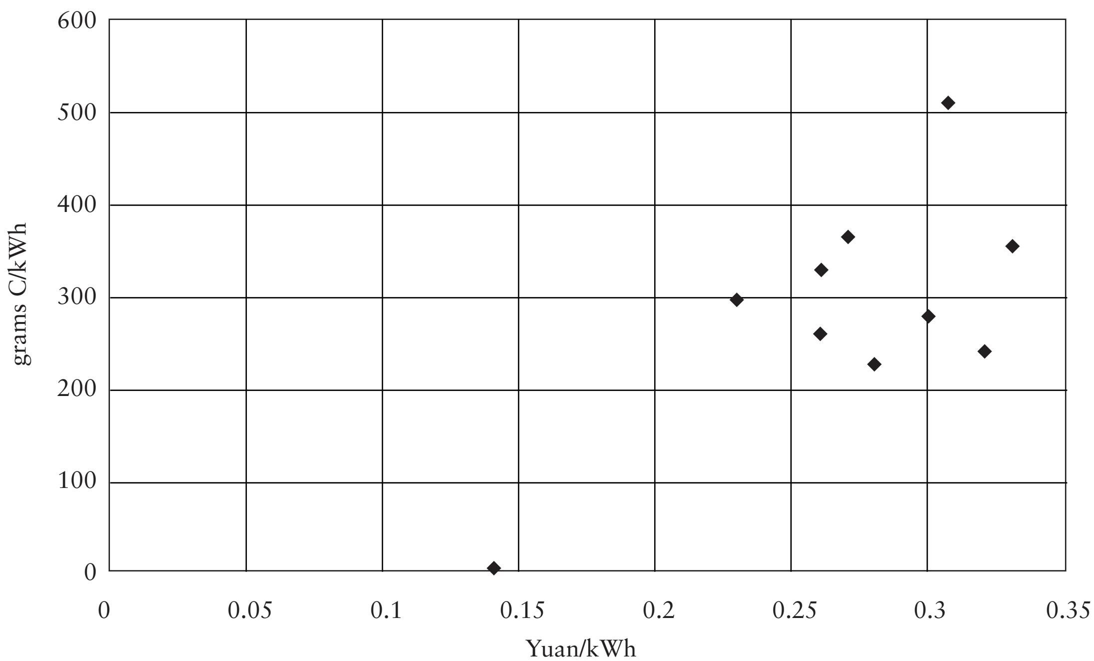
Levelized electricity costs are particularly difficult to estimate retroactively in China, however. One reason is that the costs of the nonfixed factors of production in generating electricity (fuel, labor) are in transition from managed to partially market-based. Another reason is that the capital costs of older plants are not well known. Older plants, and some newer ones as well, were built using budget allocations at various governmental levels. Records of these allocations are not always clear or available. Even when they are, comparing these records to what current market-based costs would be is an uncertain exercise.

Nevertheless, estimates were made from data obtained by a team of specialists in the Guangdong Energy Techno-Economic Research Center (GETRC 1999c). They represent summaries of fuel use and electricity generation and estimates of levelized costs by type of fuel for the years 1990 and 1998, and plans for the year 2010. From these data and data on carbon content of the fuels, carbon emissions per kilowatt-hour were derived for each type of plant. A summary of those data is shown in the following tables and charts. More detailed data are given in Table 3. It should be emphasized that both the data to be gathered and the format to be used were suggested by the authors. They do not necessarily represent the way in which this kind of information would be gathered and presented by our Guangdong colleagues in China absent interaction with us. The data set gathered by our colleagues is available in both Chinese and English from our project. In addition, our Guangdong colleagues may publish their own analyses in China.

We plot carbon emissions per kWh versus cost per kWh (in Yuan) in the electricity industry of Guangdong province for the years 1990, 1998, and 2010. Note that carbon emissions stemming from construction and land use change are not included. Including them would not make much difference to emissions from fossil fuels, nuclear, or wind generation. Carbon emission, or rather foregone carbon absorption, associated with hydroelectric power depends on the area of land covered by water for a given amount of power generated and the prior vegetation on the land submerged. Hydroelectric power is imported into Guangdong province from the Southwest of China. Neither we, nor our Guangdong colleagues have made an estimate of this foregone absorption, but, given the vertical fall associated with rivers in Southwest China and the presence of much run-of-the-river power, it is not likely to be significant.

Figure 8 shows data for 1990. Costs are particularly uncertain for that period. The point at zero carbon emissions and 0.14 Yuan/kWh represents imported hydroelectric power. The low stated cost of hydroelectric power represents the fact that dams and 500 kV transmission lines from Guanxi province and elsewhere have been used for many years, and most capital costs have already been recovered. The other points represent coal and oil-fired plants of varying vintages. Those data points show no trend, with widely different carbon emissions associated with a given cost range. This result would be expected if the cost bases for the various vintages and technologies were not consistent with each other, as might well be the case for older plants.

