Baselines for carbon emissions in the Indian and Chinese power sectors: implications for international carbon trading

Chi Zhang, P.R. Shukla, David G. Victor, Thomas C. Heller, Debashish Biswas, Tirthankar Nag

Working Paper #34

January 2005

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Program on Energy and Sustainable Development
At the Center for Environmental Science and Policy
Encina Hall East, Room 415
Stanford University
Stanford, CA 94305-6055

http://pesd.stanford.edu

About the Authors

Chi Zhang is a Research Fellow at the Program on Energy and Sustainable Development and the Center for International Security and Cooperation, both at Stanford University in California. Dr. Zhang holds a Ph.D. in economics from Johns Hopkins University.

P.R. Shukla is a professor in the Public Systems Group at the Indian Institute of Management, Ahmedabad, India. He obtained Ph.D. from Stanford in 1979. Prof. Shukla has coauthored 11 books and numerous publications in international journals in the areas of energy and environment modeling and policy.

David G. Victor is the Director of the Program on Energy and Sustainable Development at Stanford University. His research interests include energy and climate change policy and the role of technological innovation in economic growth. Dr. Victor holds a Bachelor's degree from Harvard University and a Ph.D. in political science from MIT.

Thomas C. Heller is the Lewis Talbot and Nadine Hearn Shelton Professor of International Legal Studies at Stanford Law School in California. Prof. Heller holds a Bachelor's degree from Princeton University and a LLB from Yale Law School.

Debashish Biswas is in the doctoral program in Public Systems Group at He holds a bachelor's degree in Architecture and a master's degree in Town and Regional Planning.

Tirthankar Nag is in the doctoral program in the Public Systems Group at the Indian Institute of Management, Ahmedabad, India. He holds a bachelor's degree in electrical engineering and he has worked in the Indian electricity sector for a number of years.

Abstract

The study examines the dynamics of carbon emissions baselines of electricity generation in Indian states and Chinese provinces in the backdrop of ongoing electricity sector reforms in these countries. Two Indian states-Gujarat and Andhra Pradesh, and three Chinese provinces-Guangdong, Liaoning and Hubei have been chosen for detailed analysis to bring out regional variations that are not captured in aggregate country studies. The study finds that fuel mix is the main driver behind the trends exhibited by the carbon baselines in these five cases. The cases confirm that opportunities exist in the Indian and Chinese electricity sectors to lower carbon intensity mainly in the substitution of other fuels for coal and, to a lesser extent, adoption of more efficient and advanced coal-fired generation technology. Overall, the findings suggest that the electricity sectors in India and China are becoming friendlier to the global environment. Disaggregated analysis, detailed and careful industry analysis is essential to establishing a power sector carbon emissions baseline as a reference for CDM crediting. However, considering all the difficulties associated with the baseline issue, our case studies demonstrate that there is merit in examining alternate approaches that rely on more aggregated baselines.

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1. Introduction

India and China are the two largest developing countries, and both are growing rapidly. In 2003 national income grew at 6.8 percent[1] annually in India and 9 percent in China with similar growth rates expected in the foreseeable future (RBI, 2002; SDPC, 2001) Electricity is essential to such rapid economic growth. According to government plans, generation capacity is expected to increase by 100 GW in India between 2002 and 2012 (Ministry of Power, 2001) and 200 GW in China between 2002 and 2010 (DRC, 2003). Sustaining these plans will require attracting enormous quantities of capital, either from governments or private investors. At the same time, these power sectors are under scrutiny for their heavy environmental footprint—locally and globally. Rising carbon emissions from the two heavily coal-based power systems in India and China is of particular concern. Both countries understandably have been wary of accepting mandatory limits on their emissions; yet these two nations are essential to the effectiveness of any coordinated international effort to control global warming. The challenge is to identify practical, voluntary systems through which these nations would attain meaningful limits on their carbon output while simultaneously expanding electric services needed for economic growth.

One hotly debated voluntary policy tool is the Clean Development Mechanism (CDM) under Article 12 of the Kyoto Protocol. CDM is designed to entice developing countries to participate in global carbon emissions abatement by allowing them to sell their certified emission reductions (CERs) to industrialized countries that are abiding by the strict caps on emissions set forth in the Kyoto Protocol. Numerous studies have indicated the practical challenges in identifying robust methods for implementing CDM (Chomitz, 1999; IEA, 2000). At issue is the problem that quantifying the CERs requires establishing the baseline level emissions that would have occurred in these countries in the absence of CDM activities (Article 12.5c). However, this counterfactual exercise is extremely difficult to perform since it requires knowing the unobservable future dynamics of a complex system.

Two different approaches have been proposed to deal with the problem. Project level baselines would apply market investment criteria to CDM candidate projects. Any project that is deemed profitable will not be considered "additional" to activities that investors would pursue on their own (Chomitz, 1999; Meyers 1999). Project level baselines are often criticized for various inaccuracies and subjectivities. Partly in an effort to overcome such critiques, the calculation of robust project baselines requires accounting for a multitude of

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[1] This figure denotes GDP at factor cost at current prices. This is an advance estimate provided by the Reserve Bank of India.

financial, institutional, and political barriers to the development of projects (Renz, 1998; Baumert, 1999; Heller, 1998; Michaelowa and Fages, 1999; Sugiyama and Michaelowa, 2000; Shrestha and Timilsina, 2002). Indeed, the actual evolution of the rules under the CDM appears to embody these expected flaws and the system has attracted much criticism precisely because it is complicated, politicized, and administratively inefficient (Heller and Shukla, 2003).

An alternative approach would aim not to set baselines for individual projects but rather at the multi-project level or across whole sectors (Lazarus et al., 2000; Shrestha and Timilsina, 2002). Many analysts have argued that this sectoral baseline approach strikes a balance between accuracy and administrative cost and is particularly appropriate for the electric power sector where the final product from a particular grid-connected power plant co-mingles with all others in a defined market. Even so, methodological barriers still arise against setting an appropriate sectoral benchmark in determining the level of aggregation as well as in most of the obstacles that also have confounded project level accounting (Lazarus et al., 2000; Leining et al., 2000). The most challenging aspect of setting multiproject emissions rates is determining the vintage and types of plants to include in the baseline and the stringency of the emissions rates to be considered, in order to balance the desire to encourage no or low-carbon projects while maintaining environmental integrity (Sathaye et. al. 2004). Other studies consider the operation of existing power plants (the operating margin) or the construction of new generation facilities (the build margin), as important and recommend a combined margin approach for most projects, based on grid-specific data (Kartha et. al. 2004). Despite abundant methodological debates, until recently there have been very few independent, detailed empirical studies of baselines in the real settings where CDM projects may occur.[2]

In this study, we examine the issues surrounding identification of baselines in the Indian and Chinese power sectors, and we compare the driving forces that affect the baseline trajectories over time in several key states and provinces in both nations. We focus on power generation because it is a major source of CO_2 emissions, accounting for more than 40 percent of the national total emissions in India and one quarter in China (Kapshe et al. 2003; Zhu, et al. 1999). Although previous studies have been attracted to the electricity sector in part because their homogenous output would appear to allow for relatively straightforward sectoral benchmarking, we will show that utility industry reforms in India and China are bringing about substantial changes in power generation with complex and diverging effects that severely impede efforts to identify future baselines.

Zhang et al. (2001) documented the driving forces and trends over time of the carbon intensity of power generation in the Chinese province of Guangdong; later they extended the study which to a total of three Chinese provinces- Guangdong, Liaoning and Hubei (Zhang et al 2003). A similar study, employing identical methodologies, was conducted by Shukla et al. (2004a & 2004b) for the Indian states of Gujarat and Andhra Pradesh. In both these programs, the focus on the state or provincial level reflected the need to address highly variable

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[2] The few investigations that actually look into specific cases often focus on technical benchmarking of baselines and lack detailed and broad considerations of baseline drivers. See, for example, IEA (2000) and literature therein.

dynamics in regional power markets. In neither of these large and administratively segmented nations is it meaningful to examine only national aggregated baselines. The present paper reports a comparison between the Indian states and Chinese provinces with a focus on forces that influence these power supply systems and implications for the CDM and alternative carbon control policies.

Section 2 of this paper provides a brief overview of the economies and background of power sectors of these states and provinces. In Section 3, we introduce our methodology, quantify carbon emission baselines, and analyze their driving forces. In section 4, we compare the Indian and the Chinese baselines. Section 5 concludes the paper with a discussion of policy implications.

We find that, although differences exist in both countries, the generation of electricity is generally marked by declining carbon intensity over time. These improvements tend to be strong during early stages of expansion due to the application of more efficient modern equipment and operational practices, and they moderate as the expansion continues. We estimate that the levels of carbon intensities of India and China are likely to remain far short of best international practices, and we confirm that opportunities exist in India and China's electricity sectors for abating carbon emissions. We show that local factors such as the availability and price of low-carbon fuels and rules about dispatch of power plants have a substantial influence on the level and rate of change in carbon intensity. Based on historical trends, we note that it would be difficult to predict the influence of these factors accurately *a priori*, and thus we call into question the keystone of the CDM concept: the ability to make accurate counterfactual baseline assessments, even at the sectoral level. This finding, a disappointment for adherents to the logic of CDM, suggests the need to explore alternative voluntary instruments for engaging investors and the hosts in developing countries.

2. Electricity and Fuel Markets

2.1 The National Electricity Industries

Electricity has seen steady growth since the Independence of India (1947) and the beginning of the current regime in China (1949). The growth has been particularly strong in recent years as both the economies are expanding rapidly and both are pursuing ambitious electricity growth targets through 2010 (Figure 1).

