Planning for Economically and Environmentally Sound Electricity Service in Shandong Province, China

by

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ABSTRACT

This thesis specifies, simulates and examines a number of electricity service expansion scenarios for Shandong Province, China. In this exercise it communicates how a selected assortment of generation and end-use efficiency strategies will perform over alternative 25-year futures with respect to cost and emissions goals identified by the provincial utility and project's primary client, Shandong Electric Power Group Corporation (SEPCO). For context it chronicles the expansion of electricity service in Shandong during China's post-Mao era of market reforms, and juxtaposes China's imperative for continued economic growth with Shandong's struggle to address the severe health and environmental impacts of its historical reliance on coal combustion for electricity generation. Using SEPCO's existing practices and articulated strategy as two reference cases, it then investigates the firm's options for modifying planning practices in light of four likely phenomena that will influence its operating environment over the course of the study period. To represent the hypothesized influence of these factors on SEPCO, it specifies and generates a set of scenarios crafted to model the particular impacts on the utility of China's 1) pending accession to the World Trade Organization, 2) ongoing financial market reforms, 3) introduction of electric sector restructuring and 4) implementation of stricter pollutant emissions enforcement. It finds SEPCO should be able to maintain or slightly reduce long-term unit costs over a growing rate base by virtue of efficiency gains derived from replacing its generating stock. However, aggressive end-use efficiency, risk management and organizational change at the firm level, as well as continued institutional and policy reform at the national level will be essential if these events are to have a positive impact on Shandong's and China's endemic environmental issues.

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I would like to dedicate my thesis, and this year spent here in Cambridge with Mom and Bill (I couldn't have done it without you), to the memory of Phil Krous.

We love you and miss you so.

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Chapter One- Introduction and Background

1.1 Introduction

Many of the world's expectations and concerns about China hinge on energy-related issues. As the world's largest country on a population basis, China is also poised to be the world's largest market as it moves to join the World Trade Organization (WTO) and further the impressive economic growth achieved in the 1980's and 1990's under Deng Xiaoping.

Because its coal resources are estimated to be second in size only to those of the former Soviet Union, the strict availability of energy is not an impediment to the growth China hopes to maintain. However, a limited rail network, scarce water resources, interregional transmission constraints and intraprovincial load management issues threaten both system reliability and scalability. In addition, China faces serious domestic concerns over the health and environmental impacts of coal combustion by the electric sector among others, and international pressure over its contribution to climate change.

Yet, China's relative lack of access to alternative fuels in the near term and its focus on maintaining economic productivity constitute significant barriers to its desire to simultaneously transition to a more energy efficient and less fossil fuel-intensive electricity service regime. Moreover, the prospect that China unilaterally executes on plans for a greener infrastructure to power its anticipated long-term growth is financially and institutionally impractical.

This thesis examines China's electricity service dilemma on a smaller scale. With a population of nearly 90 million and average annual GDP growth in excess of 10% this past decade[1], Shandong province typifies the energy and environmental challenges China faces as a whole. Long characterized by a shortfall, Shandong's installed capacity has only in the past several years caught up with demand given the economic dampening effect of the Asian currency

[1] Singapore-Shandong Business Council, 2/99.

crisis[2]. However, Shandong's quality of service is now constrained just as in China at large by 1) an inefficient transmission and distribution infrastructure[3], 2) an ambiguous foreign investment environment[4], 3) an underdeveloped regulatory regime in the energy sector[5] and 4) insufficient peaking capacity[6]. In addition, Shandong suffers from the poor air quality and scarce water resources typical of China's industrial northeast[7], though coal combustion is unfortunately both emissions and water-use intensive. And, as China's second most economically productive province[8] its role in China's growing share of anthropogenic greenhouse gas emissions is of growing concern.

Given Shandong's prominence as a progressive and economically important province, and because its territorial boundaries match those of its power grid, it was chosen in 1999 of the Alliance for Global Sustainability as the subject of the China Energy Technology Program (CETP). AGS is a research consortium funded by foundations and industry and comprised by research teams from the Massachusetts Institute of Technology, the University of Tokyo and the Swiss Federal Institutes of Technology. CETP is a broad energy and environmental research initiative encompassing analyses from environmental impact assessment, to life-cycle assessment and technological risk analysis for Shandong's power supply and demand chains. Through a research team at MIT's Energy Laboratory I have been engaged in an Electric Sector Simulation task for CETP. This task, described below, entails simulating the provision of electricity over a 25-year timeframe (2000-2024) for the Shandong Electric Power Group Corporation (SEPCO)[9],

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[2] Economist Intelligence Unit, p. 8.
[3] Blackman and Wu, pp. 2-7.
[4] Guohua, pp. 4-14.
[5] World Bank, p. iii.
[6] SEPCO Officials, 2001.
[7] China Infrastructure, p. 2.
[8] Chen, Weixing, Modern China. P. 74.
[9] SEPCO is also CETP's primary client and subject of its other various energy and environmental analyses.

which owns and operates Shandong's grid as well as controls the majority of the province's generating assets.

For this thesis I specify and compare fourteen electricity service planning scenarios to two base-case scenarios established by SEPCO and CETP as alternative benchmark or reference cases. The first reference case represents a SEPCO that continues, as it has historically, to rely almost exclusively on coal-fired baseload generation. The alternative reference scenario reflects SEPCO's recently articulated plans to incorporate some nuclear baseload as well as some methane-fired power imported from western provinces -or 'gas by wire'- into its generating portfolio. Chapter 4 presents the ingredients of and assumptions behind both reference cases.

In order to represent how SEPCO's operating environment will evolve over the study period, I categorize the comparison scenarios into four subsets which reflect the evolution of several likely phenomena in China, namely 1) accession to the World Trade Organization, 2) financial market liberalization, 3) electric sector restructuring and 4) stricter sulfur emissions limits enforcement. In addition to each of these subsets I also analyze two consolidated scenarios so as to represent these event streams as concurrent phenomena. Chapter 4 also details the ingredients of and assumptions behind the comparison and consolidated scenarios.

I begin my examination of the scenario subsets using multi-attribute tradeoff analysis to evaluate their performance on several broad cost and emissions metrics. In addition to highlighting some of the fundamental cost-vs.-environment tradeoffs SEPCO will have to make over the study period, this method informs a subsequent and more detailed investigation of the impacts of SEPCO's various planning choices as the above hypothesized events unfold. Finally, on the basis of the analysis in full I make some planning and operating recommendations for SEPCO going forward.

This thesis contains six chapters:

1.0 Introduction and Background

An understanding of China's unique blend of socialist and market principles informs an appreciation of the unique context within which SEPCO makes planning decisions. The first chapter provides an overview of Shandong and tells the story of the social and economic change behind its relatively recent modernization. The chapter also introduces China's energy and electric sectors, focusing in particular on the transition China has made from government-based to increasingly private investment in power generation infrastructure. To finish characterizing the backdrop for the simulation exercise, it also covers the key environmental issues China and Shandong face[10].