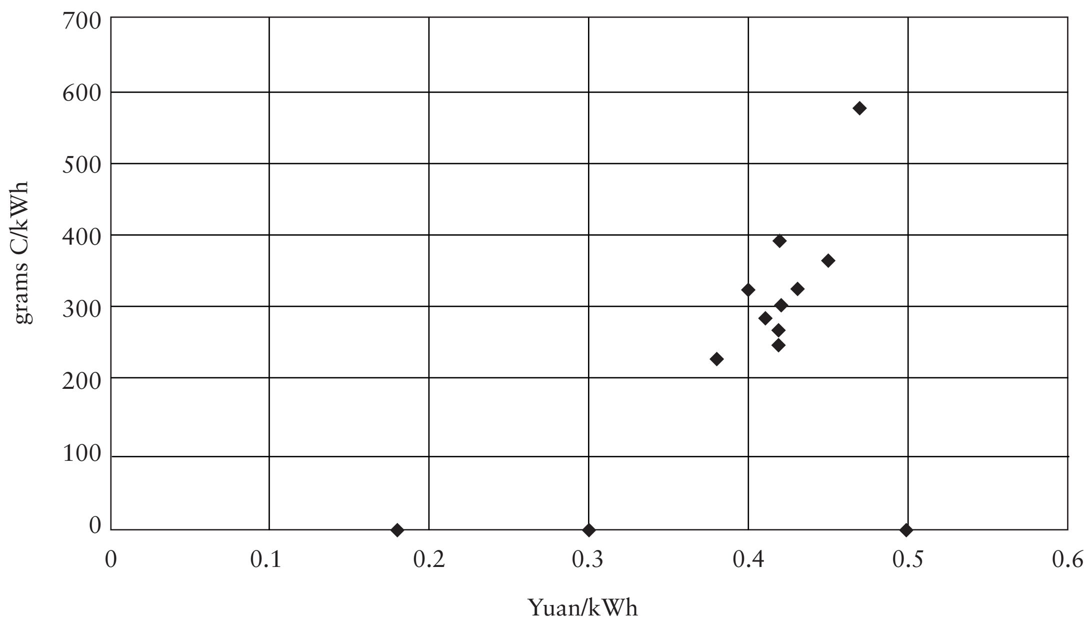
Figure 8. 1990 Carbon Emissions vs Cost



The data for 1998 show hydroelectric power, wind power, and nuclear power at zero emissions and at 0.18, 0.3, and 0.5 Yu/kWh respectively (Figure 9). We suspect that land costs are not included. Including them could bring the cost of wind power up more than proportionately. The other data points represent various categories of coal and oil-fired electric power. The data show carbon emissions rising with cost per kWh. This would be expected if savings in carbon emission per kilowatt-hour were due largely to more efficient use of coal and oil over a range of efficiencies sufficiently low that improvements in fuel-to-electricity efficiency translated into improvements in cost efficiency. A look at the more detailed data in Table 3 confirms this surmise. In 1998, as noted earlier in our discussion, Guangdong had just emerged from a severe sixteen year-long electricity shortage. During that period, a huge amount of new capacity was built to meet the demand. The efficiency changes in generation largely reflected the changes in the technologies that were being adopted. This suggests that factors underlying the choice of technology probably have played a larger role than *ex-post* efficiency in determining the pattern of the energy efficiency changes.[23] In any case, for 1998, the data indicate negative carbon abatement costs: electricity generated with less carbon emission is also cheaper.

[23]This is consistent with findings of existing empirical studies. See reference in footnote 10.