In India, the installed capacity has risen from 16 GW in 1970 to 117 GW in 2001 (CMIE, 2003a). The country's five regional transmission grids are in the process of being integrated to a single national grid; from March 2003, the western and the eastern grids have been synchronized into one west-east transmission system so that power generated in one region can be moved easily to others. Despite such accomplishments, the government of India still faces the huge challenge of increasing power supply to meet the projected 8 – 9 percent economic growth for the next decade while also delivering the government's commitment to provide "Electricity to All" by 2012. In 2000, only 47% of the Indian households were connected to grid (IEA, 2002). Per capita electricity consumption remains low (around 340 KWh); the per capita installed capacity is 0.12 KW, about one quarter of the world average

(Planning Commission, 2002).

Figure 1: Electricity Generation Capacity in China and India
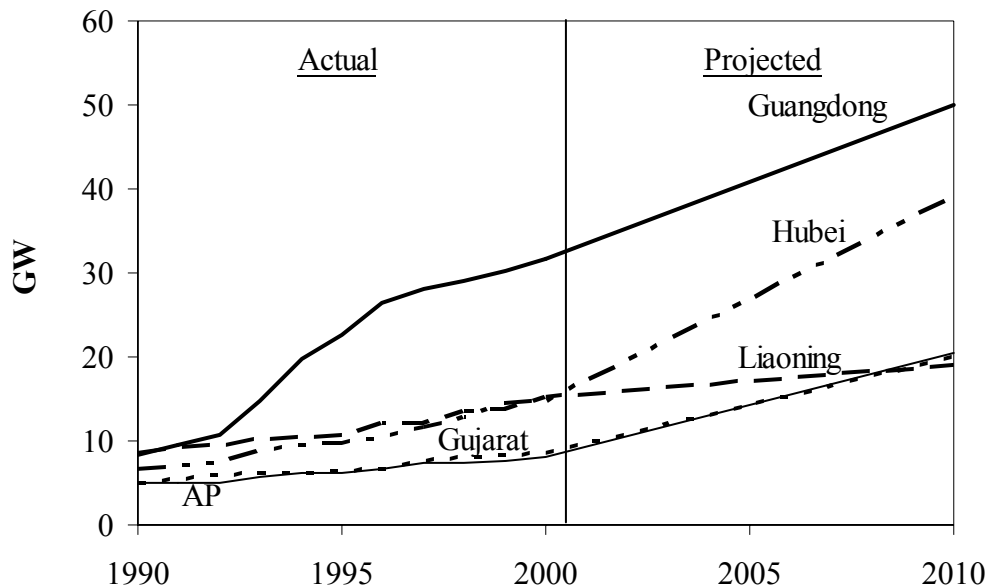
Note: 1) Projections by the 16th Electric Power Survey has been used for India. 2) The projection for 2003 to 2005 for China is based on 7 percent growth rate to reach the government 10th Five-year plan target that was revised upward in March 2003. Five percent growth rate is assumed for the second half of the decade. *Source*: CMIE(2003a), Electric Power Survey of India, various years, China Statistical Yearbook, various years

In China, the electricity industry has grown with the country's industrialization policy. Figure 1 shows installed capacity rose from 2 GW in 1953 to 353 GW in 2002. The growth has been particularly strong since reforms in the middle 1980s allowed entities other than the central government to build power systems. The growth, led by provincial governments and small local and private plants, nearly eliminated the nationwide chronic power shortage by the late 1990s and made the electric power system into the second largest in the world.[3] A similar growth trend is projected for the next two decades. However, as in many other fast-growing electricity systems, investment in China's power delivery network has continually lagged behind the concurrent development of generation capacity. To this date, China's grids remain relative fragmented and incapable of moving large amount of electricity between regions and provinces. A tremendous effort by the central government is underway to integrate the existing five regional grids and a dozen standalone provincial grids.

India started a broad-based reform of its economy in 1991—in the wake of financial crisis—with the goal of decentralizing investment and promoting competition by reducing

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[3] The turn of the power market from chronic shortage to surplus in the late 1990s was also due to 1997 Asian financial crisis and tight domestic economic policy to control inflation, both of which slowed demand for power.

regulation and opening the economy to external trade (Tongia, 2003). The power sector was part of these reforms, starting with a 1991 policy to attract private investment into independent power producers (IPPs) (Rao, 2002).   In the context of these reforms, many states (initially Orissa but later others such as Karnataka, Gujarat, Rajasthan and others) started unbundling the monolithic State Electricity Boards (SEBs) into generation, transmission and distribution companies (Planning Commission, 2002). The state and the central government also created independent regulatory commissions. In July 2003, the central government further pushed restructuring with adoption of the Electricity Act (2003) to promote further opening of the power sector to private investment and competition, but its exact effects remain unknown at present (Rao, 2004).

In India, the responsibility for the sector is shared between the federal and state governments (Planning Commission, 2002). The central government has invested in generation and transmission through centrally owned enterprises such as National Thermal Power Corporation (NTPC). The main organizations for state participation are the SEBs, which were constituted as state corporations. This mode of industrial organization existed in all states. For example, with the formation of the state of Andhra Pradesh in 1953, the state government created the Andhra Pradesh State Electricity Board (APSEB) in April 1959 as a vertically integrated entity in charge of generation, transmission, and distribution of electricity. In the period from 1960 to 1982, APSEB was the sole generator of electricity. From 1983, the central government's plants (owned by NTPC) also contributed a growing share of generation in the state. In Gujarat, the Gujarat Electricity Board (GEB) was created, along the same model, after the state was formed in 1960. However, existing private licensees were permitted to continue their operations.[4] Thus, from 1960 to 1990, GEB and the private licensee Ahmedabad Electricity Company (AEC) were the main generators. In 1990, nearly 90 percent of the installed capacity in the state was owned by GEB and the rest by AEC.

The reforms of 1991 significantly increased private ownership and changed this traditional structure of the electricity industry. By 2002, out of 124.1 GW installed capacity, 24.3% was owned by private operators such as IPPs as well as "captive" power generators that are owned and operated by large power users. The share owned by the states decreased to around 50%, while the share of the central government increased to 25.5% (CMIE, 2003a). Most of the restructuring so far has occurred in electricity generation because the initial round of reforms had a strong supply side orientation.[5] Across India transmission and distribution remain mostly under state control and are being reformed slowly.

China began to reform the electricity industry as an integral part of the country's economy-wide market reforms starting in 1979. In the middle 1980s the central government began to encourage provincial and local governments and some private companies to invest

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[4] Licensees are private players who has been issued a license for a specified geographical area for carrying out generation, transmission or distribution of electricity. These licenses are long term in nature and are usually renewed automatically.

[5] Many have questioned this orientation of the reforms and noted that they have not yielded the expected results because the failure to reform distribution has meant that power suppliers are still selling mainly to bankrupt distributors that lack financial credibility (Godbole, 2002).

in power generation to supplement the centrally managed power system, which was cash strained and unable to meet the country's surging demand for electricity.[6] Economic incentives were also gradually introduced to encourage better performance by state owned enterprises. The industry was reorganized in the late 1990s to separate business operations from government administration. More recently, the central government has separated generation and transmission services and created limited wholesale markets to introduce competition.[7]

2.2 Development of the Industries with the States and Provinces

The states of Andhra Pradesh and Gujarat and the provinces of Guangdong, Liaoning and Hubei represent diverse experiences of economic and power sector development.

Table 1: Economic Indicators (1998[a])

	India			China			
	All India	**Andhra Pradesh**	**Gujarat**	**All China**	**Guangdong**	**Liaoning**	**Hubei**
Socio-Economic Indicators							
Population (million)	982	74.3	48.6	1248	71	41	59
Area (1000 sq. km)	3287	275	196	9600	178	148	186
GDP ($ Billion)	414	25.5	23.4	944	95	47	45
GDP Growth Rate[b] (%)	6.0	4.6	7.2	9.5	14.4	9.0	10.5
Per capita Income ($)	420	344	495	760	1340	1134	758
Electricity Indicators							
Installed Capacity (GW)	101.6	7.98	8.58[c]	277	29	14	13
Generation (TWh)	501.2	45.7	47.9	1157	104	60	50
Per Capita Consumption[d]	355	391	835	929	1388	1653	769

Notes: (*a)* 1998 was chosen as the base year for comparison because it was the year for which the latest data was available when the first case study in Guangdong began in 2000. 1998 denotes the fiscal year (April 1998 to March 1999) for India and calendar year (January 1998 to December 1998) for China. (*b*) Average annual GDP growth rate between 1980 and 1998.   (*c*) This figure excludes captive power. (*d*) 1999 figures. *Source*: (1) MoF, 2000. Economic Survey 1999-2000. (2) Center for Monitoring Indian Economy (2002, 2003a, 2003b, 2003c). (3) China Statistical Yearbook, various years; (4) Zeng, et al., 1999; (5) Wang, et al., 2001; (6) Cheng, et al., 2002.

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[6] Provincial and local governments are now allowed to build their own power plants of less than 50MW capacity without the central government approval.
[7] See   World Bank (1994), Shao, et al. (1997), Zhu, et al. (1999), Zhou, et al. (2000), Xu (2002) and Zhang and Heller (2003) for discussions of recent development of the Chinese electricity industry.

Increases in capacity and power generation between 1990 and 2000 are shown in Figures 2 and 3. In Andhra Pradesh and Gujarat, capacity has increased over sixty percent and generation over hundred percent as income grew rapidly in both states (Table 1). Despite the system expansion, increases in power demand in both states have outpaced development of power supply. The estimated electricity deficit – that is, the latent demand at posted prices – in Andhra Pradesh and Gujarat is 8 percent and 10 percent respectively (TEDDY, 2003).

In the three Chinese provinces, installed capacity and power production also rose remarkably during the 1990s, with the most pronounced growth in Guangdong where the economy also grew most rapidly. Guangdong's installed generating capacity rose from 8 GW in 1990 to over 30 GW in 1999, and total generation increased from less than 40 TWh to above 110 TWh. Growth of the industries was more moderate in Liaoning and Hubei during the same period (Table 1 and Figure 2).

