CHINA ENERGY TECHNOLOGY PROGRAM

A PRELIMINARY CHARACTERIZATION OF THE ECONOMY, ENERGY INDUSTRIES AND ENVIRONMENT IN SHANDONG PROVINCE

Introduction

Shandong is one of China's most highly populated and economically productive provinces. As one of several "bonded free-trade zones" along China's eastern coast, Shandong has achieved a high degree of export-based growth through a successful blend of both foreign investment and township and village enterprises (TVEs). One of China's thirteen state-approved bonded free trade zones, Shandong is also one of its most populous, rapidly developing and economically productive provinces. In addition to being a model for Chinese development, Shandong typifies the many energy and environmental challenges China faces as a whole. These include a historically overextended power system, large seasonal variations in water supplies and poor air quality, which Shandong is striving to reconcile along with its imperative for continued economic growth.

This overview is intended to serve as a qualitative orientation to Shandong's economy, energy industries and environment. It is intended to inform the attribute identification and scenario formulation phase of CETP's electric sector analysis as we deepen our relationship with Chinese stakeholders.

Shandong Geography

Shandong Province sits on China's northeastern seacoast, southeast of Beijing, between Tianjin and Shanghai. (See Figure One.) Shandong's population numbered over 86.7 million in 1995 (Chen, 1998), with a population density of 564 people per square kilometer (Sinton, 1996). Its capital city is Jinan, while its biggest city and predominant deep water port is Qingdao (Yantai SMR, 1999).

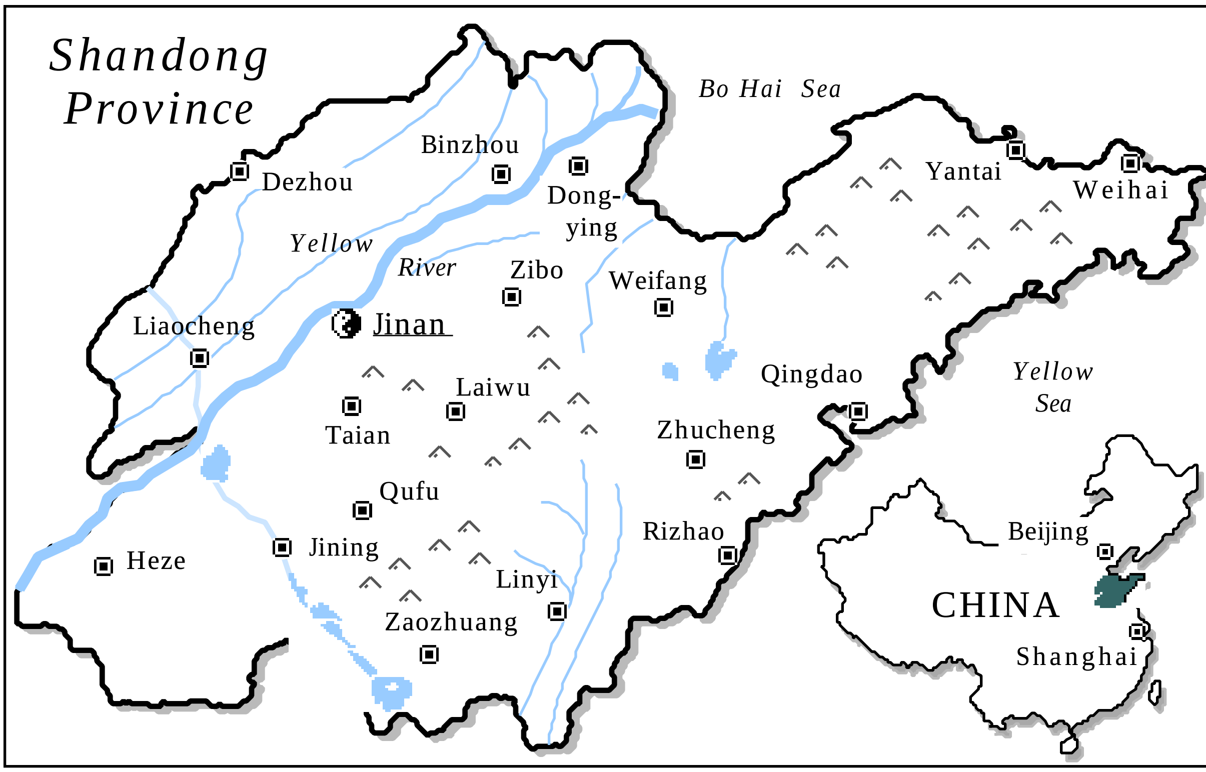
Shandong's land area covers 156,700 square kilometers,[1] and is roughly 620 km from East to West, and 420 km from North to South. Its primary river is the Huang He (Yellow River) which runs southwest to north-central. The Huang He's delta is very dynamic, a result of large seasonal variations in flow and silt content, and flows into Laizhou Bay near Dongying municipality. The Yellow River Delta also contains the Shengli oilfields, China's second largest oil reserve (Business China, 1996). Shandong's other mineral resources include gold, sulfur, granite and diamonds, while its primary agricultural resources are produce, fish, wheat and cotton (Yantai SMR, 1999). To the West of the Huang He is the Shandong peninsula, marked by a hilly range also running southwest to northeast (Jiacheng and Zhiguang, 1992), the most prominent feature of which is Tai Shan, which at 1545m (5069 ft) is one of China's five most holy Taoist mountains (Atiyah, Leffman and Lewis, 1997). Along this axis, Shandong is roughly

1 For comparison purposes, the U.S. State of Florida is about 152,000 square kilometers.

750 km long (466 miles). Another water feature of great historical significance is the Grand Canal (Da Yunhe) which cuts across southwestern Shandong, and the cities of Liaocheng and Jining, on its way from Tianjin to Nanjing and Hangzhou.

Shandong's climate is temperate but mild, with temperatures in Jinan hovering near 1 C° in the winter months, between 21° and 28° C (70-82° F) in the summer months, and between 7° and 16° C (45-61° F) in the spring and fall. Jinan's heating season is relatively short at 4 months (World Bank, 1997). Jinan's rainiest season is summer, which accounts for 65% of its 68.5 cm of mean annual precipitation (Jiacheng and Zhiguang, 1992).

FIGURE ONE: Shandong



Shandong's Economy

Because Shandong is coastal and close to Japan and Korea, it is geographically well-situated for its export oriented economy. Primary exports include oil, textiles, chemicals, consumer products, paper, machinery, electronics and building materials (Singapore-Shandong Business Council, 1999). Shandong's gross domestic product ranked second among China's provincial GDPs in 1993. Table One shows some recent key economic statistics for the province. In addition, Shandong's per capita income ranked second in China in 1996 (Triolo, 1996).[2]

2 While first-place provinces were not cited for either category, it is reasonable to assume Guangdong province was the first in both cases as it contains Hong Kong.