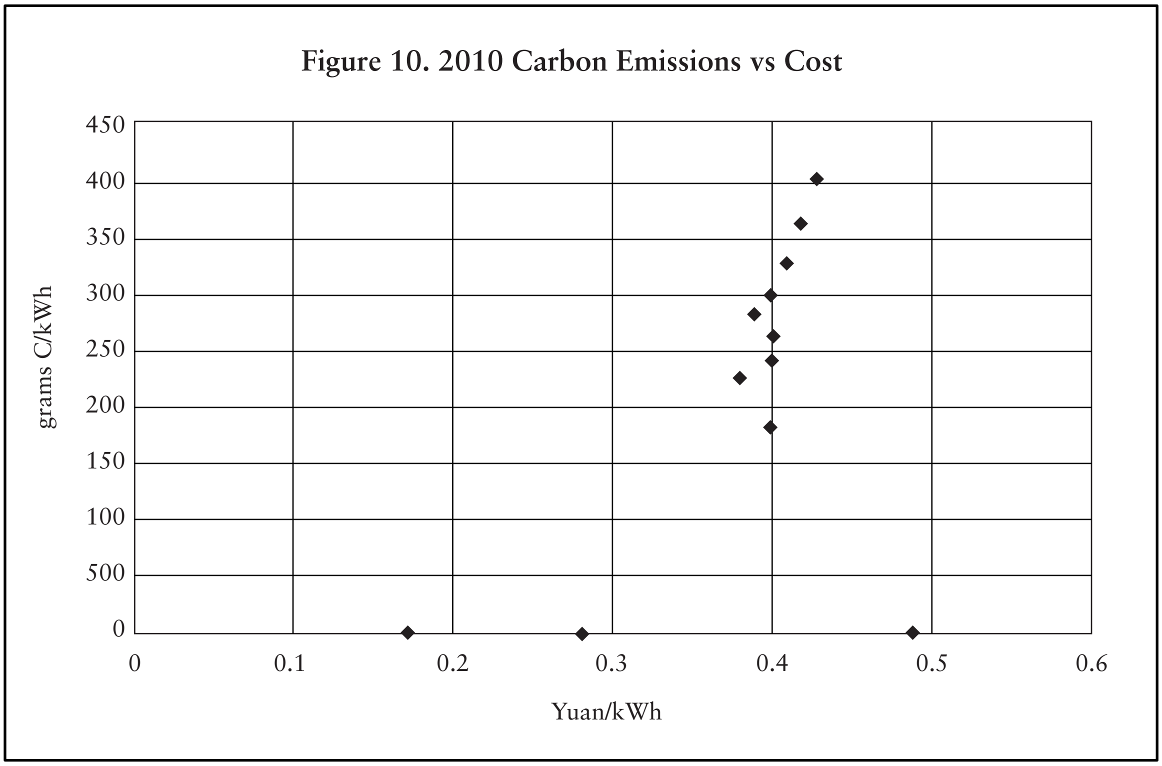
Figure 9. 1998 Carbon Emissions vs Cost



The planned 2010 figures show most cost figures clustering around 0.4 Yuan/kWh regardless of carbon emission per kWh, except for the nonfossil power that shows the same pattern as in earlier years (Figure 10). This cluster refers to planned costs. Since plans call for the elimination of the inefficient, higher-cost suppliers of electricity that the 1998 data show, the clustering effect is to be expected. For coal and oil, and to a lesser extent for nuclear power, there is sufficient experience in the province so that the planned cost figures should reflect what the actual cost of providing electricity with those fuels will be. Between now and 2010, however, there are plans for significant additions to the power supply from combined-cycle gas-fired turbines. These account for the lower (under 200 grams C/kWh) emission points.

According to GETRC, their cost includes the capital cost of building LNG receiving terminals and under-sea pipelines. These cost estimates are based on a static analysis of social cost and benefit of these investments. Whether their actual cost will be as estimated is not known.

For 2010, about 15 percent of the power is to be provided by nuclear energy, 30 TWh out of 210 TWh planned total, a proportion similar to today's 13 TWh out of 100 TWh total. The big planned change is the elimination of inefficient older coal plants, and the introduction of combined cycle gas turbine generators.

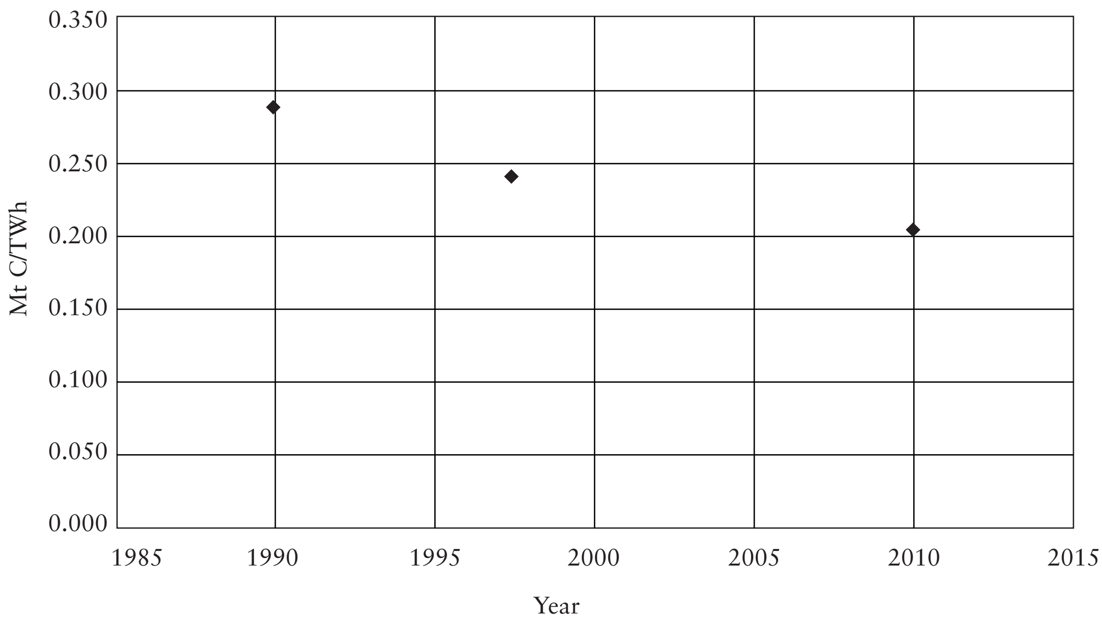


Estimated Provincial Electricity Sector Baseline

We can now integrate the data used above over all producers of electricity in proportion to their production to provide a carbon abatement baseline for the Guangdong province electricity industry between 1990 and 2010. Integrated data from all power sources at the three periods give three points on a baseline, as shown below.