Figure 2. Growth of Electricity Generation in Indian States and Chinese Provinces[8]
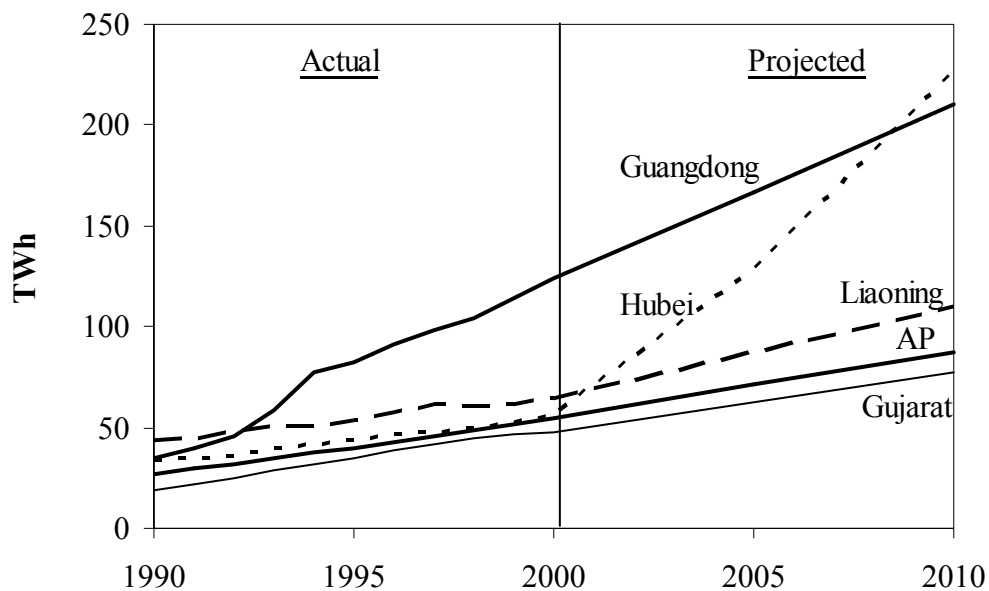
Source: CMIE (2003b, 2003c), Zeng et al., (1999, 2004), Wang et al., (2001), Cheng et al., (2002).

All three provinces have been engaged in inter-provincial electric power trade with their respective neighbors. The trade in general reflects the mandates of central planning rather than market conditions. For example, Liaoning was long ago the industrial and load center in

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[8] The data in Figures 2 and 3 refer to installed capacity and power generation geographically associated with the States or Provinces. For example, both installed capacity and generation numbers for Hubei include the Three Gorges Hydropower Station which is owned by the central government but located in Hubei. This differs from data in Figures 3 and 4 in which only the capacity and generation that actually serve the States/Province are included (see footnote 9).

the northeast. Other provinces in the region (e.g. Jilin and Helongjiang) were developed as its energy sources. Thus, Liaoning imports a large amount of electricity, even when its own generating plants were largely idle in the late 1990s. Similarly, Guangdong started to export electricity from Daya Bay nuclear power plant to Hong Kong in 1994 and at the same time it fulfilled Beijing's mandate to import outside hydropower. Hubei, rich in hydropower, exchanges power with neighboring provinces seasonally.

In all of these states/provinces, expansions in the power system have been achieved partly through sector reforms. Private participation in power generation in India and decentralization of power sector investment in China, both encouraged by their respective reforms, have also brought significant changes in the fuel mix and thermal technology of power generation – a topic we examine now in more detail since fuel and technologies largely determine carbon baselines.

2.3 Fuel Markets
2.3.1 Fuel Markets in India
The primary fuel that dominates the Indian electricity industry is coal. In recent years there has been a rising utilization of gas across the country. In 2001 about 61 percent of the national generation capacity was coal-fired and 11 percent used gas or liquid fuel, and hydro accounted for most of the rest (CMIE, 2003a). By 2012, the share of coal is expected to decrease to 52 percent and the share of gas increase to 11 percent (Tenth and Eleventh Five-Year Plan projections) because electricity reforms are causing a rise in the share of natural gas as fuel of power generation.

Broader economic reforms have forced deep changes in coal and natural gas markets. Coal mining was traditionally reserved for the public sector under the Coal Mines (Nationalization) Act, 1973. The Central Government was also empowered under Section 4 of the 1945 Colliery Control Order to administer the price of individual grades of coal. A 1993 amendment allowed private sector participation in coal mining including coal washing for power generation, and since 1999 coal pricing has been fully deregulated. However, a government owned company, Coal India Limited (CIL) and its subsidiaries produce 87 percent of coal and exert considerable monopoly power. The central government's "Standing Linkage Committee" apportions output of the coal mines to major consumers including power plants. Though state control has eroded to a certain extent, the historical planning oriented association between the buyers and sellers of coal remains. Present trade import policy allows for coal to be imported freely under open general license by consumers, which has contributed to a gradual shift to market decisions in allocating supply and pricing of coal.

One of the major issues for coal's role in power generation has been the quality of coal. In India, non-coking coal is classified from grades A to G, A being a superior grade of coal having high colorific value and low ash content. The quality of thermal coal has declined over the years and power plants today mostly receive grades E, F and G containing high levels of ash (Mathur et. al., 2003). The same trend has been observed in Andhra Pradesh between 1980 and 2000. In addition, as set forth in the Sale of Goods Act (1930) a coal company's responsibility ends after loading the wagons and handing it over to the Railways,

which exposes buyers to extraordinary transportation uncertainties and costs since the railways remain state controlled and highly inefficient and unreliable.

Regarding natural gas, the central government still largely controls prices which are linked to a basket of fuel oil prices, because price controls cause scarcity, government also allocates gas quotas. The inter-ministerial Gas Linkage Committee (GLC) allocates gas to the states. The public sector companies, Oil & Natural Gas Corporation Ltd (ONGCL) and Oil India Ltd (OIL) are the main producers of gas. Gas Authority of India Ltd. (GAIL), another public sector company, is the country's chief gas transmission & marketing company. With the growth in demand for natural gas and the prospect for liberalization, private firms are now investing heavily in the gas sector. One example is that of Gujarat Gas Company Ltd. (GGCL), a 65% subsidiary of British Gas, which is engaged in gas transportation and distribution in Gujarat. India's leading private energy company, Reliance Industries, is investing in exploration, production, and distribution of gas in Andhra Pradesh. The central government is slated to introduce gas pipeline policies that would establish a regulatory mechanism. In the present monopolistic system, most pipeline gas contracts are of the "take or pay" type that are quite favorable to suppliers as there are typically no penalties when suppliers default and there is widespread tolerance of considerable variation in gas pressures. In addition, India began importing liquefied natural gas (LNG) in 2003, and recent LNG contracts for the Indian market are set without indexing prices of oil – suggesting the first stage of gas-on-gas competition in India.

2.3.2 Fuel markets in China
The Chinese electricity industry is primarily based on coal and hydropower. The country's total installed capacity was 70 percent coal-fired and 25 percent hydropower in 2000. The rest constituted nuclear (0.7 percent), oil (about 4 percent) and renewables (National Statistical Bureau, 2001). Government energy planning and investment have recently begun to shift toward a more diversified fuel mix for electricity development out of mounting concern about the environmental consequences of coal combustion, and thus the role of hydro, nuclear and natural gas in power generation is expected to rise in the future. According to the Development Research Center (DRC, 2003), by 2020 the share of coal will fall to 59 percent and the shares of hydro, nuclear and natural gas will increase to account for 28 percent, 5 percent and 5 percent respectively if the strategy continues.

Traditionally the coal industry was exclusively under the control of the central government, which set quotas for production and allocated supply. Long-term designated supply relationships, including set price and transportation arrangements, were established between state coal mines and power plants. Against the backdrop of broad economic reforms since 1979, many small operators have entered coal sector and steadily increased their production. The state has reformed its own coal operations as well and state control over coal prices gradually relaxed. Coal markets have slowly emerged. However, coal supply for power plants has not been much affected. High grade coal for power generation is primarily produced in the state mines; traditional government supply arrangements, together with the controlled price, continue to govern coal supply to power plants although limited price adjustments have been allowed since 2002. The below market level price of coal for power plants is causing increasing resistance among government coal companies, threatening the

stable supply to power plants.

The central government has initiated large hydro and nuclear power projects since the 1990s including the Three Gorges Hydro Station, Southwestern hydropower developments to supply the East Coast and the commissioning of China's first nuclear power plants. More recently, the government has begun the construction of the 4200 km West-East natural gas pipeline between Xinjiang and Shanghai; and it has also orchestrated investment in LNG facilities in the South. These gas supplies are intended mainly to serve new gas-fired power plants. More gas transmission infrastructures are planned for the 11th Five-year plan (2006 – 2010) and beyond. Projects in these energy areas so far remain central government monopoly and do not reflect open market conditions.

3. Fuel Structure, Technology and Dispatch: Impact on Efficiency and Carbon baselines
3.1 Methods
Carbon emissions from power generation are determined by fuel mix, thermal efficiency and the total volume of power supply. The standard measure of a historical baseline of carbon emissions is carbon intensity: CO_2 emitted per KWh electricity generated. In turn, the historical baselines can serve as one basis for making future projections. To measure historical baselines we surveyed individual generating units to elicit information on fuel mix and thermal efficiency (heat rate) as well as a broad range of related factors that are likely to affect baselines over time. For comparability, we particularly focus on data of 1990 and 1999 and projections for 2010 for this cross-country comparison, although finer resolution data are available for most jurisdictions. We complement the detailed data from generating units with interviews with government policy makers and industry experts to identify factors that are influencing development of the industry.

The survey was first administered in the three Chinese provinces (Zhang et. al., 2005). Plant and unit level data on power generation, fuel, and thermal efficiency covering about 70 to 90 percent of the industry were collected through our local collaborators as the law in China forbids foreign institutions to conduct surveys directly. For bureaucratic reasons, data were not always available for very small power plants built by small operators or local governments for local uses. The same survey was later administered in the two Indian states (Shukla et. al. 2004a; 2004b). A summary of the survey data points are included below.