2.0 Shandong Electric Power Group Company (SEPCO)

Chapter 2 turns to Shandong's electric sector and to the Shandong Electric Power Group Company (SEPCO), CETP's primary client and subject of this analysis. It characterizes SEPCO's electricity service infrastructure that forms the baseline set of inputs for the simulation exercise, and explores the ownership structure of the generating units for which SEPCO dispatches. Finally, it surveys SEPCO's fuel base, and introduces the range of generating technologies SEPCO may feasibly choose from as it plans for electricity service over the next quarter century.

3.0 Rationales for Hypothesized Event Streams

This chapter moves from the baseline information offered in Chapter 2 to lay the logical groundwork for the simulation exercise. It thereby builds rationales for the hypothesized event streams I will model, and postulates their impact on SEPCO at an operational level.

[10] In Chapter 3 I look further into the environmental impacts of the power sector per se, whereas the introduction more generally considers the pervasive impacts of coal combustion in China for all purposes.

4.0 Description of Tool, Modeling Assumptions and Methodologies

This chapter describes the simulation software used, sets forth CETP's modeling assumptions and introduces the building blocks of scenario formulation. It also defines the two reference scenarios I use as benchmark cases, and distills the anticipated impacts of the four hypothesized event streams on SEPCO into modelable components of the comparison and consolidated scenarios. Finally, it describes how I approached and compared the simulation results.

5.0 Analysis

This chapter employs tradeoff analysis to communicate the results of the simulated scenario subsets with respect to SEPCO's operating costs as well as sulfur dioxide, particulate and carbon dioxide emissions. After this preliminary, orienting look at the data I further examine the subsets by comparing time series of metrics that feed into or are influenced by the coarser attributes first considered using tradeoff analysis.

6.0 Conclusion and Recommendations

This chapter reconsiders the scenario results and my analysis in the context within which SEPCO must make real operating and planning decisions. Again, I consider short and longer-term planning strategies that are and will be relevant as China accedes to the WTO, continues to implement financial market reforms, restructures its electric sector and introduces stricter emissions enforcement.

1.2 Basics

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 an aging and homogenous electricity infrastructure, large seasonal variations in water supplies and poor air quality, which Shandong is striving to reconcile with an imperative for continued economic growth.

1.2.1 Geography

Shandong Province sits, as shown in Figure One, on China's northeastern seacoast, southeast of Beijing, between Tianjin and Shanghai. Shandong's population numbered over 86.7 million in 1995[11] with a population density of 564 people per square kilometer[12]. Its capital city is Jinan, while its biggest city and predominant deep water port is Qingdao[13].

Shandong's land area covers 156,700 square kilometers,[14] and is roughly 620 km from East to West, and 420 km from North to South. Its primary river is the Yellow River (Huang He) which runs southwest to north central. The Yellow River delta is very dynamic, the result of large seasonal variations in flow and silt content, and empties into Laizhou Bay near Dongying

[11] Chen, 1998, in Modern China, p. 74.
[12] Sinton, 1996, p. X-31.
[13] Yantai SMR, 1998, www.smrintl.com.
[14] For comparison purposes, the U.S. State of Florida is about 152,000 square kilometers.

municipality. This delta also contains the Shengli oilfields, China's second largest oil reserve[15]. Shandong's other mineral resources include gold, sulfur, granite and diamonds, while its primary agricultural resources are produce, fish, wheat and cotton[16].

To the West of the Yellow River is the Shandong peninsula, marked by a hilly range also running southwest to northeast[17]. The most prominent feature of the peninsula is Tai Shan, which at 1545m (5069 ft) is one of China's five most holy Taoist mountains[18]. Along this axis, Shandong is roughly 750 km long (466 miles).

1.2.2 Weather

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[19], and summer accounts for 65% of its 68.5 cm of mean annual precipitation[20].

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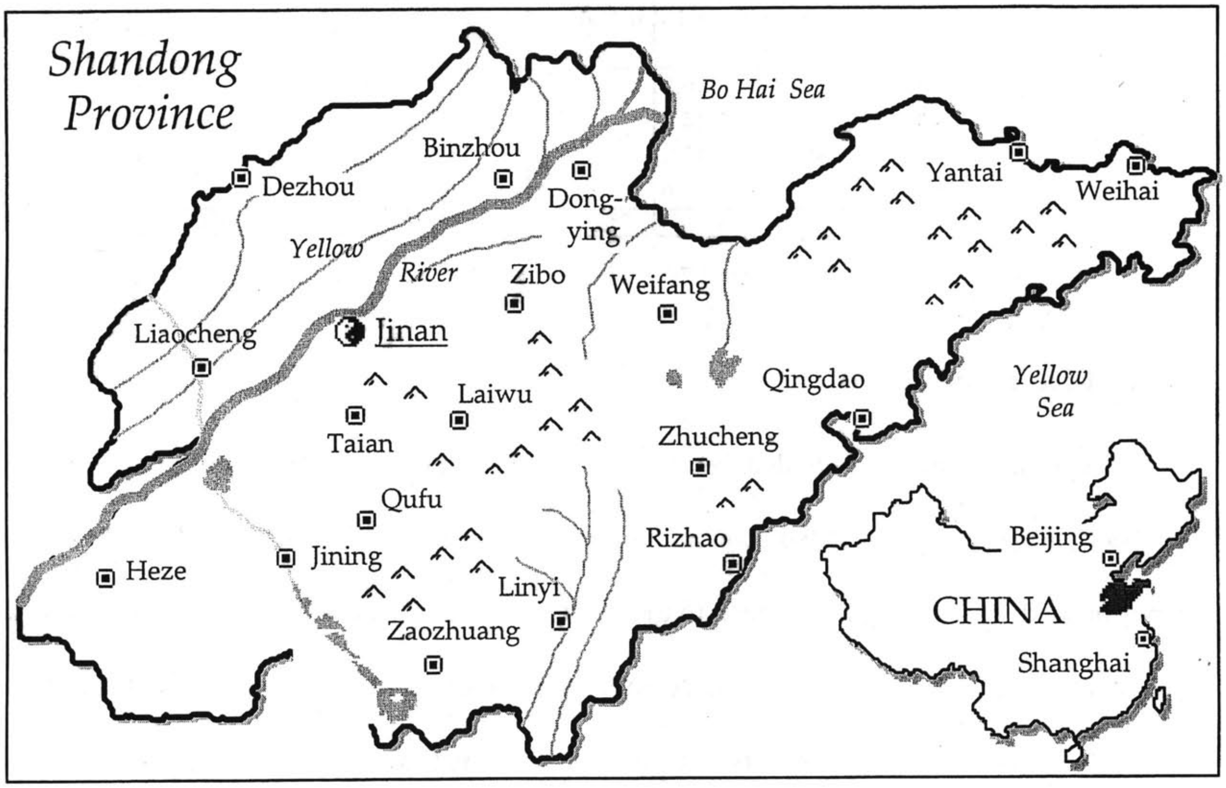
[15] Business China, 1996, p. 8.
[16] www.smirintl.com.
[17] Jiacheng and Zhiguang, 1992, p. 181.
[18] Atiyah, Leffman and Lewis, 1997, pp. 293-295.
[19] World Bank, 1997, China-Shandong Environment Project, p. 1.
[20] Jiacheng and Zhiguang, 1992, pp. 336-339.