	1990	1998	2010
TWh	24.774	71.866	155.59
Mt (C)	7.185	17.29	31.97
Mt C/TWh	0.290	0.241	0.205

Figure 11. Guandong Electricity Baseline



The planned reduction from 0.29 to 0.20 million tons of carbon per TWh generated in twenty years is quite sizable and may not be continued in the future. It would entail hydro, nuclear, and gas power going up to about 40 percent of total generation and coal heat rates coming down to about 330 grams/kWh, the present world average. The corresponding U.S. figure for 1998 was about 0.16–0.17 million tons of carbon per TWh generated.[24] The U.S. generated 45 percent of its electricity from a combination of nuclear energy, high efficiency gas turbines, and hydroelectric power and other renewables. Today, China as a whole, including Guangdong province, generates about 27 percent of its electricity from these sources, mostly hydropower. Only by going to much more gas-fueled and nuclear electricity generation, on the order of what is found in Japan, Korea and Taiwan, could the carbon per kWh go down much further than the figure planned for 2010 in China.

Both gas and nuclear-fuelled electricity generation are planned to grow over the intermediate term in China, but not enough to alter the overall coal dependence very much. Gas use will be limited by policy, given the uncertainty in gas prices in out years, the likelihood that much of China's gas will be imported, and the sensitivity of electricity prices to gas prices. Growth of nuclear electricity requires, in China as elsewhere, competitively low levelized costs for nuclear power, which in turn requires the availability of long-term (thirty to forty years) investment capital at competitive rates. It also requires, in the view of Chinese authorities (Li Peng, 1997), maintaining a high safety record as different types of imported

[24] From USDOE EIA, [http://www.eia.doe.gov/cneaf/electricity/epav2/epav2t22.txt and http://www.eia.doe.gov/cneaf/electricity/page/at_a_glance/epatab5.html]. The listed 1997 figure for CO_2 emissions was linearly extrapolated to 600 million tons of carbon emitted as CO_2 from fossil-fueled steam electric plants in 1998. 3,600 Terawatt-hours were generated from all electric plants (2500 fossil, of which 545 were gas, 673 were nuclear, and 400 were hydroelectric and other renewables).

reactors are installed, and domestic industry expands.

It is also worth noting that, while the dependence of China's electricity generation on coal is higher at 70+ percent than the world average, three of the four largest carbon emitters in the world also rely on coal for generating most of their electricity, with the U.S. at 56 percent dependence and India at 60+ percent. Given China's large direct use of coal outside the electricity sector, the least expensive opportunities for reducing carbon emissions may not lie in the electricity sector once the figures planned for 2010 are reached in Guangdong province (some time later in most other provinces).

The foregoing discussion has used carbon intensity of electricity as the figure of merit to measure cost of abatement and progress made in abating carbon emissions in the electricity sector. Whether that is the right figure of merit for the purpose of establishing a baseline to be used in determining additionality under Article 12 of the Kyoto Protocol is another question. It does capture the technical factors involved in reducing carbon emissions per unit electricity generated, and allows comparison of this factor with cost per unit electricity generated. However, at least three objections can be raised to the use of this factor to establish a baseline.

It does not capture the carbon emission abatement from reducing the amount of electricity used for a given end-use. These can stem from both reducing transmission and distribution losses and from improving end-use efficiencies. Even if the latter is deemed to lie outside the electricity sector proper and is to be the subject of separate baselines, the former is the responsibility of the electricity sector. If data were available, the proper figure of merit to be used for the electricity sector as a whole should be carbon intensity of electricity received at the user site, not of electricity transmitted at the generating site. Data for the Guangdong electricity sector in this respect should become available with further research.

It does not lend itself to calculating the marginal cost of abating the next ton of carbon as well as a carbon elasticity of electricity would. However, calculating a carbon elasticity from the data shown (beyond the simple observation that the elasticity for 1998 is positive) would clearly lead to unusable results; the scatter in 1990 and the planned price structure shown for 2010 prevent calculation of a meaningful elasticity coefficient. When and if actual comparative cost data for the years after 1998 become available, such a coefficient might be calculated.

It does not take into account the ability of the province to afford more abatement than is now planned for economic and other pollution reasons. A baseline for developing countries or their subunits should, it may be argued, take this ability into account. Thus, richer entities could be held to tighter standards. Trading in theory can take care of this if the market for emissions is established and allowed to work. To the extent that trading is restricted, however, a figure of merit related to carbon emitted per dollar of GDP might be appropriate.

2. Baseline Discussion

In this last subsection, we discuss the principal factors that affect the likelihood that Guangdong province will achieve its objectives for 2010 and later, and thereby whether those objectives constitute a realistic baseline for the purpose of applying the additionality rule of the Clean Development Mechanism (CDM) under Article 12 of the Kyoto Protocol. While the CDM provides an opportunity to reduce global carbon emissions through transferring western technologies and capital to developing countries, CDM is nevertheless challenging as an international policy instrument. Its operating rule of additionality requires a baseline estimate of what developing countries would do to reduce carbon emissions in the absence of CDM, a daunting task to work out with minimized moral hazard and other incentive problems on one hand, and reasonable institutional costs on the other (Chomitz, 1998; Heller, 1998).