Table 2: Survey Sample Statistics

	Andhra Pradesh	**Gujarat**	**Guangdong***	**Liaoning***	**Hubei***
No. of units	39	67	65	56	34
Percent of total capacity	100	100	85	71	87
No. of Interviews**	19	42	5	5	3

Note: * Unit and capacity numbers in China refer to coal-fired generation only. The Guangdong sample also includes 9.6 GW oil-fired capacity with an average size of 10.6 MW. ** The numbers in the Chinese studies refer to interviews conducted by Stanford researchers and do not include those conducted by local collaborators.

3.2 Fuel Structure

3.2.1 Fuel Structure in India

The selection of fuels in India is a result of the concurrent nature of governance in the electricity sector, which gave rise to generators that are owned by the central government and by state governments; only after 1991 privately owned plants increased. The closed nature of the Indian economy before the reforms of the early 1990s emphasized indigenous fuels – mostly coal and hydro for supplying power – and indigenous technology such as small and inefficient thermal generators.

Andhra Pradesh started with the development of hydropower with the state's formation in 1953 and complemented hydro with easily available coal. By 1990, the majority of the capacity owned by the state was hydro but thereafter total hydropower generation declined substantially (Figure 4). By 2001 hydro accounted for only 12 percent of total state generation. The decline stemmed from low inflows in hydro reservoirs as water was instead diverted for agriculture; moreover, power ratings on old dams were decreased. During the same period coal-fired generation grew rapidly, which was achieved mainly through the expansion of existing coal plants and supplied by the state's easy access to coal from the central and southeastern parts of the country. Gas and naphtha have entered as new fuels that are favored by private investors who have been able to build power plants since the passing of the 1991 policy favoring IPPs. In this study, gas and naphtha have been analyzed together as many of the plants are capable of using both fuels. In 1990, only small state owned plants were fueled by gas. During the 1990s, all privately built plants in AP were fueled with gas. Gas based plants accounted for 13 percent of the state's total capacity in 2001 as compared to 1.3 percent in 1990. Andhra Pradesh is one of the few states in India that produces natural gas. The state has also subsidized the development of wind power, but capacities remain low (89 MW in 2001, accounting for negligible percentage of total power generation). Projections of capacity additions through 2010 (the close of the tenth plan in the Indian planning system), suggest that the state will have a capacity mix consisting of 50 percent coal, 20 percent gas, 30 percent hydro and a small amount of wind power.

Gujarat on the other hand was endowed with neither local coal nor hydro. Local lignite mining was only in the rudimentary stages of development in 1960 when the state was formed. Hence, the first plants built in Gujarat were based on oil (Low Sulfur Heavy Stock-LSHS). When Gujarat was able to assure an allocation of coal from the central government and the construction of rail transport networks, then the state shifted to greater reliance on coal transported from the central and eastern parts of the country; although the coal Gujarat obtained consisted of 40 percent ash and was costly to transport. Strict controls on importing fuels from other countries left states such as Gujarat with no other option than domestic coal, oil-fired plants proved especially costly to operate after the world rise of oil prices in the 1970s. In 1990, three fourths of the generation capacity in Gujarat burned coal. As the local lignite production industry got organized, plants arose to use that fuel. Between 1990 to 2001, lignite production more than doubled and lignite-fired electricity rose from 110 to 2434 GWh. As with Andhra Pradesh since 1991, gas has risen sharply almost entirely due to privately built power plants. Gas rose from 3.5 percent of the total capacity in 1990 to 34

percent in 2002. As with Andhra Pradesh, natural gas is produced in Gujarat. During this period, nuclear capacity of 440 MW has been added to the state due to construction of one plant by the central government. Although the growth of gas has reduced the share of coal in the fuel mix, coal remains the dominant fuel. For 2010, state planner in Gujarat envisage a capacity mix consisting of 30 percent domestic coal, 20 percent imported coal, 28 percent gas, 4 percent hydro, 7 percent lignite and the rest consisting of wind and nuclear (GIDB, 1999). The main difference between Andhra Pradesh and Gujarat is the large hydro capacity in the former and faster growth of gas-fired capacity in the latter.

3.2.2 Fuel Structure in China
As in India, the backbone of the power system in these three Provinces of China – Guangdong, Liaoning, Hubei – was formed with the fuel that was initially easier to obtain. Then, since the late 1980s, the combination of a vast power sector expansion, reforms and central government energy infrastructure projects has caused substantial changes in fuel mix.

In both Liaoning and Hubei, power generation is based on a relatively simple fuel structure of thermal (predominantly coal) and hydro sources. The majority of capacity in Liaoning is fired with abundant nearby coal supplies, and the share of coal in power generation has been rising. Plans for future development are based almost exclusively on the construction of coal-fired power plants.

Figure 4. Growth of Electricity Generation and changing generation mix in Indian States and Chinese Provinces
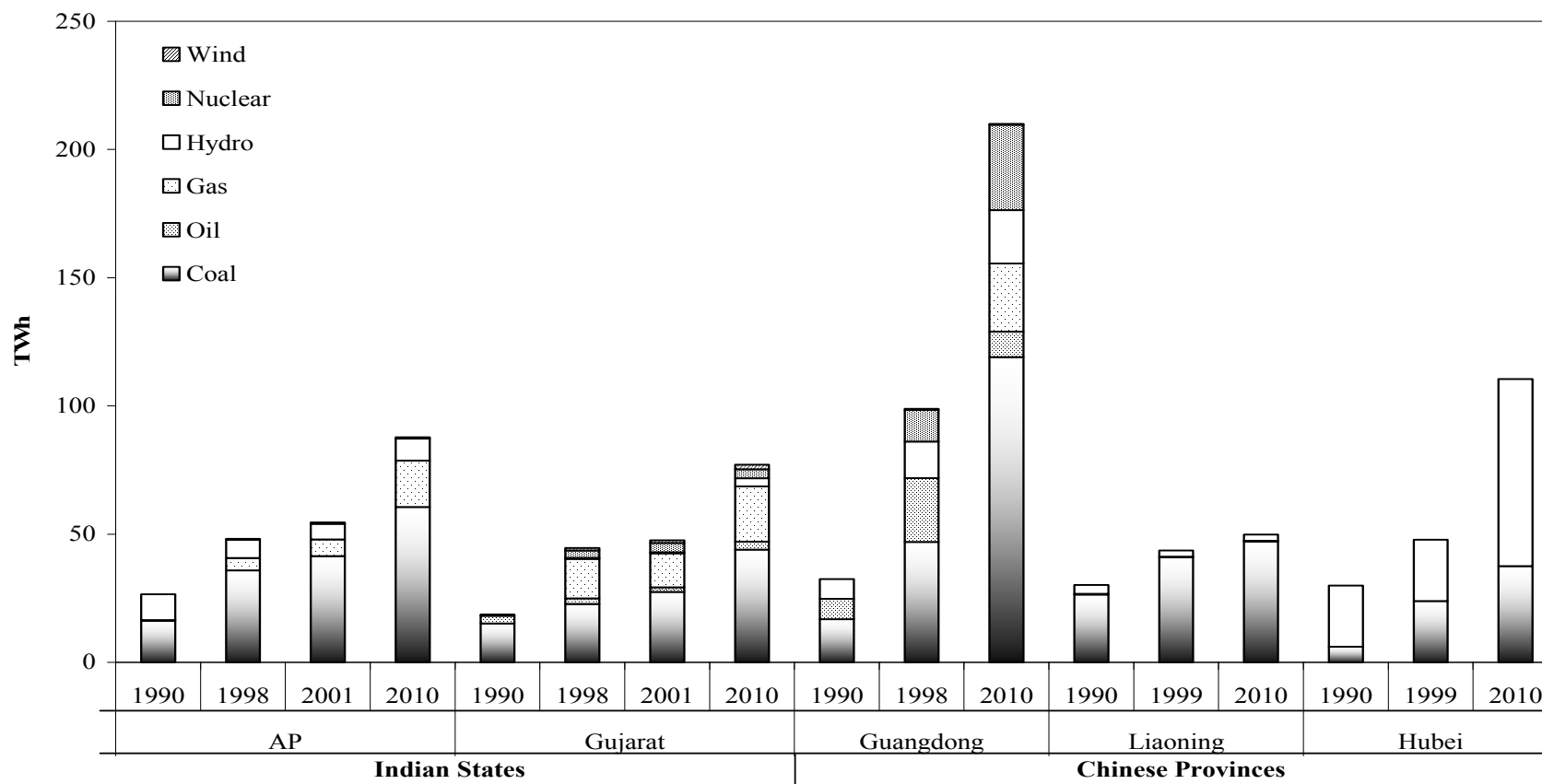
Note: (a) The Indian projections are based on the 16th Electric Power Survey, Gujarat Infrastructure Agenda: Vision 2010 and tenth plan document of GOI. (b) The Chinese numbers for 2010 are projected by provincial power sectors for the 10th Five-year Plan (2001 – 2005) and long-run development strategy of their provinces. (c) Gas-fired generation for India includes dual fuel naphtha-capable generators. *Source*: CEA (2000), GIDB (1999), Planning Commission (2002), Zeng et al. (1999, 2004), Wang et al. (2001), Cheng et al. (2002).