Figure One: Shandong



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1.2.3 Economy

Shandong enjoys a healthy and diverse economy, ranking second in provincial GDPs for 1993 and second in per capita income for 1996[22]. Because it is coastal and close to Japan and Korea, it is geographically well situated for its focus on exports. Primary exports include oil, textiles, chemicals, consumer products, paper, machinery, electronics and building materials[23]. Table One shows some key economic statistics for the province.

[21] Connors, 1999.

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)	([2]%/yr)	([2]%/yr)	(B Yuan)	([2]%/yr)	(B Yuan)	([2]%/yr)

Note: %/yr. changes are in real terms over previous year or corresponding period of previous year.[24]

1.2.4 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[25]. 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. They 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.

[22] Triolo, 1996, p. 13.
[23] Singapore-Shandong Business Council, 1999, www.ssbc.tdb.gov.sg/sd.
[24] www.smrintl.com.

- 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[26].

- 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[27].

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[25] Chen, 1998, in Modern China, p. 73.
[26] Beijing Review, 1995.
[27] Business China, May 27, 1996, p. 8.

1.3 Socialist Market Reform

An interesting aspect of China's remarkable transition from a Soviet-style planned economy was its rapid mobilization of rural 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[28]. Agriculture, livestock, forest and fishery products comprised 33% of this value, and 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 (VCs). 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[29].

1.3.1 Village Conglomerate Evolution

Another remarkable fact of China's rapid economic transition is its roots in a collectivist labor regime. 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

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[28] Chen, 1998, in Pacific Affairs, p. 26.

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 HRS, 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.

1.4 China's Energy Sector

China's provident coal endowment fueled great industrial growth in the mid twentieth century, and continued to feed its economic transition after Mao's death. As Figure Two shows, though 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.

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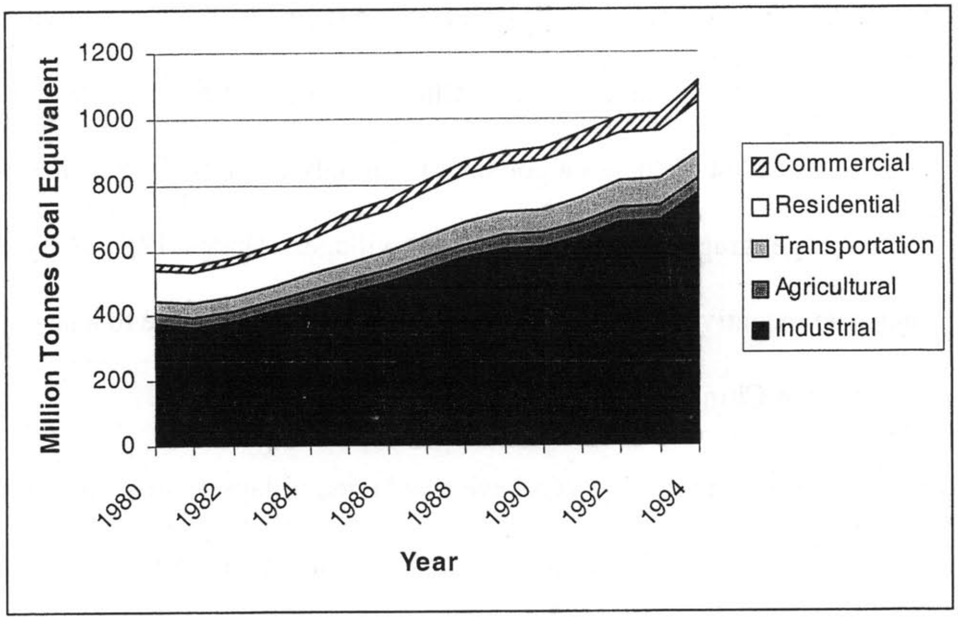
[29] Ibid.

Figure Two: China's Energy Consumption by Sector, 1980-1994



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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.

[30] Sinton, 1996, p. IV-27. Note: 1993 data inferred from 1992 and 1994 data.

Table Two: 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)

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1.5 China's Electric Power Sector

Though China has striven to manage an even progression of electricity service expansion through the provinces as its main regional fiscal and administrative units, the power sector grew quite rapidly and has coalesced more clearly around areas of economic productivity. Given China's population, its system is now the world's second largest (second to the US).

Table Three: China's Actual and Projected Electricity Networks (1995)[32]

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)	(2%)

[33]

China's power sector regulations are in a similar state of flux as its overall economy given the state's incremental approach to integrating planned growth with market precepts. Chapter 3 discusses China's recent separation of productive from regulatory functions in the power sector, and presents its plans as it looks into further restructuring and reregulation.

1.6 Private Power

Though the regulatory environment by definition governs industry structure and protects the public, changing ownership structures in generating capacity are increasingly driving how China's power industry operates. This section provides some background on the evolution of private power investment in China, while Chapter 2 looks more closely at ownership structures among the plants on SEPCO's grid.

[31] Sinton, 1996, p. IV-24. Note: time series of same data not provided by source.
[32] 2000 figures were Ministry of Electric Power projections in 1996.

1.6.1 History of Direct Foreign Investment in China's Electricity Sector

Prior to 1980 China's central government financed, constructed and took in revenues from all power projects. When faced with an acute electricity shortage in the early 80's[34], China began encouraging limited direct foreign investment (DFI) in power projects with concessional financing from mulitlateral lenders such as the World Bank's International Finance Corporation and Asian Development Bank. In 1985 the People's Construction Bank began supplementing these efforts with long-term infrastructure loans[35].

Throughout the 80's and early 90's China continued to leverage foreign capital from the development bank community as well as through selective DFI. Reforms instituted toward this end included an electricity tariff increase in 1993 and a 1995 announcement of the intention to issue explicit Build-Operate-Transfer regulations. In addition, China is looking into restructuring the power industry, as further discussed in Chapter 3.

By 1995 China boasted an estimated 400 to 500 private power projects in some phase of negotiation. Yet by 1996, a full 85% of the $14.3 billion in foreign investment in China's power infrastructure came from development banks, with only 15% attributable to DFI in the purest sense[36]. Figures reported by the US Department of Commerce via the Chinese Statistical Bureau would support the existence of a disconnect between pledged and utilized power project DFI in China. In 1997 $23 billion was reportedly contracted yet only $15 billion actually utilized[37].