TABLE ONE: Economic Statistics for Shandong

Year	Gross Domestic Product		Inflation	Exports		Imports	
1994	387.2	16.3	20.6	7.08	15.9	3.75	21.8
1995	500.2	14.1	14.1	9.65	36.3	5.97	54.4
1996	596.0	12.2	7.0	18.86	9.1	6.98	20.6
1997	665.0	11.6	–	11.80	18.6	7.90	13.2
	(B Yuan)	(Δ% / yr)	(Δ% / yr)	(B Yuan)	(Δ% / yr)	(B Yuan)	(Δ% / yr)

Note: Δ% / yr. changes are in real terms over previous year or corresponding period of previous year. (Yantai SMR, 1999)

BONDED FREE-TRADE ZONES

The establishment of bonded free-trade zones along coastlines and international waterways has been one of many post-Mao economic reforms implemented in China since 1978 (Chen, 1998). Bonded zones push customs jurisdiction back to their inland borders, serving as bases of duty- and tax-free imports and exports. Thus, while customs does exact these payments on goods shipped to or from bonded zones from other parts of China, international exchange can take place freely within them. China established its first bonded zone in 1990 near Shanghai with the aim of promoting international trade and investment. As of 1996 there were 13 state-approved bonded zones, including Shandong province. Bonded zones are attractive for the following reasons:

Warehousing- because duty, import and value-added taxes are not assessed until goods leave bonded zones to be sold within China, the ability to delay these payments increases corporate cash flows.

Manufacture and Export- because taxes are not assessed within the zones, manufacturers and export processors may freely import materials and equipment and export finished products.

Foreign Currency Exchange- unlike elsewhere in China where transactions are restricted to the Yuan, trade within the zones may be conducted in dollars or other hard currencies.

Well-Developed Infrastructure- in 1995 Beijing Review ranked Shandong first in "nationwide infrastructure," a measure that took into account density of ports, mileage of top-grade highways and sophistication of communications infrastructure. (Beijing Review, 1995).

Low Land Prices- because bonded zones were late additions to China's menu of special economic zones (SEZs), and because concessions within bonded zones differ slightly from those offered in other SEZs, land prices within the bonded zones have remained low.

Concession Phasedown in other Special Economic Zones- so as to streamline its tax and investment incentives, China has been limiting preferential policies such as corporate tax and value added tax (VAT) rebates in other SEZs, which is making bonded zones more attractive (Business China, 1996).

Direct Foreign Investment (DFI) in Shandong

Shandong Province has identified six key development categories for which it intends to attract foreign capital: infrastructure and public facilities, basic industry, high-tech industry, tertiary industry, renovation of old enterprises and agricultural industrialization (Beijing Review, 1998). Table Two shows the sources of direct foreign investment in Shandong for 1995. Foreign national and multinational corporate presences in Shandong include AT&T, Coca-Cola, Hewlett Packard, Mitsubishi, Mitsumi Electric, Daewoo and ABB.

TABLE TWO: Direct Foreign Investment in Shandong (1995)

Country/ Region	**Direct Foreign Contractural Investment**	
	Amount	Percentage
Hong Kong*	1434.5	31.0
Korea	659.1	14.2
USA	630.8	13.6
Japan	508.8	11.0
Taiwan	350.5	7.6
Singapore	295.3	6.4
United Kingdom	159.6	3.5
Germany	98.7	2.1
Total	4137.3	89.4
	(Million $)	(%)

*Since Hong Kong's repatriation, China no longer counts Hong Kong investment as foreign. (Yantai SMR and Singapore-Shandong Business Council, 1999)

The Village Conglomerate (VC) and Shandong's Socialist Market Economy

Though the state is successfully cultivating foreign and urban economic activity, Shandong's "gross rural output value" ranked first in China and accounted for 75% of the province's total output value in 1992 (Chen, 1998). Agriculture, livestock, forest and fishery products comprised 33% of this value. The balance was contributed by a diversity of rural business ventures called Township and Village Enterprises (TVEs), many of which are run by organizations called Village Conglomerates. The progress of rural industrialization through Village Conglomerates in Shandong is one of China's "socialist market" reform success stories.

Shandong VCs are particularly communal in orientation, contributing frequently to public facilities and maintaining good relations with state officials. Though Shandong's rural industrial success can be predominantly attributed to the VC spirit of collective entrepreneurship, the state does continue to exercise control over natural resources, fiscal and monetary policy. Shandong's wealthiest villages are VCs, and twenty three hundred VC-based rural communities have emerged there in the past decade. Employing nearly 14 million people, Village Conglomerates have become a vital force in Shandong's overall economy through their pioneering role in rural economic development (Chen, 1998).

THE RISE OF THE VILLAGE CONGLOMERATE

Prior to 1978 Chinese citizens were legally bound by the state to the village of their birth. A *hukou* or household registration system obligated one to labor for one's village brigade as part of the people's commune. While hukou has not been formally abolished, China implemented a Household Responsibility System (HRS) in 1984. Under HRS, individual villages retained collective land ownership but cultivation rights devolved to individual households. In addition, HRS marked the end of China's era of high grain production quotas in the countryside. This relieved the peasant population not only from its restriction to agricultural labor, but also from its geographic restriction to native villages. Under the HRS system, newly mobilized surplus labor and state incentives for rural industrialization have given rise to a new unit of economic organization in China: the Village Conglomerate or VC.

Under strong, unified leadership VCs have supplanted village brigades as hierarchically structured, comprehensive economic and social service organizations. VCs conduct highly diversified economic activities through individual Township and Village Enterprises, and also provide members with welfare services. VC membership is drawn from village residents, though VCs also employ nonmembers from outside provinces.

Energy Consumption in China and Shandong

While industry continued to dominate China's sectoral energy end-use mix in the mid-nineties, energy use in the commercial sector has been rising more quickly than in all other sectors in recent times, eclipsing that of even the agricultural sector. In addition, energy use in China's transportation sector grew rapidly over the past decade as vehicle fleets expanded. It is anticipated that energy demand in the residential sector –especially in electricity–will also swell as Chinese incomes continue to rise.

In contrast to its strong economic growth, China's energy intensity (energy consumption per unit of GDP) has decreased remarkably steadily since 1977. Sinton attributes this decline to efficiency improvements within sectors of the Chinese economy rather than to significant cross-sectoral output changes.

The Electric Power Industry in China

China's power sector is organized around five regional and ten provincial power networks which support 1500 distribution enterprises at the county or prefecture level (World Bank, 1997). According to Business China's spring, 1995 Power Supplement, the commissioning of a 550-kV line between Guizhou and Guangdong would effectively regionalize these provincial grids.