Implementing rules for the Kyoto Protocol that will define methods for baseline approval are under negotiation. They will not be settled until November 2000 at the 6th Conference of the parties to the UNFCCC. Studies of these rules have so far proposed several baseline principles, ranging from project-specific baseline, to sectoral benchmarking and technology matrix, to national top-down baseline (Chomitz, 1998; Meyers, 1999; Hargrave, et al., 1998; Lazarus, et al. 1999; Kelly, 1999). From the discussions, it appears that none of the proposed baselines are exempt from the problem of gaming the system, and all of the likely methods suffer from some kind of trade-off.[25] At the bottom level, the project specific approach may have the benefit of establishing a relatively realistic baseline by minimizing strategic behavior and specifying institutional costs that constrain the choice of economically viable projects. But it may do so at prohibitively high implementation and monitoring costs. At the relatively aggregated level, sectoral benchmarking may simplify technical baseline setting and implementation, but may cause the baseline to be unrealistic if it fails either to incorporate nontechnical institutional costs or strategic behavior.

Resolving the problem of methodology in baseline design for CDM requires a balancing of policy considerations that often lead in different directions. The most important of these policies are: (1) low transaction costs; (2) credibility; (3) dynamism; and (4) realism.

Low transaction costs are essential to CDM effectiveness. Project based CDM can contribute to GHG mitigation if the market value of emissions saved by the project beyond the counterfactual emissions baseline exceeds the incremental costs of environmentally more sound projects by amounts sufficient to render previously noncommercial projects viable. Since the net value of CDM may decline from either incremental production costs or CDM transaction costs associated with certification, verification, and monitoring, high transaction costs associated with CDM qualification will reduce the portfolio of viable CDM projects.

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[25] The top-down baseline requires some sort of voluntary commitment of national carbon emissions reduction or cap. The national government then distributes the committed reduction among sectors and regions as baselines. The approach can be considered unlikely for many developing countries including China because refusing to take such a commitment is exactly why they are put under Article 12. Some authors argue that the problem can be resolved by defining a dynamic national baseline that takes economic growth into the consideration. See Hargrave and Helme (1998) for details.

Credibility is equally central to the environmental goals and political future of CDM. Because each certified CDM project allows some actor in a nation with mitigation commitments to increase the emissions it would otherwise have reduced at home, CDM projects that do not create real (credible) offsets abroad will lower total global mitigation.[26] There are good reasons to believe that the self-interest of both home and host nations in CDM investment may overestimate the actual environmental benefits of prospective CDM projects. Host nations will prize the lower costs of capital CDM promises. Home nations will seek to reduce their costs of compliance with climate change commitments. Project credibility will also be suspect because of the asymmetric distribution of information between parties to CDM transactions and CDM certifying organizations, because of leakage associated with the transfer of displaced GHG sources to nonproject areas, and because of fears that host nations will lower their environmental standards to create assets for export through CDM. If these suspicions prove justified over the initial target period of the Kyoto Protocol, it will be hard to sustain the continuing use of CDM in later negotiations.

Dynamism is necessary in baseline definition for reasons related to the arguments for credibility. IPCC and other economic-climate models that forecast GHG emissions normally assume increasing energy efficiency in the capital stock. These gains are attributable to changes in expected relative input prices to energy production, autonomous technical change extrapolated from historical performances, and assumptions about policy or institutional factors that change incentives for energy producers and consumers. If these sources of dynamic improvement are not accounted for in the definition of business as usual (the CDM baseline), the climate change problem will be exacerbated relative to IPCC estimates. To the extent that our models of business as usual baselines already account for some level of technical and institutional changes, then not all reductions in emissions below present practices or benchmarks should qualify for CDM certification. In other words, nondynamic baselines that count all improvements from today's performances as additional will certify a number of technical and policy improvements that would have occurred in the absence of CDM interventions and would therefor not merit offset against Kyoto commitments.

Finally, baselines should be realistic in terms of actual likely behaviors rather than environmental goals or political aspirations. For example, the ambitious environmental laws on the books in China and many other countries are not well enforced. Moreover, there are comprehensive plans to reform existing power sector institutions so that competition, segregation of operations and regulation, partial privatization, and financial restructuring will create different incentives that could have impacts on environmental capabilities in a new infrastructure. If dynamic baselines are set that incorporate the effects of better legal enforcement and the growth of a merchant sector of independent power producers that are not forthcoming in the target period, valuable CDM projects that might have brought improvements over less transformed actual practice will be disqualified. In the presence of strategic behavior and moral hazard with host states, the policy goals of realism and credibility will always be in tension with one another. In many cases, it may be that political negotiation between host and home over the pace and scale of institutional reforms will be needed to deal with this tension.

China has always been imagined as a major location for CDM investment. This is espe-

[26] It should be noted that there may well be under the Kyoto Protocol other international trading opportunities, credible or not, under Articles 6 and 17 that would supplement CDM (Article 12).

cially true for the electric power sector because of its scale, rate of growth, and high rate of emissions from coal fired plant. Research into the ability to define baselines that foster confidence in incremental mitigation in the Chinese power sector would substantially help to decide whether CDM was a viable and important tool for the climate change regime. Given the policy criteria for baseline definition set out above, our work explores the development of Chinese energy and its relation to CDM baselines with particular reference to the use of benchmarks; disaggregation by sector, technology and region; differentiation of capital vintages; and political negotiation. The complications of applying these criteria to empirical conditions in China raises questions about the selective endorsement of CDM first in those economic sectors and institutional contexts where credibility, realism, and low transaction costs best converge.