1.6.2 Current Degree of Market Penetration

According to a 1998 survey conducted by International Private Power Quarterly, 24 partially privately-invested power plants with a combined capacity of 4.9 GW were operational

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[33] Business China, 1995.
[34] Merril Lynch, 1998 p. 13.
[35] US Department of Commerce, 1999, p. 3.
[36] Blackman and Wu, 1998, p. 8,

by mid-1998, though another 9 GW comprising 12 plants were under construction. Taken together these 36 operational and pending plants would constitute over $11 billion in foreign investment, though would comprise just 4.4% of China's projected generation capacity for 2000.

US companies dominate DFI in Chinese power generation, and investment is highly concentrated overall, with four firms accounting for roughly half of the projects surveyed. The majority of the 24 plants operational in 1998 were concentrated along China's east coast, and over 60% of these were under 100 MW in capacity. In addition, only half of the operational plants were coal-fired, as imported gas and oil stations are easier to finance and construct. By contrast over 40% of the plants under construction were over 300 MW in capacity, and were more geographically dispersed as well.

1.6.3 Legal Vehicles for Private Power Investment in China

Chinese law allows for seven types of foreign participation in power markets. The categories are not mutually exclusive, and the following sections discuss their implications for investors more thoroughly:

1) wholly-owned foreign ventures

2) cooperative joint ventures

3) equity joint ventures (participation limited to equity only, no managerial purview granted)

4) build-own-transfer (BOT) projects

5) build-operate-own (BOO) projects

6) commercial loans

7) participation through stock and/or bond purchases

China was a very geographically, culturally and economically insulated society for centuries, and self-reliance is ingrained in its national character. Its historical reluctance to open

[37] US Department of Commerce, 1999, p. 3.

its borders to outside influence[38] is reflected in foreign investment patterns in the electricity sector, and wholly-owned foreign ventures are quite rare. Thus, though they afford foreign participants less control, cooperative joint venture arrangements predominate among private power projects in China. The presence of Chinese partners -many of whom are direct affiliates of provincial governmental bodies or the State Power Corporation itself- is apparently critical to securing necessary political alliances -known as *guangxi*- as well as access to fuel and foreign exchange.

The second most popular form of private participation is via equity joint ventures, though growing numbers of recent approvals for projects in the wholly foreign-owned, BOT and commercial loan categories may indicate the sector is liberalizing to a greater extent[39].

1.6.4 Historical Challenges to Sound Private Power Investment in China

The gap between contracted and utilized foreign funds in China's power sector has been exacerbated in China by several factors that have worked to drive investors away:

Ownership Restrictions

In 1994 China issued Interim Regulations for the Use of Foreign Investment for Power Projects. They mandated that Chinese partners in non-BOT joint ventures maintain controlling interests in plants with single unit capacities at 300 MW or larger, or with overall capacities of 600 MW or larger. In addition, the regulations restricted foreign ownership in existing facilities to under 30%, yet permitted wholly-owned ventures of any size. Thus, foreigners have been relegated either to minority positions in larger plants, or to full ownership which then precludes the guanxi so vital to project success.

[38] Harvard Business School, 1997, pp. 1-10.
[39] Blackman and Wu, p. 9.

Rate of Return Restrictions

In 1993 the State Planning Corporation stopped approving projects with rates of return in excess of first 12% and then 15%. As 20% rates of return in other Asian private power projects is common, many investors may have simply lost interest in China. And, because units under 300 MW do not need central planning approval, this policy may further encourage an institutional bias in China (and Shandong) towards the construction of smaller plants.

Cumbersome Project Approval Requirements

The approval process is reportedly protracted and susceptible to corruption. Though procedures have been refined since the wave of private power interest China experienced in the early 1990's, it remains ill-defined, and can last between 18 and 60 months. In addition, as approval requirements are biased towards larger projects, exemptions for small scale proposals may undermine China's attempt to increase returns to scale in the electricity sector[40].

Lack of Tariff Reform

Electricity prices are controlled and subsidized throughout China at generally below-market levels. Resources for the Future guages prices to be 10 to 15 percent below long-run marginal costs in coastal provinces, and as much as more than 30 percent below marginal costs in China's interior. Though a 1995 Law on Electric Power allowed plants to negotiate tariffs with local authorities, they are subject to the additional red tape this introduces as well as constrained by consumers' ability to pay given China's concern over keeping inflation in check.

Contractual Risk

Legal ambiguity and unfamiliarity with western contractual conventions tends to heighten private power project risk in China. In addition, there is a reported bias in China against the

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[40] Blackman and Wu, pp. 14-15.

negotiation of price-predetermined long-term power purchase agreements (PPAs)[41]. Nevertheless, one recent project has been heralded as a breakthrough in this respect. Sithe China Holdings, Ltd. undertook a joint venture in 1996 to build and operate two 50 MW cogeneration stations. The terms of its contract are considered to be among the most sophisticated to date, and include provisions for:

- China's first ever "fixed price, date-certain, engineering, procurement and construction (EPC) turnkey contract with a well-recognized international contractor",[42]
- Default insurance through China's largest state-owned insurer, covering force majeure events such as war, expropriation and foreign exchange fluctuations,
- A 20-year fuel supply contract with one of China's largest coal mines[43].

Overarching Institutional Impediments

China's attempt to encourage private power is further hindered by its command-and-control approach to regulation in general. The World Bank has identified the following four fundamental obstacles to more open and efficient electricity markets in China: a) the centralized organization of the power sector, b) direct management of electricity enterprises by governmental institutions, c) a lack of transparency in China's legal and regulatory framework and d) the general absence of market incentives for efficient electricity provision[44]. Again, Chapter 3 surveys China's recent and planned attempts to ameliorate this situation.

1.7 Chinese Environmental Policy

The environment constitutes the final key dimension to the setting in which SEPCO conducts its planning activities. As described in Chapter 3, China's most pressing environmental

[41] Blackman and Wu, 1998, p. 17.
[42] Blackman and Wu, p. 18.
[43] Ibid.
[44] World Bank, 1997, p. xiii.

issues -the human health effects of particulate inhalation and the health and ecosystem impacts of sulfur dioxide (acid rain)- are coal-derived. However, even though China has developed extensive environmental planning strategies plus enacted a series of strict environmental regulations, they are not fully monitored and enforced. This situation results from 1) the structure of government and 2) incentives given to local officials.

On the first point, Chinese hierarchy consists of vertical as well as horizontal relationships. For example, the State Environmental Protection Agency (SEPA) has a vertical chain of command reaching from Beijing down through offices at the provincial level. Yet, each of these provincial offices also has horizontal, nominally consensual relationships with local government. Historically in China the inclusion of the horizontal ties made policy decisions very consensus-driven given the equal hierarchical footing of agency and local officials. However, over time the provinces have grown much more powerful than the various locally represented state agencies. As a result, SEPA regulations can tend to lack teeth where local economic productivity is more of a priority than the environment[45]. In this setting many Township and Village Enterprises, which use older and dirtier equipment, can operate unmonitored due to their vital role in China's economy[46].