TABLE THREE: Energy Intensity by Province (1990)

Planning Region	Province	Primary Energy Consumption	National Income	Energy Intensity
North	Beijing	27.1	36.7	0.74
	Tianjin	20.7	25.6	0.81
	Hebei	61.2	70.2	0.87
	Shanxi	47.1	31.6	1.49
	Inner Mongolia	24.2	23.3	1.04
Northeast	Liaoning	78.6	78.4	1.00
	Jilin	35.2	33.7	1.04
	Heilongjiang	52.9	56.4	0.94
East	Shanghai	31.8	61.7	0.52
	Jiangsu	55.1	113.8	0.48
	Zhejiang	25.8	72.7	0.36
	Anhui	27.6	51.9	0.53
	Fujian	14.5	38.9	0.37
	Jiangxi	17.3	35.4	0.49
	Shandong	**68.3**	**114.4**	**0.60**
South -Central	Henan	52.1	75.4	0.79
	Hubei	40.0	66.1	0.68
	Hunan	38.2	59.1	0.34
	Guangdong	40.7	113.2	1.21
	Guangxi	13.1	33.6	1.70
	Hainan	1.2	7.7	0.16
Southwest	Sichuan	63.5	79.9	0.79
	Guizhou	21.3	17.9	1.19
	Yunnan	19.6	24.0	0.82
	Xizang		1.6	
Northwest	Shaanxi	22.4	24.0	0.94
	Gansu	21.8	16.4	1.33
	Qinghai	5.1	4.2	1.23
	Ningxia	7.1	3.7	1.90
	Xinjiang	20.7	15.4	1.34
National Total/Average		987.0	1438.4	0.69
		(Mtce)	(B Yuan)	(kgce / 1000 Yuan)

(Sinton, 1996)

Though China has striven to manage an even progression of electricity service expansion through the provinces, its main regional fiscal and administrative units, the power sector has coalesced more clearly around areas of economic productivity. In addition, China's power sector has been historically fraught with unclear relationships and conflicts of interest, as well as real and perceived barriers to foreign investment. China is progressing towards resolving these issues, and in recent years has implemented a series of ministerial reforms aimed at separating productive and regulatory functions in the power sector.

TABLE FOUR: China's Regional and Provincial Electricity Networks (1995)[3]

Region/Provincal Power Network		Generating Capacity 1994	2000	Percent Increase
East China Power Network	EPCN	28695	55000	91.7
Northeast Power Network	NEPN	25756	46000	78.6
Northeast China Power Network	NCPN	25728	57500	123.5
Central China Power Network	CCPN	25617	49432	93.0
Guangdong Provincial Grid	GDPG	14005	32540	132.3
Northwest Power Network	NWPN	11382	20000	75.7
Shandong Provincial Grid	**SDPG**	**10690**	**23000**	115.2
Sichuan Provincial Grid	SCPG	8460		
Fujian Provincial Grid	FJPG	3788	10850	186.4
Yunnan Provincial Grid	YNPG	3634	6295	73.2
Guangxi Provincial Grid	GXPG	3558	4230	18.9
Guizhou Provincial Grid	GZPG	2596		
Xinjiang Autonomous Region	XJAR	2553	5000	95.8
Hainan Provincial Grid	HNPG	897	3000	234.4
Xizang (Tibet)	XZAR	173	560	223.7
	Total	167532	313407	87.1
		(MW)	(MW)	(Δ%)

(Business China, 1995)

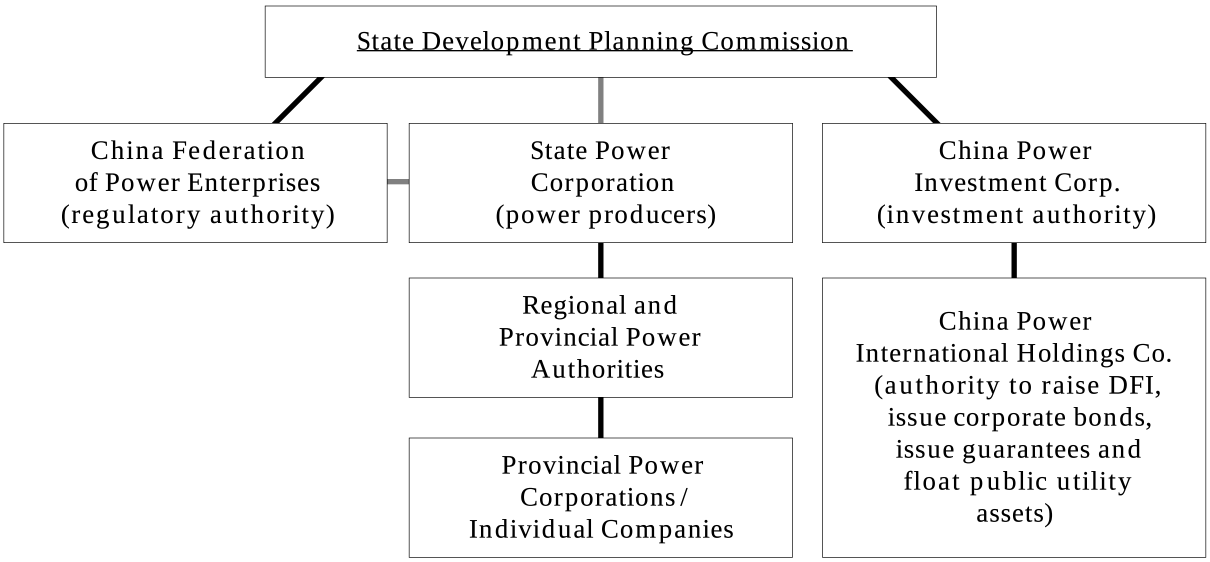
In 1993 the Coal Ministry, Machinery and Building Industries Ministry and Water Resources Ministry were consolidated into the Ministry of Electric Power (MEP). While it existed, MEP organized many of China's provincial power companies into five regional authorities with jurisdiction over five regional power "networks." The remaining provincial power companies maintain jurisdiction over smaller, provincially-demarcated 220 kV and 110 kV "grids." The MEP also charged regional networks with the task of furthering the state's ambition to enable greater interregional 330kV and 550 kV transmission of electricity, the Three Gorges Dam being this effort's grandest legacy. Disincentives to smaller-scale T&D investment persist due to interjurisdictional competition and the state's reluctance to cede property rights to China's T&D infrastructure to foreign interests who might invest in such projects (Business China, 1995).