Unlike Liaoning, Hubei is rich in hydro potential, which traditionally formed the main component of the province's power system. However, as demand for power surged in the 1990s, there was a rapid increase in coal-fired capacity because coal plants can be built more rapidly. (Hydro resources are controlled by the central government and it is difficult for the province to plan its own power acquisitions within the protracted decision and planning processes a process that is often further slowed by central government budget constraints. Coal surpassed hydro as the province's dominant source of electricity by 1999. However, as the central government is shifting policy to encourage hydropower development with big projects such as the 18.4 GW Three Gorges dam (located in Hubei) for 2003 and 2009, a significant increase in hydropower is expected in the next few years. The Three Gorges power will be supplied not only locally to Hubei, but also to load centers in East and Southeast China.[9]

The fuel structure of Guangdong's electricity industry is more diversified and dynamic than those of the two other provinces. Guangdong's power generation has long suffered from lack of local fuel resources and thus provisional officials have pursued all options simultaneously. Coal-fired power plants quickly achieved dominance thanks to coal imported from the Northern provinces by rail and barge.[10] Reforms and decentralization of investment in power generation in the past fifteen years have caused a sharp rise in the combustion of oil because oil-fired plants are the quickest to build and easiest to scale to rapidly changing local loads. (Plants with capacity less than 50 MW have been particularly attractive because they do not require advance approval from central government before construction.) The central government also built nuclear power plants in the province.[11] Projected changes for the next ten years include major new hydro imports and accompanying transmission investments, further increases in nuclear power and the expansion of natural gas (from pipelines and imported LNG). Guangdong will develop 2,000 MW gas-fired generating capacity, importing 3.3 million tons of LNG annually from Australia starting from 2005. These increases will eventually replace oil primarily for the same reasons that oil has largely been replaced as a fuel for electricity worldwide: fluctuating prices, dependence on foreign cartelized suppliers and relatively higher value in transportation and other non-generation uses. Even with these diversifications, coal will remain the dominant fuel in Guangdong. By 2010, coal will account for half of the total provincial capacity –   an increase of almost ten percent from 1998.

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[9] Large central government projects in China such as the Three Gorges Hydro Station often serve beyond the provinces in which they are located. To estimate the provincial carbon emissions baseline, we treat such projects as provincial in proportion to the power actually supplied to the province. For example, in 2003, only about 15 percent of the Three Gorges hydropower was assigned   to Hubei by the central government.

[10] Coal imports from overseas remained small due to the restrictive policy of the central government among other reasons. For example, foreign coal import was 500 thousand tons, or less than one percent of total provincial coal imports in 2002.

[11] Daya Bay nuclear power plant (2X900MW), the second in the nation, was commissioned in 1994. Ling Au nuclear power plant (3X900MW) was commissioned in 2002 and 2003.

3.3 Generation Efficiency

Energy efficiency of a thermal power unit (plant) is expressed as the heat rate, measured as grams of standard coal equivalent (gsce) consumed per KWh electricity generated. The total system efficiency of generation depends on the heat rates of individual plants and the number of hours each is dispatched. Our surveys collected such data from plant operators.

Each generating unit has an actual heat rate realized during real generation. This heat rate is dictated by technical factors such as size, combustion technology and vintage, as well as operational factors. Actual heat rates are often higher (i.e., less efficient) than the design heat rate due to factors such as management practices, maintenance and fuel quality. Studies carried out in selected plants of Gujarat Electricity Board have found significant deviations of the actual heat rate from the designed one (Alagh, Shah and Shah, 1998).

3.3.1 Generation Efficiency in India

The energy efficiency of thermal units in AP and Gujarat varies. In AP the range is 260 gsce to 570 gsce per KWh; in Gujarat it is 270 gsce to 650 gsce per KWh. Both states have seen a shift of the distribution of heat rates toward higher thermal efficiency between 1990 and 2001 as newer plants have lower heat rates than the older ones. Figure 5 shows the allocation of thermal plants among heat rate classes over time. For example, in Andhra Pradesh, by 2001, plants having thermal efficiency in the range 250-349 gsce /KWh produced 15 percent of thermal generation compared to just 2 percent in 1990. Similarly in Gujarat, by 2001, plants having thermal efficiency in the range 250-349 gsce /KWh produced 46 percent of thermal generation compared to none in that range in 1990. The average heat rate in AP has gone down from 382 gsce /KWh to 350 gsce /KWh between 1990 and 2001. Gujarat also has shown similar trends with the average heat rate going down from 385 gsce/KWh to 344 gsce /KWh between 1990 and 2001.

In both states, recent technologies based on gas turbines have sharply cut the average heat rate because these plants operate in the range from 270 to slightly over 300 gsce per KWh. Within this class of plants, there have been few shifts in heat rate over time since essentially all of these plants are of new and homogenous technology. However, in some of the years, the heat rate has risen due to low capacity utilization of these plants caused by scarcity of natural gas supplies. Generators have deployed dual fired plants (naphtha and natural gas) to overcome this problem, but in recent years even dual plants have not been dispatched due to the steep rise in naphtha prices.

Figure 5. Efficiency of Coal, Oil and Gas Fired Generation in Indian States and Chinese Provinces
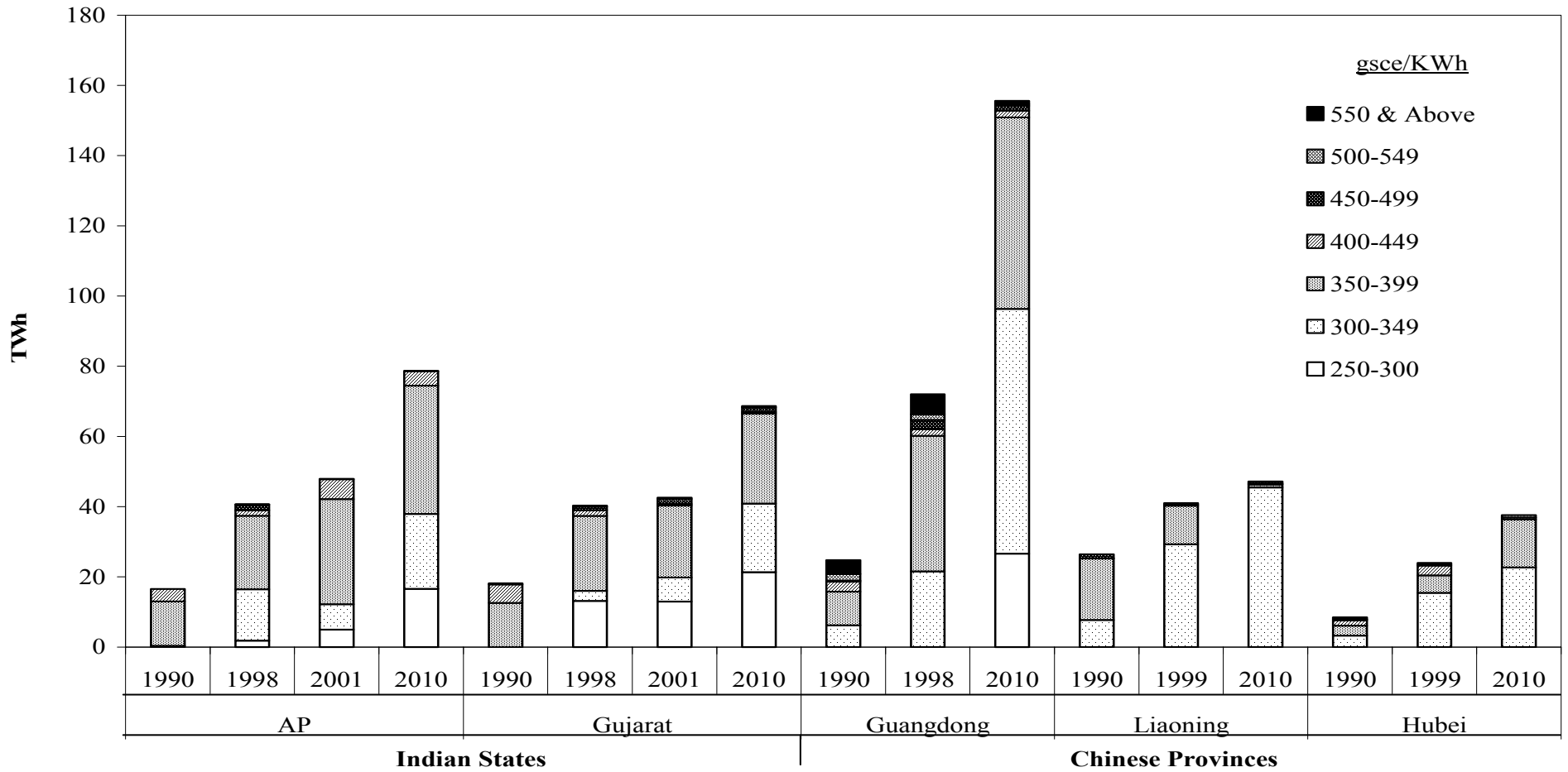
Note: 1) See Figure 4 for sources of Indian and Chinese projections. 2) 1 gram standard coal equivalent (1 gsce) is assumed to have heat value equivalent to 7000 calories (29.3 kJ) for the purpose of conversion. Indian coal has around 40 percent ash and its actual calorific value is usually below 4000 calories/gram.

In the two Indian states, ownership of plants is associated with significant differences in heat rates. The plants built by the central government – coal in AP and gas in Gujarat – are the most efficient in their respective fuel class. In Gujarat, the only one of theses two states with private ownership of coal plants, the private plants were less efficient than those built by the state because the private units were typically smaller and burned less efficient lignite (Shukla et. al., 2004c). In AP, the gas plants built by cooperatives and private investors have approximately the same efficiency as those built by the center. Indeed, in both states, ownership and unit size for gas plants has little impact on efficiency (Shukla et. al., 2004c). What matters most is the selection of gas as fuel in the first place.

Regarding size of units the results are as expected. Coal units with capacity less than 100 MW are particularly inefficient. Technology and vintage of the plants has been observed to be another important factor influencing the actual heat rates. Older coal plants have considerably higher design heat rates due to lower steam temperatures and pressures and actual heat rates have gone up due to poor maintenance. Neither state has adopted clear policies or practices on retirement of old plants. In both, there are examples of plants that operate far beyond their originally expected life. Apart from the technical constraints, political incentives have led each state to favor keeping generating plants within their own jurisdiction, which allows the state to assure its own supply of electricity. The same effect has also been witnessed for the Chinese provinces (Zhang et. al., 2003). Finally, the application of significant environment standards in electricity generation only started in the early nineties and even these new norms are not strictly enforced.