On the second point, the state's system of incentives tends to reward provincial officials with recognition and promotions above all else for economic growth and for maintaining social stability. This only reinforces a system in which the environment is already at a disadvantage[47].

China is also involved in the global climate change debate. As part of its Agenda 21 plan drafted at the United Nations' 1992 Conference on Environment and Development in Rio de Janeiro, China pledged to increase energy efficiency through the use of cleaner coal combustion

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[45] Lieberthal, 1997, pp. 3-4.
[46] Chandler and Logan, 1998, p. 14.

technologies and renewables, and to accept foreign financial and technological assistance in these endeavors[48]. Though China's participation is encouraging, no statements made in this arena by China have to date been legally binding.

Basically, it is China's understandable position that domestic economic, human and environmental health are its first priority, and that it is developed countries' responsibility to demonstrate a commitment to greenhouse gas reduction given their historically disproportionate contribution to climate change[49]. Nevertheless, China continues to be exceedingly concerned over the domestic impacts of coal combustion, and mitigating these is a central objective of its plans for power sector reform, as presented in Chapter 3.

1.7.1 Air Quality in China

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[50], acid deposition was identified in the 1990's as a problem in Shandong. As the geographic distribution of particulate emissions tends to follow that of sulfur dioxide, Shandong also has one of China's highest particulate emission densities[51].

Though more conventionally 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. And, though the international environmental

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[47] Lieberthal, 1997, pp. 4-5.
[48] Energy Information Administration, 1999, pp. 11-12.
[49] Chandler and Logan, 1998, p.p. 14-15.
[50] Sinton, 1996, p. VIII-2.
[51] Sinton, 1996, p. VIII-15.

community has become increasingly aware of the acute health impacts of NOx as a constituent of ozone (urban smog), China is not particularly focused on this pollutant at present[52].

Table Four: 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)		($\mu g/m^3$)

1.7.2 Air Quality in Shandong

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"[53]. Jinan also suffers from a scarcity of both surface and groundwater resources, which is again is an issue when siting new power plants, since many technologies are water cooled, as described in Chapter 4.

Table Five: Average 24-Hour Ambient Air Quality in Shandong (1992) [54]

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/

[55]

[52] Norberg-Bohm, conversation, April, 2001.
[53] World Bank, 1999.
[54] 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.
[55] Sinton, 1996, pp. VIII-22-27.

1.7.3 Water Supply

The whole of China's per-capita water resources are only 25% of the world's average[56]. 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[57].

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 Yellow River. 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[58]. Nonetheless, the state's 1995 master plan proposed 27 dams be built on the Yellow River. Seven of them were completed by 1997[59], including one across the dry riverbed delta near Shandong's Shengli oilfield[60]. 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[61].

[56] The source does not specify whether 'resources' include ground and surface water resources.
[57] China Infrastructure, May, 1998, p. 8.
[58] China Infrastructure, November, 1997, p. 3.
[59] World Bank, 1999, China-Xiaolangdi..., p. 2.
[60] China Infrastructure, May, 1998, p. 8.
[61] World Bank, 1999, China-Xiaolangdi..., p. 2.

1.7.4 The Yellow River Delta Project

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 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 the delta's recurring seasonal water shortage, the report does mention plans to add 750 MW of oil-fired generating capacity at the nearby Shengli Power Plant[62].

1.7.5 Shandong Environment Project

To combat further environmental deterioration in Shandong, three municipalities and the provincial government initiated a partially World Bank-financed $215M Shandong Environment Project in 1995. The Project generally aims to address air pollution, acid rain, groundwater supply and wastewater treatment issues. Electric sector-specific measures to be addressed include peak boiler system installations and infrastructure management capacity building in the three cities[63].

1.3 Chapter Summary

Chapter One provided a backdrop for the ensuing analysis of a provincial Chinese utility along economic, environmental and power sector dimensions. In short, Shandong province embodies China's aspirations to contend in the global economy, yet it also typifies the severe health and environmental issues the country faces given its huge population and the rapid, coal-based approach it has taken to development. China's (and Shandong's) power sector has recently transitioned from a situation of basic undercapacity to one of scarcely-met transmission and peak

[62] UNDP, 1997, pp. 7-33.
[63] World Bank, 1999, China-Shandong..., pp. 1-7.

load needs. The sector's financial makeup is also in flux as it moves towards increasingly private sources of investment, a process at times both helped and hampered by nascent electricity and environmental regulatory regimes. Chapter Two introduces the subject of study, SEPCO, within this setting in more detail.

Chapter Two- Shandong Electric Power Group Corporation

This chapter moves in to a firm-level view on electricity service in Shandong for a survey supply and demand, and to introduce the Shandong Electric Power Group Company (SEPCO). SEPCO is both CETP's client and subject of study.

2.1 Supply

China as a whole more than doubled its generation capacity in the 1980's in an attempt to keep pace with demand growth. From 1978 to 1998 generation capacity in Shandong grew from almost 2.8 GW to just shy of 18 GW at a 21% compounded annual growth rate, making Shandong China's second largest province in terms of installed capacity. Over the same period electricity sales increased from 15.4 TWh to 84.2 TWh, for an 18.5% compounded annual increase in consumption. Generation in Shandong is predominantly coal-fired. For the 1996 generation figures listed in State statistical journals, only 40 GWhs (less than 1%) were derived from hydropower.

Table Six: Breakdown of Shandong's Thermal Generating Capacity, 1996[1]

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)	(%)

[2]

[1] Note: SEPCO statistics for installed generating capacity in Shandong in 1996 were 14200 MW.
[2] State Statistical Bureau, 1996.

2.2 Demand

By September 1994, every village in Shandong province had been electrified, and by February 1996 all households were electrified[3]. Since full electrification consumption has grown steadily.

Table Seven: 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)	(^{2}%)

[4]

2.3 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. For 1999, SEPCO's revenues of 32.07 billion Yuan on 71.039 TWh of sales yields an average rate of 0.4514 Yuan/kWh or $.036/kWh[5]. CETP uses this average rate as a baseline modeling assumption.

[3] SEPRI, 1999.
[4] SEPCO, 1999.
[5] SEPCO, 2000.

Table Eight: Electricity Prices in Shandong (1999)[6]

Customer Class	Rate	
	Yuan/kWh	$/kWh
Large Industrial	0.462	0.058
Small Industrial	0.553	0.069
Commercial	0.635	0.079
Residential	0.420	0.053
Agricultural	0.442	0.055

2.4 Shandong Electric Power Group Company

The Shandong Electric Power Group Corporation (SEPCO) manages dispatch and transmission across the over 36,000 km of predominantly low-voltage transmission lines[7] that comprise Shandong's provincial grid[8]. This 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%	(%)

[9]

[6] SEPCO, 1999.
[7] Russo, 1999, p. 26.
[8] Business China, December 9, 1996, p. 9.
[9] SEPCO, 1999.