China's establishment of the China State Power Corporation in 1996 technically dissolved the Ministry of Electric Power, though it is said to have simply taken on a new permutation as the regulatory arm of China Power – China Federation of Power Enterprises. In addition to nominally achieving the functional separation of production and regulation, the creation of the State Power Corporation included provisions for the active pursuit of foreign investment for build-operate-transfer (BOT) projects under the China Power Investment Corporation. Under China Power Investment's authority, China Power International Holdings Company was imbued with the power to raise direct foreign investment, as well as to issue corporate bonds and rate-of-return guarantees on a case-by-case basis. Figure One illustrates the general relationships among the various institutions

3 2000 figures were Ministry of Electric Power projections in 1996.

While the establishment of China Power Investment was a promising move, private power development may continue to be hindered in China by the state's reluctance to implement comprehensive electricity tariff reforms.

FIGURE TWO: Organizational Structure of China's Power Sector



(Business China, 1996)

Energy Policy and Planning in China

China issued its first energy policy in 1997, which reaffirmed coal's central role in the economy (China Infrastructure, 1997). China's Electric Power Law sets forth similarly broad goals, but does not specify service obligations such as maintaining coordination among generation, transmission and distribution enterprises, ensuring reliability, or safeguarding customer interests (World Bank, 1997).

Directives under China's 9th Five Year Plan are also general though more extensive. The Plan calls for the electricity sector to:

- Upgrade existing generation stock,
- Emphasize development of plants with capacities greater than 300 MW[4],
- Encourage adoption of cogeneration technologies in urban areas,
- Continue to support cleaner technologies, especially clean coal,
- Create further opportunities for foreign investment, and
- Strengthen indigenous industry's position in the heavy electrical equipment supply chain (Russo, 1999).

4 Business China reported in 1995 that state approval was not necessary for new power projects at or under 200MW. While our team has yet to confirm the current status of this policy, its persistence could provide a perverse incentive to replicate past expansion patterns. In addition, Chinese power generation projects are apparently subject to approval processes at the provincial and state/national levels. As China's oldest, strongest and most centralized bureaucratic authority, the State Planning Commission (SPC) is reported by China Infrastructure to be known for protracted approval processes and susceptibility to corruption. The December, 1997 issue references over fifty types of approvals that power plant projects must pass, attributing twenty of these to SPC approval.

Shandong's Electric Sector

Electricity Supply

China as a whole more than doubled its generation capacity in the 1980's in an attempt to keep pace with demand growth. Though 12 GW were added each year from 1987 to 1993, it has been estimated that 15 GW / year was needed until 2005 to satisfy changing consumption patterns and an increasingly productive economy (Business China, 1995). The latest statistics from Shandong's largest electric utility, Shandong Electric Power Group Co. (SEPCO), shows that from 1978 to 1998 generation capacity in the province has grown from almost 2.8 GW to just shy of 18 GW, a 532% increase, making Shandong second largest province in terms of installed capacity.. Over the same period electricity sales increased from 15.4 TWh to 84.2 TWh, nearly a 450% increase in consumption.

Generation in Shandong is predominantly coal. For the 1996 generation listed in State statistical journals, only 40 GWhs were derived from hydropower.

TABLE FIVE: Breakdown of Shandong Thermal Generating Capacity, 1996[5]

Plant Size	**No. of Plants**		**Combined Output**	
0-49 MW	71	73.2	929	7.5
50-99 MW	2	2.1	128	1.0
100-299 MW	10	10.3	2004	16.3
300-999 MW	12	12.4	6868	55.7
>999 MW	2	2.1	2400	19.5
Total	97		12329	
	(No.)	(%)	(MW)	(%)

(*State Statistical Bureau*, 1996)

Electricity Demand

By September 1994, every village in Shandong province had been electrified, and in February 1996 all households were electrified. (SEPCO). In 1997, rural electricity consumption (20 TWh) represented 24% of all electricity demand. Unmet demand in Shandong Province for 1996 was estimated to be 18 GW (Yongxin, 1996), but with a strong building program this gap appears to have been closed. (SEPCO)

5 Note: SEPCO statistics for installed generating capacity in Shandong in 1996 were 14200 MW.

TABLE SIX: Electricity Consumption in Shandong

Year	Installed Capacity	Electricity Sales	
1996	14.2	79.3	
1997	16.2	84.2	6.2
1998	17.5	84.3	0.1
	(GW)	(TWh)	(Δ%)

(SEPCO)

TABLE SEVEN: Principal Thermal Power Plants in Shandong (1999)

Plant Name	Plant Size	In Operation	Under Construction
Zhouxian	2400	1800	1x600
Laiwu	1530	330	4x300
Liaocheng	1400	200	2x600
Shiheng	1335	735	2x300
Shiliquan	1243	943	1x300
Huaneng Dezhou	1200	1200	
Longkou	1000	1000	
Huangtai	925	925	
Huaneng Weihai	850	250	2x300
Heze	850	250	2x300
Qingdao	710	710	
Huangdao	670	670	
Xindian	600	600	
Weifang	600	600	
Yantai	418	418	
Linyi	380	130	2x125
Jining	300	300	
Total	16411	7053	9358
	(MW)	(MW)	(No./Size)

(SEPCO, 1999)

Electricity Prices

Wholesale electricity prices have generally risen over the past decade in China, though prices can vary widely among regional grids as well as between sectors within each grid. In addition, the highest costs tend to be paid by rural users, though all users in China are currently being surcharged to help subsidize the Three Gorges dam project. Table Seven shows electricity rates from 1994 for Jinan. In 1996, SEPCO revenues of 20.8 billion Yuan for 61.9 TWh of sales yields an average rate of 0.336 Yuan/kWh (SEPCO).

TABLE EIGHT: Electricity Prices in Jinan (1994)

Customer Class	Retail Rate
Industrial	0.17-0.22
Agricultural	0.22
Commercial	0.35
Residential	0.22

(Yuan/kWh)

(Sinton, 1996)

Shandong Electric Power Group Corporation (SEPCO)

The Shandong Electric Power Group Corporation manages dispatch and transmission across the over 36,000 km of predominantly low-voltage transmission lines (Russo, 1999) that comprise Shandong's provincial grid (Business China, 1996). The Shandong grid is China's largest stand-alone provincial network. Headquartered in Jinan, SEPCO is a diversified conglomerate with business interests in construction, mining, real estate, manufacturing, tourism and telecommunications as well as electricity. SEPCO employs 66,000 people, and actively contributes to Shandong's economic, social and cultural development.