Setting benchmarks aims at reducing transaction costs of baseline determination by minimizing the variability and expenses of project-by-project evaluation. Carefully established benchmarks can require more front-end investment than project baselines in order to investigate whether there are predictable practices at scale across a given sector and region. Benchmarks will be more useful in some sectors than others and may create incentives, other things being equal, for CDM projects to concentrate in these activities. Although past investment in electric power in Guangdong has clustered around two distinct poles, it should not be assumed that uniformity will continue in this way in future periods. Defining benchmarks has public goods characteristics and may require public subsidies and political intervention (see below). However, once well-defined for a specified investment period, the potential for certifying agencies to recognize mutually validated benchmarks can lower private transaction costs for multiple actors and enhance system credibility.

Credible baselines in Chinese power will demand disaggregation along several vectors. The combination of China's size, rapid economic growth, and partial institutional reform creates the possibility of significant variation between technologies and regions. State owned enterprises and alternative forms of industrial organization still operate with different managerial incentives, corporate governance, and access to finance. Conditions and risks for foreign investors who may initiate CDM projects may not be similar from sector to sector or technology to technology. Changes in access to new designs and equipment may shift at different paces in different regions. Aggregating such variability in homogeneous baselines will create obvious, politically vulnerable instances of CDM subsidy to business as usual practices and exclude opportunities for realistic mitigation in lagging regions and sectors. Our work looks at variation in the Guangdong power sector that reflects ongoing differences in industrial organization and uncertain institutional restructuring in several electricity technologies. At the same time, recognizing that Guangdong is a province of advanced economic growth and leading edge institutional reform, the research will be further disaggregated in future extensions of the analysis to other provinces.

We use a three-vintage analysis to account for the pace of technological change in baseline definition. Using historical data or cross-period averages of all power installations would understate the dynamic baseline for added capacity. The institutional context of investment in power generation and distribution has changed markedly in the original reform period between 1978 and 1990 from that of the growth years between 1990 and 1999, even as tempered by the recession of 1997-99. It is projected to change again in the decade to come. Credible benchmarks are not the same in each of these periods, even though different benchmarks may be appropriate for each of them separately. Because the most important segments of Chinese electric power are dominated by large scale investment dependent on state capital or offshore project finance, transparency in the sector reduces asymmetric information problems. Nor is leakage likely to be as serious as in other sectors due to the long-term and lumpy character of planning for power development. If there can be reasonable consensus on acceptable geographic, organizational, and temporal differentiation in baseline setting, high relative credibility in benchmarked electric power baselines may suggest selective favor of CDM certification in this field.

Moral hazard or gaming problems are a final concern of credible baseline benchmarks. Again, compared to other potential areas for CDM qualification, electric power may have relative advantages. The power sector has always been at the core of the public sector and has been dominated by national policies in both market and planned societies. Strategic adjustments in China's fundamental power sector policies to create assets for international sale of mitigation is somewhat improbable. However, at the edges of the national planning process that explores new technologies or in environmental enforcement, there may be some concern for slowed domestic investment. Benchmarked baselines might incorporate negotiated agreements between host and home nations on the pace at which local externalities associated with power generation or other aspects of mitigation enhancing reforms will be internalized to enforced environmental standards.[27] These negotiations could help to determine the politically acceptable (realistic) pace of institutional change and foresee staged baseline improvements that recognize the endogenous dynamics of greenhouse gas mitigation.[28]

In light of Guangdong's utility experience, our study suggests that a basic understanding of economic, political and institutional characteristics of the sector development is instrumental for establishing a realistic baseline that combines a technology benchmark and institutional costs that constrain "additional" technology to fall below the benchmark. Guangdong's energy efficiency and fuel structure data discussed in Section II suggest that future carbon emissions of Guangdong's electricity sector depend on the answers to three questions:

Will the province be able to achieve its declared goal of replacing energy inefficient technology with better ones, including shutting down existing small power plants? Will the conditions that have prevented the province from outperforming its goal of technology advancement change? Will the conditions that have prevented the province from further substituting carbon cleaner fuels for coal change?

The answers to these questions lie largely in how the planning based and multilevel government centered electricity supply system evolve, and how broader market reforms, most importantly the financial market reform, will proceed. To predict future development in this area is risky, but a series of recent policy announcements by the government does give some indication of the direction of the future change.

The announced policy reforms can be grouped into categories of actions aimed at reducing short-run sluggish electricity demand, and long-run market reform oriented policy mea-

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[27] Environmental reform may not always be greenhouse gas mitigating. Mandating the use of flue gas desulfurization, for example, may reduce the net efficiency of coal based power plants and thereby increase carbon emissions.

[28] Alternatively, the inducements provided by CDM could cause governments to reduce barriers to foreign investment that would otherwise prevent commercially sound projects. To the extent that CDM projects would remain noncommercial even with well-defined baselines because of other risks to foreign investors, negotiations on benchmarks and baselines could refer to nonenvironmental reforms necessary to bankable projects.

sures.[29] The former includes the following four policy elements: (1) to invest in and upgrade transmission and distribution grids to reduce losses and lower the electricity price; (2) to eliminate below county level management layers "toll booths"; (3) to eliminate or reduce fees in the tariff the end-users pay, and; (4) to shut down the small energy inefficient thermal power plants. Some of these changes, especially one and four, also serve long-term policy objectives.