In addition to managing transmission and distribution in Shandong, SEPCO owns and operates the majority of its generating stations. Shandong grew rapidly in the 90's, and SEPCO plans to further expand the system via construction of an integrated mining and electricity-generating venture in the Heze coalfield[10]. The coal mines of Shanxi province represent potential added capacity for Shandong, though construction of a mine-mouth power station to wheel electricity to Shandong were thwarted in 1995 for lack of sufficient water resources, as were plans for a 300-km Yellow River transfer project. Northern China's lack of water may thus significantly limit power development[11].

Table Ten: 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)

[12]

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[10] SEPCO, 1999.
[11] Business China, Spring, 1995 Power Supplement, p. 3.
[12] SEPCO, 1999.

2.5 Ownership Structure of SEPCO's Generating Capacity

Shandong is home to several of China's quasi-private and private power ventures. Shandong's Zhongua Power Company, Ltd., at 3000 MW of Shandong's capacity through its Heze, Shiheng and Liaocheng units constitutes China's largest private power producer[13]. Because China is looking into but has not yet gone so far as to legally separate generation from transmission and distribution enterprises[14], there is significant generation investment by spin-offs and subsidiaries of both provincial and national transmission and distribution entities. This practice also apparently continues via regulatory bodies, in spite of China's recent nominal separation of regulatory from commercial activities.

Though SEPCO's full ownership and operating structure is not transparent to CETP, reference has been made in the project finance literature to the effect that it does manages dispatch and maintenance for several of Shandong Zhongua's generating stations. SEPCO was also it seems until recently 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 1998[15]. In 2000 Shandong Huaneng was acquired by Huaneng Power International, a New York Stock Exchange-listed firm that is also China's largest Independent Power Producer. As Table Eleven shows, ownership in Shandong plants is diverse.

[13] Modern Power Systems, August, 1998.
[14] World Bank, 1999, Power Sector Regulation…, pp. viii-xxvi.
[15] Yahoo Finance, 2000.

Table Eleven: Private and Quasi-Private Power Projects in Shandong[16]

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)	

China had twenty-two power companies listed on the domestic stock markets in Shanghai and Shenzen in 1993. Shandong Huaneng Power Development Corporation was one of three power companies also listed in foreign markets that year though has as mentioned been since acquired. The stocks of neither domestic nor foreign-listed Chinese power companies fared very well in the 1990's[17].

However, analysts this year upgraded Huaneng Power International's (ticker symbol HNP) stock to a strong buy given the company's recent growth and China's recovery from the Asian crisis. It is possible to look more closely at Huaneng Power International's fundamentals since NYSE listing requires its financials be made public. Its stock hovered near $22 a share in early May 2001, up from a 52-week low of $8,

[16] Compiled through survey of project finance literature, 1999. Ongoing. Note: Qingdao Phase 1 is a natural gas turbine plant.
[17] China Infrastructure, September, 1997, p. 5.

which would indicate confidence in its future performance. Indeed, profits were up 35% for this past year, its predicted annual earnings per share (EPS) growth rate at 34.12% exceeded the industry's at 11.65% and even the S&P's at 20.16%, and HNP's return on investment of 5.96 exceeded the industry's of 4.02 [18].

In sum, equity investments in Shandong's generating capacity appear to mirror the intricate ownership arrangements prevalent in Chinese power projects at large. In spite of this complexity, however, the accelerating stock performance of Huaneng Power International (as a 13% owner in the generating capacity SEPCO dispatches) indicates at least one of SEPCO's key generators may be emerging as a firm that is increasingly exercising market discipline in the western tradition.

2.6 Fuel Supply in Shandong

The diversity, availability and robustness of Shandong's fuel supplies were key determinants of the simulation inputs. The following sections provide a brief overview of SEPCO's primary energy supply categories. While Shandong has more indigenous fossil resources than most other provinces, due to the size of its population and economic output, inter-provincial fuel supply and transportation issues remain important.

Table Twelve: Commercial Fuel Production- Shandong 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)	(%)

19

[18] Yahoo Finance, 2001.

2.6.1 Coal

While China's mainstay of coal production is Shanxi Province, several mines are located in Shandong. Yet, as Table Thirteen shows, Shandong imports much of the coal it uses from other provinces, mainly Shanxi[20]. Northern Chinese coal is high quality, with an average gross calorific value of 21 GJ/tonne, and less than 1% sulfur.

Table X: Net Coal Production by Province (1990)[21]

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)

22

[19] Sinton, 1996, pp. II-13-15.
[20] SEPCO, 1999.
[21] National production and consumption figures differ due to transportation and processing losses, net exports and net changes in national stockpiles. Provincial figures because statistical coverage is not consistent across Chinese provinces.
[22] Sinton, 1996, p. II-13.

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)

23

2.6.2 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[24].

2.6.3 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[25], according to PNL it could supply up to one-third of China's electricity needs by 2020[26].

Proven Reserves

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

[23] Sinton, 1996, p. II-34.
[24] Sinton, 1996, pp. II-13-15.
[25] Russo, 1999, p. 42.

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.

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[27], and a lack of domestic gas turbine manufacturing capability[28]. These barriers notwithstanding, foreign investment deterrents may constitute China's biggest impediment to expansion of natural gas markets.

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 did call for the construction of three LNG terminals on the South China Sea for operation beginning 2002-2005.

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[26] Logan and Chandler, August, 1998, p.5.
[27] China Infrastructure, August, 1998, p. 2.

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[29], 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.[30]

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,
- Lack of field data accessibility,

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[28] Russo, 1999, p. 42.
[29] China Business Review, July, 1998, p. 2.
[30] MMBtu = million British Thermal Units

- Lack of incentives to pursue coal bed methane or 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 and the Kuwait Foreign Petroleum Exploration Company[31]. 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[32].

2.6.4 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 (unless it is flared). 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[33].

[31] Logan and Chandler, 1998, pp. 5-7.
[32] Reuters, April, 1999.

2.7 SEPCO's Generation Technology Options

At present, all of China's preferred fuel supply for power generation is coal. SEPCO 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 emissions 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.

Chapter 4 presents a detailed catalogue of the range of generating technologies CETP simulates based on SEPCO's operating environment, existing infrastructure and fuel supply situation as presented below.

2.7.1 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[34]. 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[35][36]. Four others are under construction and due to come on

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[33] China Business Review, August, 1998.
[34] China Infrastructure, August, 1998, p. 2.
[35] Business China, May 1, 1995, p. 1.
[36] In 1995 Beijing Review reported that a preliminary feasibility study for a nuclear power station in Shandong had passed state examination, though my review of current literature has yielded no further information on the status of the proposed Shandong facility.

line in 2003 and 2004, in Quinshan (2 plants), Guangdong and Jiangsu Provinces. These plants have been largely financed by foreign commercial loans and export credits[37].