TABLE NINE: SEPCO Key Operating Data for 1998

Assets	62.8	(B Yuan)
Power Sales Revenue	27.38	(B Yuan)
Diversified Revenue	10.1	(Yuan)
Installed Capacity	17430	(MW)
Generating Volume	84.3	(TWh)
Electricity Sales Revenue	27.38	(B Yuan)
Coal Consumption	377	(g/kWh)
Average Utilization Hours	5012	(Hours)
500 KV Transmission Line	739	(km)
220 KV Transmission Line	7426	(km)
Line Loss	5.55%	(%)

(SEPCO, 1999)

In addition to managing transmission and distribution in Shandong, SEPCO owns and operates the majority of its generating stations. Shandong's capacity has grown rapidly this decade, and SEPCO plans to further expand the system via construction of an integrated mining and electricity generating venture in the Heze coal field (SEPCO, 1999). The coal mines of Shanxi represent potential added capacity for Shandong, though construction of a mine-mouth power station to wheel electricity to SDPG were thwarted in 1995 for lack of sufficient water resources. Development of a proposed 300-km Yellow River transfer project was also tabled that year. Northern China's lack of water resources may be a significantly limiting factor in power development (see Water Resources below) (Business China, 1995).

Private Power in Shandong

Shandong is home to many of China's quasi-private and private power ventures. Shandong's Zhongua Power Company, Ltd., at 3000 MW of Shandong's capacity via its Heze, Shiheng and Liaocheng stations is China's largest private power producer (Modern Power Systems, 1998). Because a regulatory framework that clearly separates generation, transmission and distribution enterprises from regulatory functions has not yet coalesced in China (World Bank, 1997), there is apparently significant generation investment by spin-offs and subsidiaries of both provincial and national regulatory, transmission and distribution entities. For example, SEPCO both manages dispatch and maintenance for several of SDPG's generating stations, but is also a major shareholder in Shandong Huaneng Power Development Company, a domestic and foreign joint venture whose assets accounted for 13% of Shandong's installed capacity in 1995 (Business China, 1996). China Power Investment Corporation is also invested in Shandong plants, as are Shandong International Power Development, Hong Kong's China Light and Power, Siemens, Electricité de France and The Southern Co., an American electric utility.

TABLE TEN: Private and Quasi-Private Power Projects in Shandong[6]

Plant Name	Plant Size		Equity Investors
Zouxian Phase 3	1200	2x600	n.a.
Rizhao Phase 1	700	2x350	Siemens, UDI (Israel), China Power Investment Corp., Huaneng International Power Dev. Corp., Shandong International Trust and Investment, SEPCO
Qingdao Phase 1&2	600	2x300	80% US / 20% Chinese
Shiliquan Phase 4	600	2x300	n.a.
Wehai Phase 2	600	2x300	Shandong Huaneng Power Dev. Corp.
Liaocheng	600	1x600	China Light and Power Co., Electricité de France, Shandong International Trust and Investment Corp., Shandong Electric Power Group Company
Heze Phase 2	600	2x300	same as above
Shiheng Phase 2	600	2x300	same as above
Laicheng	600	2x300	n.a.
Dezhou Phase 3	600	1x600	Shandong Huaneng Power Dev. Corp.
Weifang Phase 2	600	1x600	n.a.
Longkou Phase 3	200	1x200	n.a.
Zaozhuang	2.4	1x2.4	Imatran Voima Oy (Finland), Tomen (Japan)
Pingdu City	n.a.	n.a.	Huaneng International Power Dev. Corp.
	(MW)	(No. / Size)	

Compiled through survey of project finance literature, 1999.
Note: Qingdao Phase 1 is a natural gas turbine plant.

6 Compiled through survey of project finance literature, 1999. Ongoing. Note: Qingdao Phase 1 is a natural gas turbine plant.

China had twenty-two power companies listed on domestic stock markets in Shanghai and Shezen in 1993. Shandong Huaneng Power Development Corporation was one of three power companies listed in foreign markets that year. Apparently neither domestic nor foreign-listed companies have fared extraordinarily well in terms of market valuation (China Infrastructure, 1997).

Shandong's Fuel Supply Situation

One of the key topics determining what range of resource options to consider, and whether fuel supply as well as electric supply and demand options will also need detailed consideration, is the diversity, availability and robustness of current fuel supplies. The following sections provide a brief overview of the primary energy supply categories. While Shandong has more indigenous fossil resources than most other provinces, due to the size of their population and economic output, fuel supply and transportation issues remain important.

Coal

While China's mainstay of coal production is Shanxi Province, several coal mining operations are located in Shandong. Yet, Shandong imported 43% of the coal it used from other provinces in 1994 (Zoo, 1996) mainly Shanxi (Sinton, 1996). Coal mined in northern China is high in quality, with an average gross calorific value of 21 GJ/tonne, and less than 1% sulfur content.

Oil

With respect to China as a whole, Shandong has much more oil than natural gas or coal. For example, Shandong contributed 22.5%, 8.2% and less than 6% respectively to China's overall oil, natural gas and coal production figures in 1993 (Sinton, 1996).

Natural Gas

The U.S. Department of Energy's Pacific Northwest National Laboratory (PNL), the Energy Research Institute of China, and the Beijing Energy Research Center recently produced a report entitled "China's Electric Power Options: An Analysis of Economic and Environmental Costs." Though natural gas accounted for 2% of China's energy use in 1997 (Russo, 1999), according to PNL it could supply up to one-third of China's electricity needs by 2020 (China Infrastructure, 1998).

<u>Proven Reserves</u>. Proven reserves estimates of natural gas in China range from 1.2-5.3 trillion cubic meters, though 1.7 trillion is the figure most frequently cited. Output from onshore reserves predominates. Sichuan Province currently contributes 40% of China's total natural gas reserves, all of which comes from non refining-related sources. Shaanxi, Gansu, Ningxia Hui and Xinjiang Uygur also account for some onshore production, though natural gas from these areas is derived from refining byproducts. China's proven offshore natural gas reserves are clustered in the South China Sea and Donhai regions. The promise of further natural gas discoveries through advanced exploration technologies is high, especially given the size of China's known fossil deposits.

TABLE ELEVEN: Commercial Fuel Production: Shandong Province vs. China (1993)

	Commercial Fuel Production (1993)					
	Coal		Oil		Natural Gas	
Shandong	68.0	5.9	32.7	22.6	1.4	8.2
China	1151.0		145.0		16.8	
	(Mt)	(%)	(Mt)	(%)	(bcm)	(%)

(Sinton, 1996)

TABLE TWELVE: Net Coal Production by Province (1990)[7]:

Planning Region	**Province**	**Raw Coal Production**		**Coal Consumption**		**Balance**
North	Beijing	9.1	0.9	23.1	2.3	-14.0
	Tianjin	n.a.		17.3		n.a.
	Hebei	64.3	6.6	77.6	7.8	-13.3
	Shanxi	246.5	25.2	72.5	7.3	174.0
	Inner Mongolia	37.4	3.8	34.0	3.4	3.4
Northeast	Liaoning	45.9	4.7	79.3	8.0	-33.4
	Jilin	22.3	2.3	36.2	3.6	-13.9
	Heilongjiang	71.7	7.3	55.9	5.6	15.8
East	Shanghai	n.a.		24.7		n.a.
	Jiangsu	23.3	2.4	60.7	6.1	-37.4
	Zhejiang	1.4	0.1	23.4	2.4	-22.0
	Anhui	30.5	3.1	31.6	3.2	-1.1
	Fujian	8.5	0.9	12.1	1.2	-3.6
	Jiangxi	20.5	2.1	23.2	2.3	-2.7
	Shandong	**55.6**	**5.7**	**64.7**	**6.5**	**-9.1**
South -Central	Henan	82.5	8.4	62.7	6.3	19.8
	Hubei	10.0	1.0	33.7	3.4	-23.7
	Hunan	35.6	3.6	41.1	4.1	-5.5
	Guangdong	9.3	0.9	22.8	2.3	-13.5
	Guangxi	10.4	1.1	15.0	1.5	-4.7
	Hainan	0.0	0.0	n.a.		n.a.
Southwest	Sichuan	67.1	6.8	66.8	6.7	0.3
	Guizhou	32.1	3.3	23.9	2.4	8.2
	Yunnan	20.6	2.1	21.0	2.1	-0.4
	Xizang	0.0	0.0	n.a.		n.a.
Northwest	Shaanxi	27.7	2.8	25.5	2.6	2.2
	Gansu	13.6	1.4	17.1	1.7	-3.5
	Qinghai	2.7	0.3	4.5	0.5	-1.8
	Ningxia	13.3	1.4	7.3	0.7	6.0
	Xinjiang	18.1	1.9	16.0	1.6	2.1
National Total/Average		979.9	100.0	993.5	100.0	-13.6
		(Mt)	(%)	(Mt)	(%)	(Mt)

(Sinton, 1996)

7 National production and consumption figures differ due to transportation and processing losses, net exports and net changes in national stockpiles. Provincial figures do not sum to national totals due to discrepancies from conversion to units of 'standard coal' and because statistical coverage is not consistent across Chinese provinces.

TABLE THIRTEEN: Major Coal Mines in Shandong (1992)

Major Coal Mine	Raw Production
Yanzhou	10.9
Xinwen	7.2
Zaozhuang	5.8
Zibo	4.5
Feicheng	3.8
Total	**32.1**
	(Mt - 1992)

(Sinton, 1996)

Domestic Natural Gas Infrastructure Development. Obstacles to a substantive gas infrastructure development commitment in China have been difficult to overcome. These include China's past dependence on conventional fossil generation, an absence of consensus over administrative control of a national natural gas distribution system (China Infrastructure, 1998), and a lack of domestic gas turbine manufacturing capability (Russo, 1999). These barriers notwithstanding, foreign investment deterrents may constitute China's biggest impediment to expansion of natural gas markets. (More below.)

Liquid Natural Gas Imports. China does not currently import liquid natural gas (LNG), though its industrialized coastal provinces are well-situated for LNG delivery via "thermal flask" ships, which is cheaper than pipeline delivery. China's Ninth Five Year Plan does call for the construction of three LNG terminals on the South China Sea for operation beginning 2002-2005.

Transnational Pipeline Prospects. With combined proven reserves of 56 trillion cubic meters, Russia and Kazakhstan are China's nearest potential sources of natural gas imports. The Irkutsk Basin gas fields near Siberia's Lake Baikal lie 3000 km from Beijing (China Business Review, 1998), and have been estimated to contain 30% of the world's reserves. China and Russia signed a memorandum of understanding in 1997 to build a $12 billion pipeline from Siberia to China's Pacific coast, and both Japan and Korea hope to cooperate in the venture. Alternatively, China could construct a 6000 km pipeline from Kazakhstan to its eastern coast. The World Bank has predicted that this undertaking would deliver 28 billion cubic meters per year at a cost of $3 per MMBtu.[8]

According to the Advanced International Studies Unit of the PNL, obstacles to foreign investment in natural gas exploration and development in China include:

- Return on equity limitations,
- Relegation of natural gas to selected industrial uses,
- Fuel price distortions,
  At $1.60-$1.90 per MMBtu, average prices for natural gas in China are currently below international levels of $2.50-$3.00 per MMBtu. Competing uses and subsidizations, for China's fertilizer industry is natural-gas fired for example, create disincentives for expansion and more efficient use.
- Inconsistent transmission and distribution tariffs,

[8] MMBtu = million British Thermal Units

- Lack of field data accessibility,
- Lack of incentives to pursue coal bed methane or employ liquefaction technologies, and
- Bureaucratic opacity.

Though foreign investment issues persist, many multinational energy companies are engaged in on and offshore natural gas exploration in China. Active firms include Unocal, Chevron, BP-ARCO and the Kuwait Foreign Petroleum Exploration Company (Logan and Chandler, 1998). In addition, a subsidiary of Enron Corporation recently signed a memorandum of understanding with China National Petroleum Company (CNPC) for 45% ownership of a $400 million natural gas pipeline. The jointly constructed project will stretch 745 km to connect Chonqing and Hubei Provinces, and according to CNPC will mark the first onshore pipeline built in cooperation with a foreign company (Reuters, 1999).

Coal Bed Methane

China currently recovers approximately 500 million cubic meters of coal bed methane (CBM) annually, though has estimated ultimately recoverable CBM reserves to be 35 trillion cubic meters. China's coal mines contain over 15 cubic meters of methane per ton of coal, most of which is tapped and flared, even though methane's climate change potential is twenty times greater than carbon dioxide's. In 1998 Texaco entered into a $500 million contract with China United Coalbed Methane Corporation to recover an additional 500 million cubic meters annually from Anhui Province, which alone is thought to contain 60 billion cubic meters of CBM (China Business Review, 1998).

Overview of Alternative Generation Options

At present, the preferred fuel supply for power generation is coal. Shandong and other Chinese electric utilities are reviewing a wide variety of coal-based technologies as they rapidly expand their power generation capabilities. In addition to the more conventional pulverized coal with flue gas desulfurization (FGD), fluidized bed combustion (FBCs) and integrated gasification combined-cycle (IGCC) technologies are also under consideration. Application of FGD and other environmental control technologies are also a high priority from an environmental management perspective. Even so, coal transportation, water consumption and other environmental considerations have Chinese electric power professionals looking at alternatives sources of power generation.

Nuclear

Though the State Development Planning Commission hopes to increase nuclear generating capacity nationwide, capital requirements are prohibitive at 70% more than thermal plant development costs (China Infrastructure, 1998). China has commissioned only two nuclear plants thus far in Zhejiang and Guangdong Provinces, which accounted for 1.4% of China's generating capacity in 1995 (Business China, 1995)[9]. Four others are under construction and due to come on line in 2003 and 2004, in Quinshan (2

9 In 1995 Beijing Review reported that a preliminary feasibility study for a nuclear power station in Shandong had passed state examination, though our review of current literature has yielded no further information on the status of the proposed Shandong facility.

plants), Guangdong and Jiangsu Provinces. These plants have been largely financed by foreign commercial loans and export credits (China Infrastructure, 1997).