The long-run policy measures feature five components: (1) long term grid investment and gradual connection of regional grid to form the national grid; (2) separation of generation from transmission, and further transmission from distribution after 2010 to promote market competition of electricity supply; (3) separation of government from business and corporatization of utility sector enterprises to improve economic efficiency; (4) increased role of domestic and foreign equity and bond markets in financing utility sector development, and; (5) change of tariff policy from "cost + profit + tax" structure to tariff based on levelized cost.

These planned policy measures as well as other long term reform policies have several implications for the future changes of the important carbon emissions determinants of Guangdong's utility sector identified in the last section. First, the reform policy may bring minimum change to the planning based and multilevel government centered electricity supply system. While these deeply rooted institutions of a government-managed economy are difficult to change, the reform plans are particularly weak in redefining the role of the government and economic planning in future utility development. As long as the government continues to assume majority ownership right of the public enterprises, and government officials are charged with the responsibility of broad local economic and social performance, efforts to separate government from business will be difficult and may be inconsequential. That local governments invest in utility to serve the local market according to the general balance principle of planning is the fundamental cause of the adoption and continued operation of small scale power plants. The prolonged existence of this public supply arrangement implies that the utility market is likely to remain divided and limited in scale at lower administrative level.

The arrangement will also have potentially conflicting effects on the operation of energy-inefficient power plants. On the one hand the government control can make the closing of these plants possible. The hierarchic authority structure of the Chinese political system gives the central government a very strong control power over the local economy and government. To assure the implementation of the policy to shut down small thermal power plants, the State Economic and Trade Commission has recently ordered that the grid not purchase power from these plants, coal and oil companies not to sell fuel to them, and bank loans be not extended to them (China Economic Times, May 28, 1999). If they do not comply, local government officials may face the danger of being stripped of their positions. Under heavy political pressure, local government officials will shut down inefficient plants, though involuntarily. On the other hand, local governments often have incentives and find system loopholes to bypass the restrictions and keep these plants running. As Chongqing's case indicates, local government can build transmission network right next to central government grid, and order end-users within its jurisdiction to take electricity only from the local power

[29] China Daily, May 18, 1999; Xinhua News Agency, October 19, 1999; January 18, January 26, and February 14, 2000; China Economic Times May 27, 1999; People's Daily, July 9, 1999; October 12, 1999; and China Light Industry News, February 18, 2000.

plants. The fact there is no policy to compensate local governments for the closure of their power plants will reinforce the resistance.

Second, utility demand, which will still be the driving force, is on a long term rising trend. The recent excess supply on Guangdong as well as China's electricity market is a temporary phenomenon associated with the business cycle. The per capita levels of installed capacity and electricity consumption in Guangdong are still very low as compared with industrial countries. Any economic growth, even in the lower range of the usually forecast levels, will push the electricity demand up, tightening up the electricity market condition. This situation, combined with the above-mentioned Chinese market characteristics, will jeopardize the effort to shut down inefficient power plants and to restrict the construction of small inefficient ones. This danger is very real. Guangdong's electricity demand has increased significantly since 1999, and essentially wiped out market surplus. The province is expecting a consumption quota for the summer peak season, and faces a new round of shortage if new capacity building does not catch up (South China News, January 21, 2000).

Third, separating generation from transmission and promoting utility sector competition is good for reducing electricity price and economic efficiency. But it raises the question of its compatibility with the current stage of China's utility sector development, and its impact on other growth promoting, especially financing, policies. Deregulation and market competition have been a trend of the public utility policy of governments of many developed countries and some developing countries since the 1970s. Given the natural monopolistic nature and the economic characteristics of the utility industry, successful market competition requires a sound regulatory framework and experience as well as a well developed supply system with adequate generation capacity. Whether it is optimal for China to take on market competition at this stage of development, and how the reform should be implemented remain questions to be studied.

Meanwhile, there is some indication that grid competition is likely to hurt China's effort to raise fund for the utility sector, which is probably the most difficult problem of the sector. Grid competition will lower the electricity price and increase uncertain and risks for the investors (Rossin, 1999). In addition, under the current "cost + profit + tax" tariff policy, foreign investors are at a special disadvantage as compared with the existing state-owned power plants, whose capital cost is virtually zero (Wall Street Journal, January 28, 2000).

Fourth, financial market development will be a long process requiring difficult legal and other institutional changes. Financing has been among the biggest problems in China's utility sector development. It has traditionally been dependent on government support, either through direct budgetary allocation or through policy lending from government banks. Both central and Guangdong provincial governments now place high hopes on equity financing of future projects. However, it is not clear whether stock offerings can raise sufficient funds for the sector. Power projects usually involve large capital investment, long payback period and, in a developing economy, risks of significant fluctuations in demand. For the power sector to compete with other industries, it has to offer a steady rate of return. This was guaranteed in the past by the government's tariff policy and electricity purchase contract. As just mentioned, the grid competition being introduced in the sector is likely to make investment seem more risky, making equity funding more difficult. The lack of institutional investors will reinforce this effect. The lack of protection of minority or public equity interests in the Chinese companies will hinder the long-term development of the stock market.