2.7.2 Hydroelectric Power

Shandong also has a modest hydropower potential of 1 GW[38],[39] 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, SEPCO has plans to initiate construction of a 4 x 25 MW pumped storage facility[40].

2.7.3 Windpower

At an estimated resource potential of 253 GW, wind may represent China's biggest renewable resource[41]. In 1998 China's grid-connected wind capacity was only 200 MW. 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[42], a demonstration wind-farm in Pingtan of ten 30 kW turbines[43], and a 9 x 600kW installation on Changdao Island[44].

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[45]. By circumventing import duties, domestic

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[37] China Infrastructure, December, 1997, p. 8.
[38] Sinton, 1996, p. 1-10.
[39] The reference does not specify from which Shandong river this hydropower comes.
[40] SEPCO, 1999.
[41] China Infrastructure, March 1997, p. 4.
[42] International Energy Agency, 1996, p. 361.
[43] International Energy Agency, 1996, p. 423.
[44] Connors, March, 2001.
[45] China Infrastructure, March, 1997, p. 3.

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[46].

2.7.4 Solar and Other Renewables

China's Ninth Five Year Plan also called for the construction of 10 million square meters of passive solar housing by the end of 2000[47], plus mentions biomass, geothermal and ocean generation.

Table Fourteen: Renewable Capacity Expansion Projections (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)					

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2.8 Chapter Summary

Chapter Two introduced key operating data for SEPCO and highlighted the physical and financial characteristics of its infrastructure. It then described SEPCO's prospective fuel supplies, and gave a broad overview of its available generating technologies going forward. Chapter Three builds specific rationales for several series of events which, as they unfold in China should impact SEPCO considerably.

46 International Energy Agency, 1996, p. 460.
47 International Energy Agency, 1996, p. 461.
48 International Energy Agency 1996, p. 421. Solar capacity includes thermal and PV.

Chapter Three- Rationales for Hypothesized Events

This chapter moves from China's history and Shandong's context to contemplate how several impending economic and regulatory changes will affect SEPCO's future. In turn it thinks through four probable series of events that will unfold over CETP's study period, and postulates how they should impact SEPCO on an operational level.

3.1 WTO Accession

The world and the US in particular expect China's accession to the World Trade Organization (WTO) to spur unprecedented market access. A corollary prediction is that economic growth in China will reflect the increased consumption and investment WTO accession stimulates. This chapter looks into expectations voiced by academic journals and the popular press about WTO's impact on China's economy, and investigates the implications of that kind of growth on SEPCO at an operational level.

3.1.1 What is WTO

The WTO is an international regime created in 1995 to provide a framework for and series of agreements governing trade in goods and services on an equal and open basis between member countries. WTO effectively replaced the General Agreement on Tariff and Trade (GATT), though its founding principles of Normal Trade Relations (NTR) and transparency are similar to GATT's. For example, all WTO members receive and are also required to extend NTR to other members. Like GATT's Most Favored Nation status, NTR requires members to treat the products of a given trading partner no less favorably than the products of any other member, including one's own domestically-produced goods. And, as under GATT, members of WTO receive full access to the legislation other members pass in order to ensure compliance. WTO also sets forth a series of agreements designed generally to reduce tariffs, to convert non-tariff protectionist measures (such as quotas) into tariffs for clarity, to standardize customs protocols and to establish procedures for the pursuit and resolution of trade disputes.

3.1.2 Status of China's Accession

China was one of the original signatories to GATT in 1947, though it withdrew in 1949 upon Mao's declaration of the People's Republic. China reinstated its status to negotiate GATT entry in 1986, and formally converted this process to target WTO in 1995. Since then China and China's 'working party' of other WTO members have together developed China's protocol of accession package to WTO, which spells out the terms and conditions that will govern China's accession. This package includes market access schedules for specific goods and services that China has, per WTO rules, had to negotiate bilaterally with WTO members who requested them.

China and the US reached agreement on their set of market access schedules in 1999, and in so doing set parameters for other countries making such requests, as US businesses are expected to take the lead in pursuing opportunities presented by China's entry[1]. WTO officials predict China's accession sometime in 2001 pending resolution of whether China will be allowed to accede with developing country status -which would afford looser phasedown terms for tariff barriers- for its agricultural sector. Though the US Congress voted to grant Permanent Normal Trading Relations to China under the Clinton administration, if China does not accede by June 2001 the US will have to revert to asking Congress to grant China Normal Trading Relations every twelve months[2].

3.1.3 Major Sectors Affected

The US market access schedules address agriculture, industry, distribution rights and services. China will allow trade in agricultural commodities outside of government channels,

[1] China Business Review, 27(1), January-February, 2000, pp. 17-34.
[2] Financial Times, February 28, 2001.

reduce tariffs and eliminate export subsidies. It will also phase out quotas for information technology, paper, chemical, automotive and electronic goods. And, China will allow US firms to wholesale, distribute and retail goods directly, as well as to offer ancillary maintenance and repair services[3].

Though US firms eagerly anticipate the opportunities the above concessions will present, China's WTO concessions in services will perhaps have the greatest impact on Chinese firms and on the Chinese economy. Under WTO China has most notably agreed to eliminate or relax foreign equity restrictions for financial and professional services providers and for telecommunications companies.

Financial and professional services providers affected will include banks plus accounting, insurance, management consulting, law and securities firms. For example, US banks will be able to begin conducting Yuan transactions (such as granting loans) with Chinese firms two years after accession, and will be able to begin conducting consumer transactions (such as granting loans and taking deposits) in Yuan three years after accession. Foreign investment banks and fund managers will be allowed a 49% stake in like Chinese firms three years after accession. And, whereas foreign participation was hitherto prohibited, investment banking joint ventures with minority US stakes will be allowed to underwrite domestic securities, and to trade foreign-currency-denominated securities in China.

Finally, in the historically closed telecommunications sector, upon accession China will immediately open to competition its main telecom services corridor, which carries some 75% of domestic calls through Beijing, Guangzhou and Shanghai. China has also agreed to allow 49%

[3] China Business Review, 27(1).

foreign ownership in mobile services within five years of accession, and in landline services within six years[4].

3.1.4 Implications for the Electric Sector

3.1.4.1 Economic and Electricity Demand Growth

Future economic growth in China will inevitably lead to growth in electricity demand, assuming GWh growth will not be outstripped by the rate of improvement in generation, T&D and/or end-use efficiency measures.

Though China's accessions in the areas of agriculture and industrial products are not directly pertinent to utilities, they should flow through to GDP by stimulating consumption. Changes in distribution rights could have potentially powerful implications for coal transport should that sector also eventually liberalize, though foreign participation in that sector is not currently being discussed. However, the allowance of foreign distribution generally should also stimulate growth via the introduction of information technology and practices geared towards more efficient supply chain management. And, the advent of performance-based credit discipline in the banking sector should contribute to investment by rewarding competitive and productive companies. Moreover, the inevitable exposure to western accounting practices and management consulting WTO accession will bring should further rationalize how Chinese businesses operate.