Hydroelectric Power

Shandong also has a modest hydropower potential of 1 GW (Sinton, 1996),[10] though given the extent of hydroelectric exploitation upstream on the Yellow River as well as the region's water shortages further development may be limited. However, the Shandong Electric Power Group Corporation (SEPCO) has plans to initiate construction of a pumped storage facility in 1999 (SEPCO, 1999).

Barriers to the development of low-emissions distributed generation in China include an institutional preference for large fossil projects as well as an institutional approach that favors centralization. In addition, renewables projects tend to lack financial wherewithal more than conventional ones (Borray, 1995).

Windpower. At an estimated resource potential of 253 GW, wind may represent China's biggest renewable resource (China Infrastructure, 1997). In 1998 China's grid-connected wind capacity was only 200 MW, though that year the state announced its Cheng Feng (Ride the Wind) program, which calls for 1000 MW of installed capacity by 2000. Current capacity is concentrated primarily across Inner Mongolia, though there are currently three 55 kW Danish Vestas 55/11 turbines on Shandong's Rongcheng island (International Energy Agency, 1996), as well as a demonstration wind-farm in Pingtan of ten 30 kW Belgian Aeroman turbines (International Energy Agency, 1996).

Windpower also represents a manufacturing opportunity in China. Tens of thousands of small-scale wind generators are produced annually for agricultural applications, and in 1998 a Danish-German-Chinese contract was signed to manufacture utility-scale wind turbines in China (China Infrastructure, 1997). By circumventing import duties, domestic manufacturing capability may ease the historically high costs of renewably-generated electricity in China, which in 1996 exceeded costs abroad by 30%. However, VATs continue to be charged on electricity sold to power networks irrespective of fuel source. Furthermore, a unified accounting scheme that enables fuel cost deductions to reduce VAT liabilities may inadvertently penalize "fuel-free" providers (International Energy Agency, 1996).

Solar and Other Renewables. China's Ninth Five Year Plan also addressed solar, calling for the construction of 10 million square meters of passive solar housing by the end of 2000 (International Energy Agency, 1996)[11]. It also lists other renewables such as biomass, geothermal and ocean generation. As with all renewables, knowledge of local resource availability is key to sizing renewable resource options. Also essential is an understanding of the diurnal and seasonal availability of these resources, and the coincidence with the need for energy and electricity in the province.

10 The reference does not specify from which Shandong river this hydropower comes.

11 Area is assumed to be floor area of housing, though this is not specified.

TABLE FOURTEEN: Renewable Capacity Expansion Projections of Ninth Five Year Plan (MW)

	1994 Capacity	Projected Capacity Additions '94-00	'01-'10	'11-'20	Total 2020	National Resource
Wind	30.4	1010	2130	5330	8500	250000
Solar	3.3	66	130	300	500	450-1200
Geothermal	30.4	76	94	130	330	500
Biomass	7.1	13	25	55	100	700-900
Ocean	6.0	34	160	200	400	9830

(MWs)

(International Energy Agency 1996)[12]

Environment

Chinese Household Characteristics and Pollutant Exposure.

Average Chinese family size was reported to be 3.3 people per household in 1993. The demographic implications of this number are significant. It indicates that, in contrast with most other developing nations, China will have a more even population distribution. In the future, China may face the same aging population problems currently facing OECD countries, but with significantly higher population density and pollution exposures. With average annual household expenditures on water and electricity only about 2% of annual income (38.26 Yuan), due in part to subsidization (Sinton, 1996), coordination between economic and environmental policies need to be addressed. Better knowledge about exposures, and their resulting health and economic impacts, is needed, especially as exposures may differ markedly in the home, in the workplace and via mode, location and distance of transportation.

TABLE FIFTEEN: Indoor Air Quality in Rural Chinese Households Using Coal for Heating (1995)

Pollutant	Range	Unit
Carbon Monoxide	0.58-0.97	mg/m^3
Sulfur Dioxide	0.01-5.80	"
Nitrogen Oxides	0.01-1.80	"
Particulate Matter	0.16-0.27	<= 10 Microns
Benzopyrene	000.3-190.0	ng/m^3

(Sinton, 1996)

Air Quality

China is the world's third largest contributor of anthropogenic CO_2 emissions, 95% of which come from fossil fuels combustion. Though SO_2 emissions declined in China during the 1980's (Sinton, 1996), acid deposition was identified in the 1990's as a

12 Solar capacity includes thermal and PV. The source does not specify whether given units are peak or average megawatts.

problem in Shandong. As the geographical distribution of particulate emissions tends to follow that of sulfur dioxide, Shandong also has one of China's highest particulate emission densities (Sinton, 1996). Though more closely associated with vehicles, nitrogen oxides emissions have also been increasing in China in step with rising incomes. Yet, only several Chinese cities recorded regular NO_x exceedences in 1995.

TABLE SIXTEEN: Indoor Air Quality in Rural Chinese Households Using Coal for Heating (1995)

Air Quality (Jinan, 1992)		
SO2	NOx	Acidity
226	74	5.17-7.24
(Point Scale)		(µg/m^3)

The National Environmental Protection Agency ranks Jinan fourth among the 37 "most environmentally stressed cities in China. Jinan not only has a high concentration of industrial and residential boilers, it experiences over 200 days of inversion each year" (World Bank, 1999). In addition, Jinan suffers from a scarcity of both surface and groundwater resources.

TABLE SEVENTEEN: Average 24-Hour Ambient Air Quality in Shandong (1992) [13]

Pollutant	Jinan	Qingdao	Standard	Unit
Sulfur Dioxide	226	207	150	(mg/m^3)
Nitrogen Oxides	74	51	100	(mg/m^3)
Total Particulates	642	177	300	(mg/m^3)
Carbon Monoxide	n.a.	2.6	4	(mg/m^3)
Acidity of Precipitation	5.17-7.24	n.a.	n.a.	(tonne/ km^2/mo/).

(Sinton, 1996)

Water Supply

China's per-capita water resources are only 25% of the world's average[14]. Additionally, China's rivers and groundwater resources are distributed poorly with respect to its population centers. While the area north of the Yangtze contains over half of China's population, it contains only 19% of its water. Thus in Beijing, for example, annual per-capita water resources amount to just 5% of the world's average. State water price controls and a lack of conservation programs exacerbate the situation. In contrast, recent reforms set Qingdao city's water prices at $.20 per cubic meter, $.08 higher than China's average. Qingdao's water usage is now reportedly more efficient than any other city in China (China Infrastructure, 1998).