3.3.2 Generation Efficiency in China

Figure 5 shows the heat rates for thermal (mostly coal) power plants in the three Chinese provinces. The data for Guangdong are based on electricity supplied (generation less plant internal consumption), while data for Liaoning and Hubei are based on electricity generated. In all three provinces, the heat rate for coal plants spanned a wider spectrum in 1990 than in the two Indian states. Both highly efficient (below 350 gsce/KWh) and highly inefficient (above 450 gsce/KWh) thermal plants were generating power. It was clearest in Guangdong, where each of these groups supplied about one third of provincial power consumption, and least obvious in Liaoning. It should be noted that the sample data do not include very small thermal units that account between 10 to 20 percent thermal capacity. Their inclusion will likely raise the inefficient end of the distribution in the figure. Cross sectional comparisons thus must be made with caution.

The two factors driving the change in heat rates between 1990 and 1999 are the increasing size of new generation units and explicit government policies to curtail generation in old inefficient plants when power is not in short supply. The central government promoted construction of large-scale units when they became available in the 1980s in the context of the country, allowing imports of western technology as well as active efforts to improve domestic equipment manufacturing capability. The government adopted the technological standard of 300 MW unit capacity and restricted construction of smaller power plants. Through building of these new larger plants a power shortage was gradually alleviated during in the 1990s.   As the power supply turned into surplus in 1997, the central government also

ordered the shutdown of many small, inefficient thermal power generators that had been built as stopgap measures. Although figure 5 shows that efficient (lower heat rate) technology became relatively more important in the three provinces by the end of 1990s compared to 1990, a noticeable amount of electricity was still generated from low-efficiency power plants, especially in Guangdong where the demand for power has been especially high and where our sample includes the small inefficient generators that are being used to fill the gap between soaring demand and supply.

The government of Guangdong's plan envisions further improvement in the efficiency of new generators and decommissioning of older inefficient plants. According to provincial projections, by 2010 most power generated in Liaoning will have a unit coal consumption of 350 gsce per KWh or lower. Similarly, due to the mandated greater scale and technical quality of new plants and the expected removal of less efficient units, average performance in Hubei and Guangdong is officially estimated to further converge to 300-400 gsce per kWh power generated. However, past experience suggests that realization of these official plans is likely to depend on several other factors. The resumption of robust economic growth since 2002 will blunt efforts by policy makers to shut down small old plants. Since power capacity is already inadequate in much of the country, further inadequate investment and financing from central and provincial governments to meet the urgent demand may lead to frantic rush to build small power plants by local investors to make up shortfalls (see Zhang, et al., 2001 and May, et al. 2002 for details).

3.4 Implications for Carbon baselines

The changes in fuel structure and generator efficiency evident in the 1990s and projected for 2010 have a direct impact on carbon emissions. We calculated carbon emissions[12] in both Indian states as well as the three Chinese provinces by calculating carbon emissions per unit output for each generator and then scaling to the actual power generated.

Changes in Carbon Intensity: India
The collected data allows estimates for average carbon intensity for four years between 1990 to 2001. In addition, we project to 2010 by relying on state projections that extend to 2007 (AP) and 2009 (Gujarat); to extend those projections to 2010 we utilize the state level rate of growth in generation calculated from the projections to 2011 that are reported in the central government's sixteenth Electric Power Survey. In applying these projections to AP and Gujarat we assume that the electricity reforms, under way since 1991 are likely to continue. The recently introduced Electricity Act, 2003 has provisions to introduce competition at all levels in the electricity industry and has been appreciated by most in the industry as continuing the spirit of the reforms.

The baselines for Andhra Pradesh and Gujarat are presented in figure 6 (together with that of the Chinese provinces). In both states, the carbon intensity of generation from fossil fuels has

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[12] The studies in both the countries used fuel consumption, calorific values, heat rates and actual generation provided by the individual generating units through the primary survey. The carbon emission factors for India were taken from the study published by Garg and Shukla (2002) and for China from Energy Information Administration of US Department of Energy (1992).

declined. In Andhra Pradesh, the fossil fuel baseline declined by 12 percent from 1990 to 2001 and in Gujarat the decline was 18 percent. Looking at the fuel types individually, in Andhra Pradesh the coal and gas baselines decreased by 4 percent and 10 percent respectively as new, more efficient plants accounted for a larger share. In Gujarat, the gas baseline rose in the late 1990s because of problems with the availability and quality of gas.

However, the overall industry baseline diverged sharply in the two states. In Andhra Pradesh it rose as zero carbon hydro generation declined from 38 percent of total generation in 1990 to just 11 percent in 2001. The change in fuel mix alone would have caused the baseline to rise by 0.04 Kg(C)/KWh by 2001. The rise was offset by 0.03 Kg(C)/KWh due to overall carbon intensity decrease from 1990 to 2001. In Gujarat, of the total decline in intensity, 81 percent is attributed to changes in fuel structure (i.e. shift to gas) and 19 percent to improvement of energy efficiency (i.e. lower average heat rates of each generator type).

Figure 6. Baseline for electricity industry

AP

Gujarat

Guangdong

Liaoning

Hubei
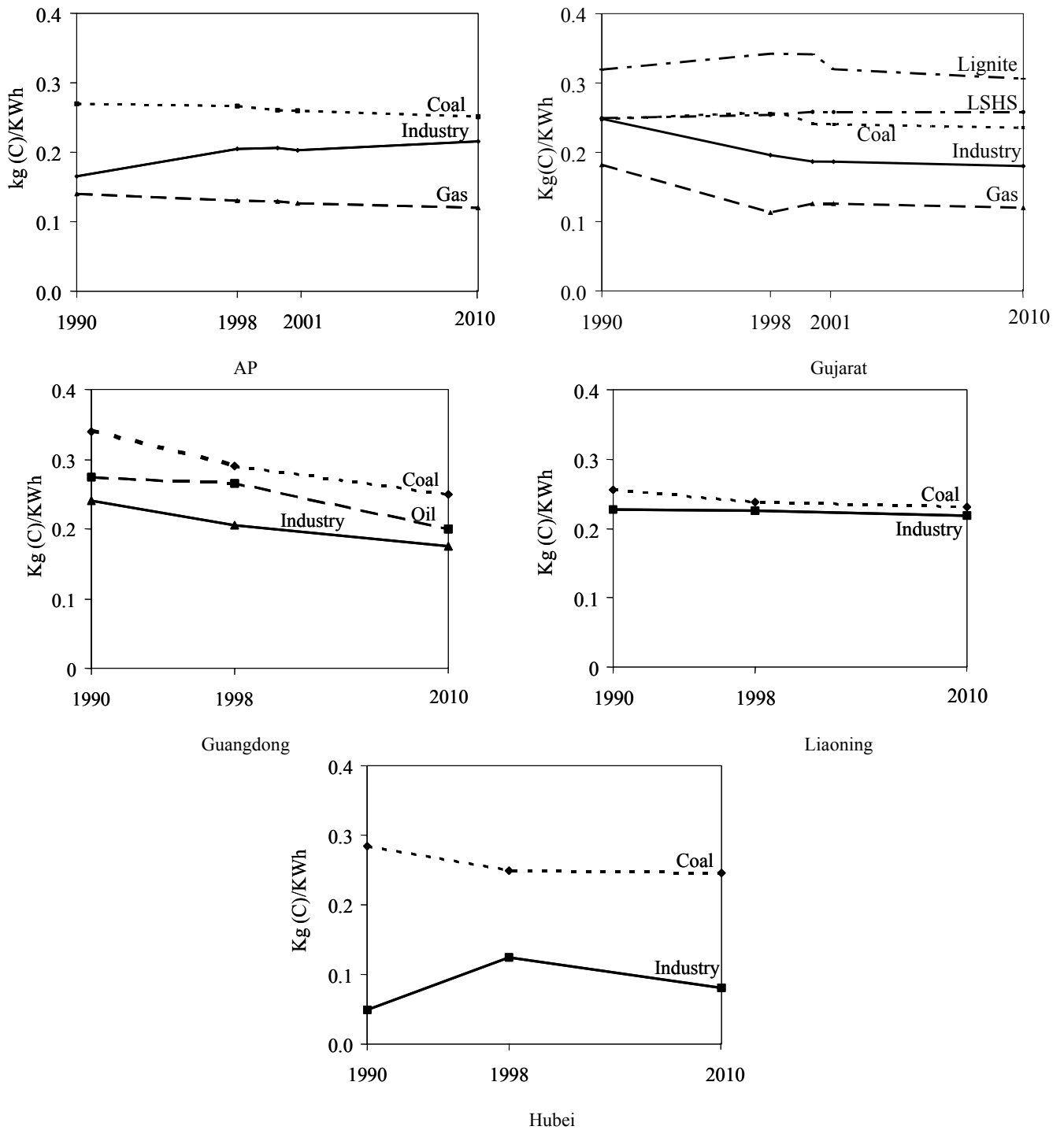
Changes in the Carbon Intensity: China