Foreign investment in the sector will have a minor role for two reasons. The reform strategy stresses public ownership, especially in vital industries such as electricity, and thereby will limit the level of foreign involvement. On the foreign investors' side, investment in the utility sectors in China and many developing countries has become less appealing due to the increased uncertainty and risks, especially as compared with industrial countries. In brief, lack of financing will likely be a serious constraint on decisions pertaining to scale, source of fuel, and technologies for new projects. It reinforces the adverse effect of divided markets on energy efficiency.

Fifth, despite the importance of price for energy efficiency and fuel structure, government policy for future electricity and fuel prices remains most confusing. The State Economic and Trade Commission has recently announced that future generators' price will be determined by competition. At the same time, the State Development Planning Commission has announced that future price will be determined by a new levelized cost-based pricing policy. In addition, government also indicates price support to encourage such source as wind power. Price policy for different fees that are added to the end-user tariffs is unclear. And, fuel prices including coal, oil, and gas are also subject to government control or intervention. Institution wise, the reform plan does not have the indication that government will eliminate multiple levels of price bureaus and related offices any time soon. This implies that the government will continue to control the price, which will interfere with the functioning of price as the market signal. This in turn will cause uncertainty in fuel and technology costs.

Lastly, the long run development of the utility sector may also be constrained by the availability of capital equipment with embodied advanced technology. China's domestic ability to manufacture the most modern generation equipment is growing slowly. At the same time various factors create a bias against imports of foreign equipment. China traditionally adheres to national industrial policy. In order to support the maufacture of domestic electricity equipment, the government emphasizes the principle of domestic production first and imports as supplement. The principle stresses that under the same conditions, power projects should use domestic equipment first. When foreign import is necessary, both the equipment and the manufacturing techniques should be imported (Energy Research Institute, 1998). The government practices a restrictive import policy also through import approval or foreign exchange controls. Moreover, power plants favor domestically manufactured equipment over imports because of lower initial cost. Some studies estimate that this cost difference can be as high as 30–50 percent (Holt, 1998). This will limit the extent to which the Guangdong provincial government can utilize the best technology currently used in industrial countries.

Implications for CO2 emission baseline and CDM implementation

Data of Guangdong power generation in Section 2 projects that the 2010 vintage technologies for the sector will feature predominant coal technologies (59 percent of provincial generation) with a standard heat rate of 350–400gce/kWh or lower. Our study argues that, on at least two grounds, this technology projection can be used as a first proxy of the sectoral benchmark for CDM implementations. These future vintage technologies represent carefully planned provincial target for power sector development, and will guide policy design to reach the target.[30] More generally, government Five-Year and Ten-Year medium term plans are always the result of multiple rounds of balancing among different interests and

[30] These 2010 power development targets are an integral part of the tenth Five-Year and next Ten-Year economic plans of Guangdong province being drafted.

prioritizing of various programs. Using plan specified technology targets as the benchmark could be less prone to gaming problems than might be estimated from economic considerations because the cost of gaming the complicated planning for the benefit of CDM revenue would be simply too large. It is ironic that it may be the persistence of the residual of central planning that reduces the uncertainties otherwise associated with baseline design. Guangdong's electricity sector advancement is not likely to outperform this projected energy efficiency improvement and reduction in the share of coal. The considerations of various factors determining the changes of power supply relationship, and institution suggest that the existing power supply model will only change slowly. It will take more than a decade to sort out some of the fundamental relations and develop a more market-based supply relationship. Particularly, provincial or central government whose investments are usually in large scale and more advanced technology power projects will continue to be constrained by finance and perhaps availability of technology, while local governments whose investments are mostly seen in small inefficient plants will continue to be important players of local power supplies.

However, it is more difficult to determine whether some specific projects with heat rate above some specified figure of merit, such as a coal heat rate above 400 gsce/kWh, are additional or not. By the technical benchmark they are not. But political, institutional and financial factors discussed above may make them the actual choice in the absence of CDM. Largely due to these factors, the bifurcation of new power investment into large provincial and small local plants has prevailed until the 1997 economic slow-down. These same factors in a period of renewed growth could again revive this second track of electricity expansion and make the plants plausible subjects for CDM improvement. Baseline considerations that do not take into account the slow changes of investment constraints and power sector institution can lead to missed opportunities, but may require specific political negotiations on the enforced phase-out of these plants to establish a baseline.

A final question on the utility of CDM in Guangdong concerns the relative values of carbon mitigation and risks to foreign direct investment. If typical CDM investments will take place through FDI projects that improve energy efficiency or substitute fuels in the power sector, these projects must be sufficiently close to the commercial margin that the added value of carbon emission reductions offsets the incremental costs of improvements. If, on the other hand, contract, property, and regulatory risks to power sector FDI move investment opportunities far from the commercial margin, then expected carbon values may still make such projects nonbankable. We will examine this question in greater detail in forthcoming papers.

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