13 Standards quoted are 24-hour average, Chinese Class II standards. These are modeled on US NAAQS, and are intended to protect human health in residential areas. China's class I standards apply to scenic, tourist and sensitive areas, whereas Class III standards are used as interim targets for heavily polluted areas.

14 The source does not specify whether 'resources' include ground and surface water resources.

Ironically, China's big rivers have been historically characterized by both severe drought and major flooding due to heavy silt deposition, which has the effect of driving rivers from the confines of their banks or levees. As home to the lower reaches of China's second most powerful river, Shandong Province has always borne the severe drought-flood cycles of the Huang He. In recent years droughts have prevailed. In 1997 a 700 km stretch of the Yellow river was completely dry for 188 days, the longest period ever recorded (China Infrastructure, 1997). Nonetheless, the state's 1995 master plan proposed 27 dams be built on the Yellow River. Seven of them were completed by 1997 (World Bank, 1999), including one across the dry riverbed delta near Shandong's Shengli oilfield (China Infrastructure, 1998). Currently under construction and second in size only to the Three Gorges Dam, the Xiaoliangdi Dam will block sediment and generate 1800 MW of electricity in Henan province (World Bank, 1999).

<u>The Yellow River Delta Project</u>. In 1997 the UNDP, the China International Center for Economic and Technical Exchanges, and The Yellow River Delta Conservation and Development Research Centre published "Support for Sustainable Development of the Yellow River Delta." The report outlines Dongying Municipality's and the area's strategy for long-range integrated regional planning that encompasses sustainable economic, environmental and social development. While the project's focal point is Dongying's recurring seasonal water shortage, the report does mention plans to add 750 MW of generating capacity at the nearby Shengli Power Plant before 2000 (UNDP, 1997).

Shandong Environment Project

To combat further environmental deterioration in Shandong, three municipalities and the provincial government initiated the partially World Bank-financed $215 m Shandong Environment Project in 1995. The Project generally aims to address air pollution, acid rain, groundwater supply and wastewater treatment issues. Specific investments will go toward:

- Air pollution control, wastewater treatment and surface water storage in Jinan,
- Municipal district heating and cogeneration in Wehai,
- Municipal district heating and peak boiler systems in Yantai,
- Administrative, regulatory and infrastructure management capacity-building in all three cities (World Bank, 1999).

China's Environmental Protection Law

China formalized its comprehensive Environmental Protection Law in 1989, though its style is broad and generalized. Some provisions are:

- Devolution of environmental regulatory authority to the provinces,
- Allowance for provinces to set emissions standards more stringent than national standards,
- Requirement for environmental impact assessments at provincial level for smaller projects, and through the State Environmental Protection Administration for larger projects,
- Provision for penalties for compliance failures (Business China, 1996).

Conclusion

This document is intended to serve CETP research teams as 1) an orientation to the economy and status of the environment in Shandong province, 2) an overview of China and Shandong's energy sectors and 3) a qualitative characterization of Shandong's electricity infrastructure and load characteristics. As such, it is intended to aid our next phase of research as we work with Chinese stakeholders to specify attributes and formulate scenarios that will initiate more extensive electric sector analysis.

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References

Asian Development Bank, Electric Utilities Databook (Manila, Philippines, 1997).
Beijing Review, "Shandong Sets Key Foreign-Funded Projects," May 11-17, 1998, pg. 26.
Borray, Edward, "Structural Change in the PRC," Independent Energy 25(6): 24-28.
Business China, Power Supplement, spring 1995, pg. 1-7.
Business China, "Environmental Regulation: Through the Labyrinth," April 1, 1996, pg. 9-10.
Business China, "The Shengli Oil and Petrochemicals Complex: Extracting Itself from its Past", August 5, 1996, pg. 8-9.
Business China, "Shandong Huaneng Power Development, Provincial Power," December 9, 1996, pg. 8-9.
Business China, "China Reorganizes its Energy Sector: Change for the Better?" January 22, 1996, pg. 6-7.
Business China, " Qingdao: Investors at Last," May 1, 1995, pg. 8-9.
Business China, "Development Zones: Ripe for Investment", May 27, 1996, pg. 8-9.
Chen, Weixing, "The Political Economy of Rural Industrialization in China," Modern China 24(1): 73-96.
Chen, Weixing, "Politics and Paths of Rural Development in China: The Village Conglomerate in Shandong Province," Pacific Affairs 71(1): 25-39.
China Infrastructure 2(6): pg. 2.
China Infrastructure 2(11): pg. 8.
China Infrastructure 2(3): pg. 3.
China Infrastructure 3(4): pg. 8.
China Infrastructure 2(10): pg. 3.
China Infrastructure 2(8): pg. 5.
International Energy Agency, Energy Efficiency Improvements in China (Beijing: Chinese State Planning Commission, 1996).
Jiacheng, Zhang and Zhiguang, Lin, Climate of China (Shanghai: Scientific and Technical Publishers, 1992).
Logan, Jeffrey and Chandler, William, "Natural Gas Gains Momentum," China Business Review, August, 1998, pg. 1-7.
Modern Power Systems, "Chinese Boiler Contracts: Persistence Pays Off" 18(8): 33.
Reuters, April, 1999.
Russo, Christopher J., A Multi-Attribute Analysis of Electrical System Expansion Options for China (Cambridge, MA: Massachusetts Institute of Technology, 1999).
Shandong Electric Power Group Corporation (SEPCO) overview and website, www.sepco.com.cn.
Sinton, Jonathan, China Energy Databook (Berkeley, CA: Lawrence Berkeley Laboratory, 1996).
Atiyah, Leffmand and Lewis, China: The Rough Guide (London: Penguin Books, 1997)
Singapore-Shandong Business Council, 1999, www.ssbc.tdb.gov.sg/sd (accessed 4/8/99).
State Statistical Bureau, The Basic Situation of Industrial Enterprises of the People's Republic of China: Electric Power Volume, pp. 254-268. The Third National Survey of China's Industries, 1996.
Triolo, Paul S., "The Shandong Experiments," China Business Review 23(5): 12-13.
United Nations Development Programme, Support for Sustainable Development of the Yellow River Delta (Dongying, Shandong, China: 1997).
World Bank, China: Power Sector Regulation in a Socialist Market Economy (Washington, DC: 1997).
World Bank, China-Shandong Environment Project, CNPA40185, 1999, pg. 1.
World Bank, China- Xiaolangdi Multipurpose Project Stage II, CNPE34081, 1999, pg. 1-2.
Yantai SMR International Information and Staffing Consultancy Company, Ltd., www.smrintl.com (accessed 4/8/99).
Zou Yongxin, "Scaleup in Shandong", Independent Energy 26(6): 10-12.