The collated data allowing historical assessment of the projected baseline emissions for 2010 are based on the projected figures from the Chinese provincial Five-Year and other plans. It may be argued that the history of China's energy sector has often shown these plans to be inaccurate in their predictive power. However, we rely on these projections for at least three reasons. First, the central government still retains strong coercive power and control over financial resources to ensure the fulfillment of the national plants. Second, the government's Five-Year and Ten-Year plans are the result of multiple rounds of balancing among different interests and prioritizing of various programs and thus the planning process is often a highly effective instrument for eliciting synthetic information about the Chinese policy-making process. Using the plan-specified technology targets as benchmarks could be less prone to gaming problems than might be estimated such as solely by examination of economic considerations that, often, do not determine investment patterns in China. Third, to the extent these plans are inaccurate, they are more likely to be underperformed than outperformed, leading to a baseline that changes less radically than expected which in turn may yield a smaller supply of certified emissions reductions.
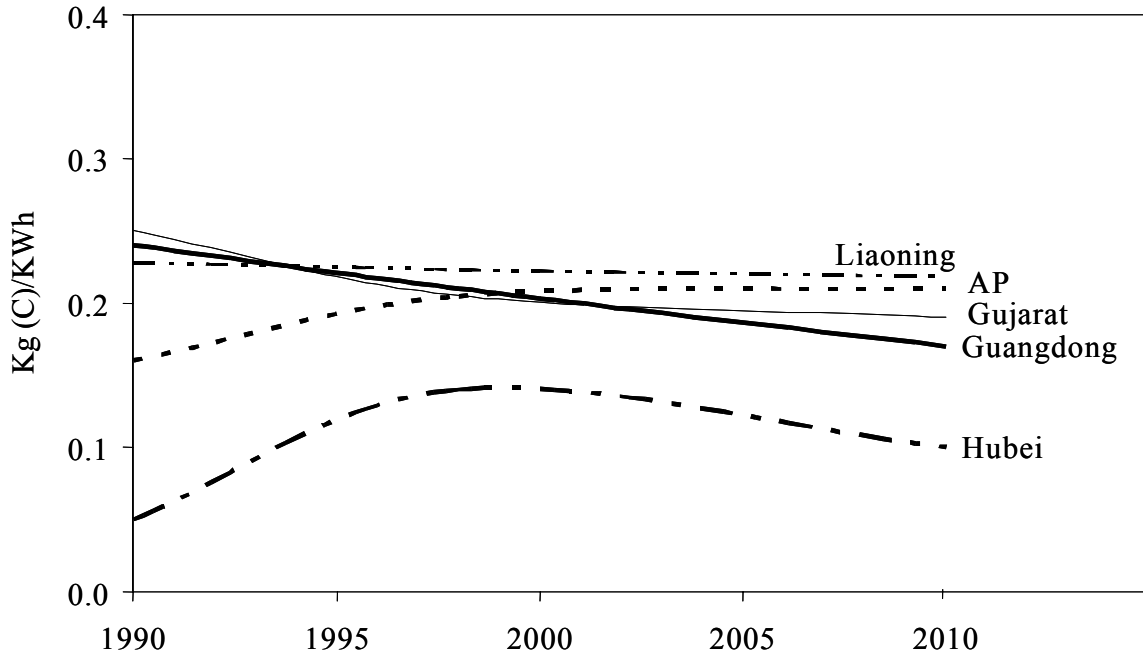
In Guangdong as in Gujarat, carbon intensity of the total industry has declined for the past ten years. We project that this trend will continue in the next decade as new (more efficient) plants are installed and especially with the expected shift to gas in the province. In Liaoning and Hubei, the carbon intensity of fossil power generation also displayed a modest decline between 1990 and 1999, but is expected to remain flat, because new coal-fired generators are not expected to be much more efficient than the 300 MW units already being installed, and those provinces are not slated to shift to gas. For Liaoning, the net effect is that carbon intensity is flat. For Hubei, however, carbon intensity has risen sharply in the 1990s. The rich hydropower resources of Hubei have had an overwhelming impact on average carbon intensity. In the future Hubei's carbon intensity is set to decline as Three Gorges and other large hydropower projects are commissioned between now and 2009.

4. Driving Force: A comparison

While there are no general pattern in carbon intensity baselines, as shown in Figure 7, there are three general characteristics:
- Gujarat and Guangdong, saw and will see impressive drops in their carbon emissions measured in terms of per kWh electricity generated.
- Liaoning's electricity industry has a relatively flat long-term trend of carbon intensity.
- In Andhra Pradesh and Hubei conversely, carbon intensities have risen, although Hubei will fall back from its recent high level as new hydro power is supplied.

Figure 7. Comparative Carbon Intensities of Electricity Industry in India and China

The primary driver, of these patterns, is fuel mix. The impressive decrease in carbon intensity in Gujarat and Guangdong coincides with the increase in gas and naphtha capacity in Gujarat and adoption in Guangdong of low carbon and carbon free fuels including oil, nuclear and in the future natural gas. By contrast the lack of alternatives to coal in Liaoning is responsible for its very slow decline in carbon intensity in the past (and expected for the future). In hydro rich Andhra Pradesh and Hubei, the broad patterns in carbon intensity are predominantly driven by availability of water and capital available for hydro projects. In both during the 1990s the share of hydropower declined and carbon intensity climbed. With substantial share of coal technologies continuing in future in both countries, focusing on renewables and end use efficiencies could be an option for emissions reduction (Kroeze et. al. 2004).

A secondary driver is the adoption of advanced thermal generation technologies in new and retrofit power plants, especially coal-fired units. In Andhra Pradesh and Gujarat, the use of coal generation units larger than 100 MW has played a prominent role because there are steep efficiency of scale up to that size (Shukla et. al., 2004a and 2004b). Even controlling for unit size, in both India and China, recent vintage plants are more efficient than older ones. Even in Guangdong where small power plants continued to be added and kept in operation during the 1990s, large power plants with modern technologies were constructed on a larger scale, which lifted average energy efficiency of the entire fleet. Between fuel switches and improving energy efficiency, the former accounted for an estimated 70 to 80 percent of carbon savings in our samples.

Overall the findings in Figure 7 suggest that the electricity sectors in India and China are

becoming friendlier to the global environment. Except in hydro-rich Hubei, the carbon intensity of power generation has generally declined to about 0.2 kg (C)/KWh. (Despite this decline, total emissions from power generation in each state and province have risen due to the sharp rise in total power generated.) For comparison, the U.S., which gets 30 percent of its electricity from non-fossil sources and has carbon intensity about 0.17 kg (C)/KWh.

The patterns in both countries suggest a large role for government policy. In both countries the desire to favor local generation and locally available fuels drove the interest in coal (and hydro in AP and Hubei) and generally favored smaller and less efficient generators. In recent years, Indian policies have allowed private ownership of power plants and private participation in fuel markets, which is largely responsible for the development of natural gas and gas-fired power plants in Gujarat and Andhra Pradesh. In China, recent policy changes to promote cleaner energy has raised the projected share of hydropower in Hubei Province and created the context for imports of LNG, which will further reduce carbon intensity in Guangdong.

The traditional use of coal as the main feedstock in power generation in both countries is also reflected in its low relative price. In Andhra Pradesh and Gujarat power producers began to use new fuels such as natural gas and naphtha in the 1990s as they became available and competitive, but rising costs have checked that trend.[13]   In China, Guangdong data in Figure 4 show that, despite the government's wish to develop cleaner energy, if economic factors dominate the coal consumption will increase relative to other types of fuels in the future even after including the costs of controlling pollution. A recent study in Guangdong further indicates that many policy and economic factors can also cause cost disadvantage of competing fuels. For example, a price cap on peak power tariffs, regulations to limit operating hours of gas-fired power plants and special infrastructure costs of the LNG delivery system all make LNG use in power generation uneconomical (Zeng et al. 2004). Despite that fact, government policy encourages LNG as part of an effort to diversify fuels and LNG will enter the market.

The role in state planning is much greater in affecting carbon intensities in China than in India, but the effects of planning are complicated. On one hand, the central government in China still maintains tight control over electricity development after 25 years of economic reforms. All power projects require approval either by the central government (large or foreign invested projects) or provincial governments, and must comply with the government five-year plans and energy strategy. Within this broad requirement there are provincial differences in the degree of central control and local discretion. Guangdong indisputably has the most liberal market and policy environment in the nation. This situation implies that fuel changes at the provincial level in Guangdong are predictive if they are consistent with the central government policy but more sporadic and buffeted by local factors when the province pursues policies that deviate from the center. Huge increase in hydropower projected for 2010 in Hubei and rise in oil-fired generation in Guangdong in the 1980s and 1990s illustrate one point – Hubei's hydro is following a central plan that is easy for outsiders to observe and verify; the role of small oil generators is a provincial phenomenon that, by contrast, is very

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[13]   Increases in naphtha prices are due to the rise of oil price and rupee depreciation.

difficult to track.

In both countries industrial policy has affected the choice of generating technologies. Both countries supported domestic manufacturing of power generation equipment and imposed import restrictions. As a result, coal-fired power plants installed before the 1970s in all the sample states and provinces were mostly small in size and low on energy efficiency. The constraint was more serious in China due to the Cold War embargo and severing of diplomatic relations with the Soviet Union which forced Chinese equipment manufacturers to complete autarky (Xu, 2002). Although both governments still emphasize and protect domestic equipment manufacturing today, the stronghold of domestic technology on these markets have declined. Exposed to foreign competition and external ideas, Indian and Chinese manufacturers today are capable of producing 300 MW and 600 MW coal-fired units that are markedly more efficient than the smaller units that they produced behind the wall of import barriers. The reductions in heat rates for coal-fired power generation that we document and project in all states and provinces is primarily associated with development of modern power plants by in-country vendors.

Financial constraints have also affected technology decisions – with varied effects on heat rates and fuel choices. Power generation is capital intensive, and both countries have had long histories of charging tariffs that did not cover the cost of developing new capacity. New higher tariffs in China have solved this problem, but India still charges barely 2/3rd of the long run marginal cost of power on average (Zhang and Heller, 2003; Tongia, 2003).   Thus state fiscal budgets have been a main source of investment capital. Particularly in the case of India, the electricity sector has been almost totally under the control of the state and the federal government until 1990. Private capital began flowing in after the initiation of the reforms in India, but their contribution to total capacity has not been much. With the loss making Indian SEBs contributing little to required capacity addition and government funds having been insufficient to support the growth of power supply, there has been a slow adoption of modern technology - retrofitting projects have been delayed and planners have sought to avoid capital expenses. As our next discussion will further suggest, financial constraints have also interacted with constraints on local planning in China to cause a different experience from India.

The observed choice of inferior technology and size of plants in China represents, to an extent, a quick response to a sudden increase in power demand from a surging economy and massive shortage. This demand impact was clearest in Guangdong. China's market economic reforms that started in 1979 brought their earliest and most rapid income effects to Guangdong; quick relief took the form of building smaller power plants that did not need a lot of financing (and thus could operate without central government approvals and capital allocations) and had short construction periods. Coupled with relatively liberal local policy discretions, many such small energy inefficient plants were built at the same time that government agencies were also building large modern power plants, giving rise to the unique bifurcated development of coal-fired generators shown in Figure 8. A similar situation unfolded in other provinces on a much smaller scale.

Figure 8. Efficiency of Coal-fired Generation in Guangdong (1990)
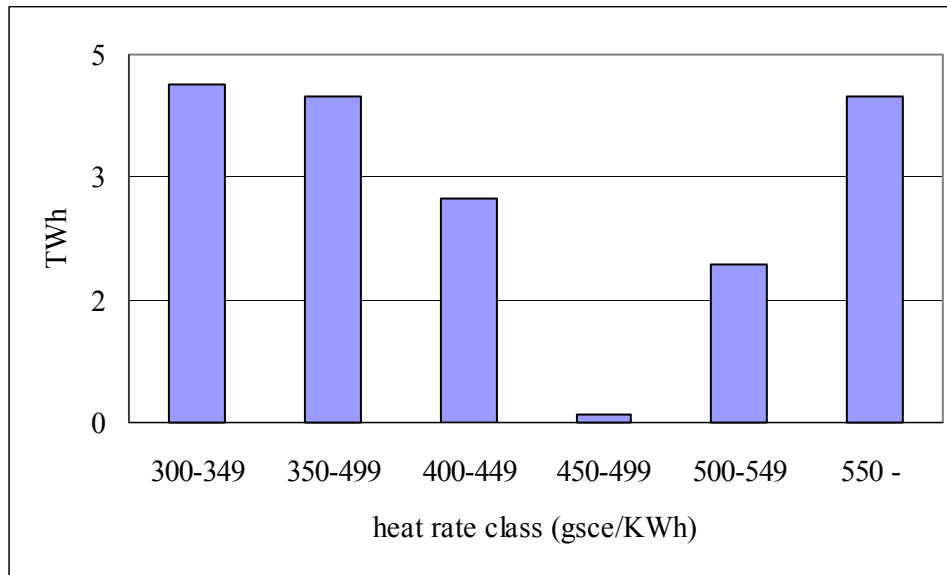
Source: Zeng et al. 1999.

Why Chinese power producers sometimes choose to build small inefficient coal-fired plants and operate extremely dirty and inefficient units while large economical and cleaner capacity sits under-utilized may be understood from the institutional nature of the government controlled electricity industry. The influence here is threefold. Firstly, the central control of the economic as well as the power sector relied in the past on a hierarchical government structure in which provincial, county and city governments were charged with the responsibility of local economies within their respective jurisdictions. At the bottom, county and city governments typically had to make sure that they provided power to end-users within their counties or cities when power allocated to them from the grid was not enough. For these local governments, small power plants were sufficient (Zhang, et al., 2001).[14] To some extent, this feature of the Chinese economy still exists. Secondly, local governments are responsible for raising funds to finance power projects although they sometimes receive support from higher-level government units. Small local budgets and limited access to borrowing are often the reason for the choice of less capital intensive small power plants – even though such plants use more expensive fuels less efficiently. Thirdly, since the late 1980s, the central government has shared its approval control of new power projects with provincial governments. According to the policy, large projects (above US$30 million which buys about 50 MW) must go through central government approval which is an extremely long process given the five-year planning cycles, but smaller projects only need provincial approval which is a much shorter process.[15] Many developers have in the past broken up large projects to bypass the red tape.[16] Again, in Guangdong's case, especially these three

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[14] Building large power plants to also supply end-users outside the administrative area was politically unwise and difficult since it would expose local administrators to decisions from other jurisdictions.

[15] The central government later banned construction of plants less than 300 MW as power market became slack in the late 1990s.

[16] Survey of plant managers in Gujarat suggest that there are also technical considerations for such break-ups.

factors explain why local governments built many small plants during booming years; when demand went slack in the late 1990s, these local officials then used their political power to fiercely protect their investment from being shut down, which is why these plants kept being dispatched even though that was economically suboptimal.

5. Summary and Policy Implications

Large scale expansions of the Indian and Chinese electricity industries in recent years and expected growth in the future have generated international concern about the implications for emissions of the gases that cause global warming. At present, the only international regime for addressing developing country emissions centers on the CDM, which requires determination of baselines against which "additionality" of emissions would be determined. We have presented results from an in-depth study of power sector baselines in five states and provinces of India and China. Three policy implications follow from the analysis.

First, these five cases confirm that opportunities exist in the Indian and Chinese electricity sectors to lower carbon intensity-- mainly in the substitution of other fuels for coal and, to a lesser extent, in the adoption of more efficient and advanced coal-fired generation technology. As the baselines in the five states/provinces show, carbon intensity of power generation generally decreases with expansion of the electricity sector, but the rates of change vary considerably due to a complex array of factors, many of which operate at a fine level of geographical resolution.

Disaggregated analysis of the baselines suggests that the potential of further improvement in carbon intensity through improved generation efficiency appears to be low. The review of the data and field interviews both reveal that energy efficiency varies little among gas-fired or oil-fired turbine based power plants. Among coal-fired power plants, the only substantial difference in heat rate exists between small power plants and larger power plants, and for generation units larger than 100 MW it is insignificant (Shukla et. al., 2004a and 2004b).

Second, detailed and careful industry analysis is essential to establishing a power sector carbon emissions baseline as a reference for CDM crediting. The credibility of such a baseline depends on how well the analyst understands ex ante the determinants of investment decisions with respect to fuel and technology choices in future power sector expansion. We find that the factors that affect power investments often extend far outside the power sector to include industrial policy, tariffs on imported equipment, exchange rates and financial reform. Our analysis suggests that the most glaring inefficiencies in each country's investment paradigm have at least been partly eliminated – namely, the protection of local manufacturers whose coal plants were markedly inferior to world standards. Still, numerous barriers remain. In China for example, the same industrial policy that used to promote domestic technology and coal-fired power equipment manufacturing has slowed the import of gas turbines,   gas delivery equipment and technology. Similarly, lack of well functioning financial markets and uncertainties associated with power market reforms in both countries are likely to continue to affect investment in energy infrastructure and the adoption of new fuels and technologies.

Two 100 MW units may be preferred to one 200 MW unit in terms of managing load and maintenance schedules.

The capital intensity of infrastructure choices will depend on the costs of capital faced by investors. On critical issues such as whether old or inefficient thermal generation technologies are retired and replaced, we have shown the difficulty in untangling the economic, financial, political, and institutional factors that determine the business as usual trajectory. We question whether policies and investments to supplant these inefficient small units could (or should) be the subject of CDM credit since their persistence is a reflection of uneconomic (but politically rational) forces at work.

A parallel dependence of business as usual baselines on political choices also casts a shadow over the use of CDM even for new less carbon intensive infrastructure projects. The biggest current obstacle to adopting alternative fuels is the low relative cost of coal. It is far from clear whether this cost advantage will diminish significantly in the foreseeable future in either China or India, even after accounting for government policy initiatives to include pollution charges or to subsidize the infrastructure costs of developing new fuel sources. Analysis of neither the Indian nor the Chinese case can count upon large drops in the share of coal as feedstock of power generation. Plausible scenarios still suggest that coal's share could rise in Guangdong and Liaoning. The economic persistence of coal suggests that it should be relatively easy to ascertain baselines for projects that switch to lower carbon energy sources. Yet many such low-carbon energy systems are nonetheless proceeding – even in instances where the project does not appear evidently economic. In China, for example, large energy infrastructure projects, such as Three Gorges Hydropower and LNG receiving terminals have been initiated by strong governments and implemented through central or provincial economic plans. Changing load curves, the quest for energy autonomy, and rising demand for reliable, high quality power may cause some regions to favor increased investment in alternative fuels to coal. Reasonable estimates of the variable scale of the development of these projects can be incorporated into regional carbon baselines despite their apparent disadvantages in relative fuel price. Private project development in this area, however, remains especially unpredictable because of continuing uncertainties about the future of market institutions, a stable policy environment and access to financing.

The third policy implication is that, considering all the difficulties associated with the baseline issue, our case studies demonstrate that there is a merit in examining alternate approaches to engaging developing countries. Some scholars have advocated the use of aggregated national baselines and the setting of countrywide targets for developing countries, which would enable them to participate in international emission trading systems (Stewart and Weiner, 2003). We remain skeptical of the functional feasibility of such schemes because of the profound uncertainties in ascertaining baselines ex ante. Such uncertainties will make it difficult to gain agreement on meaningful caps on emissions for developing countries, and such uncertainties are prone to result in large quantities of excess credits that will undermine the integrity of emission trading systems (Victor, 2001, Ch. 2). Rather, this study suggests that attempts to integrate developing countries into the global effort to control emissions will be more effective if they don't focus on project-based accounting or countrywide emission caps; instead, more leverage is available by focusing on broad packages of policies that will change the baselines in developing countries. Rather than promoting projects that deliver marginal changes from existing baselines, this alternative approach would identify carbon-friendly development pathways that are also consistent with developing countries'

own development priorities (Heller and Shukla, 2003). Such approaches are less likely to be opposed by developing countries and would focus, notably, on the promotion of low-carbon energy infrastructures that lock-in low-carbon trajectories for economic development. Examples include the promotion of natural gas infrastructure that, as we have shown, direct development of electric power systems toward much less carbon-intensive outcomes.

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