Yet, one school of thought warns that WTO accession will induce widespread bankruptcy and unemployment in China as inefficient domestic firms go under, which would countervail the effects of the above stimuli. While this argument points to an economic dampening in the short term, its logic also leads to the release of resources to more efficient enterprise, the assumption by the state of social security and health care and subsequent economic recovery in the long

[4] Ibid.

term[5]. Indeed, China's healthy foreign reserve position and reasonable level of national debt should help it through the probable shorter-term pains[6]. Moreover, China's exports are falling as the US economy slows, its use of fiscal stimulus is limited given the looming social burden of the government and domestic consumption is only recently recovering from an Asian currency crisis-induced stagnation. That is to say, export-led, investment and consumption-based growth strategies may have limited potential in today's China when compared to WTO's promise of competition-based economic expansion[7].

A 1999 paper out of the National Bureau of Asian Research compares the results of several studies undertaken -by the US International Trade Commission, Goldman Sachs and the Congressional Research Service (CRS)- to estimate the impact of WTO accession on the Chinese economy. This paper concludes that expectations of wholesale growth in US exports to China are overoptimistic, though it does acknowledge the potential for quite considerable growth in targeted sectors. It goes on to conclude that China's economy would have to exceed an 8% GDP growth rate through 2005 to meet Goldman's aggregate estimates, and/or around a 7% rate to meet CRS's.

Impact on SEPCO

In light of the above and using annual electricity demand in gigawatt hours as a proxy for economic growth, I specify in Chapter 4 and examine in Chapter 5 the potential impact on SEPCO of electricity demand in China growing by 7% annually over the study period.

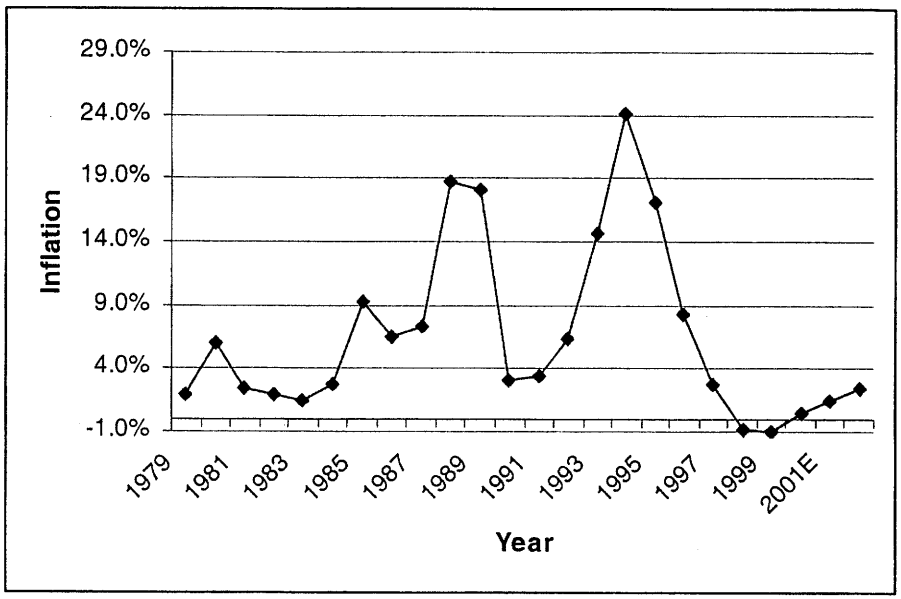
[5] Cheng, 1999, p. 2.
[6] EIU, February, 2001, p. 4.

3.1.4.2 More Volatile Inflation

Overview of Inflation in Post-Mao China

Another consequence of WTO accession for China may be periods of inflation and recession as the economy grows and the state imposes measures to keep it in check. China's post-Mao period of socialist market transition was in fact marked with several periods of rapid inflation and recession, as Figure Three shows.

Figure Three: Inflation in China, 1979-2001E



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According to a Cato Institute report from the fall of 2000, the World Bank associates both of the above extreme jumps in inflation, in 1988 and again in 1993, to periods of an increasing consolidated government budget deficit in China. This consolidated statistic includes not only the real fiscal deficit but also incorporates central bank lending for policy purposes. The assumption here is that the government printed money and allocated it via bank loans to favored sectors -including the financial system- to bolster an already expansionary fiscal policy. Both

[7] Rosen, 1999, pp. 12-13.

spikes were also likely fed by an up to 60% administrative increases in the prices of many staple food products in 1988, and by a 40% increase in grain procurement prices in 1994.

In both cases China worked to curb the impact of price increases in part by indexing government bond and bank deposit rates to inflation so as to preserve the incentive to save. Some cities also worked to hoard and then more tightly ration stocks of household products such as meat and grain, and the state imposed periodic restrictions on the speculative trading of commodity futures. In addition, China passed a law in 1994 prohibiting the government's borrowing from the People's Bank, which by driving an increase in government bond issues helped to stem the money supply and hence inflation.

Near Term Inflationary Prospects

Though China's budget deficit to GDP ratio is low by developing country standards, it has nonetheless been increasing since the Asian currency crisis as China has turned again to fiscal policy to combat rising unemployment and weak spending. China's accession to WTO should increase fiscal pressures even more as the state's social security obligation rises. Though WTO's expected boost to consumer spending might be delayed as China struggles through the initial restructuring accession will induce, increased consumption should also soon be reflected in the rate of inflation. Thus, as Figure X shows, China is expected to climb further out of its recent deflationary period in the near term[9]. China's increasing participation in global goods and capital markets should additionally expose it to bouts with inflation as WTO participation propels the migration of its economy along the command-market spectrum. Moreover, this

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[8] Burdekin, 2000, p. 2.
[9] Ibid., p. 5.

exposure will increase to the extent competition in turn spurs the liberalization of previously state-controlled input prices[10].

Even so, two factors may help China keep inflation below the exorbitant levels seen in 1988 and 1993. Firstly, the state's power to tax is on the rise since a 1994 law gave it priority access to tax revenues over the provinces. Since then tax revenues have risen from 11% of GDP to 13%, which -however low when compared for example with this statistic for the US at 31%- does represent a substantive increase in the state's ability to control deficit spending. Secondly, China has initiated some serious restructuring in the banking sector, which I more fully address in the next section. These reforms have been aimed at decreasing the rate and amount of soft loans to inefficient state enterprises, and at recovering for nonperforming loans on behalf of the state banks. Because these measures will in turn stem unnecessary output, they should also help China to better keep inflation in check[11].

Impact on SEPCO

In light of the above I specify in Chapter 4 and examine in Chapter 5 the potential impact on SEPCO of a slightly more volatile inflation trajectory in China over the study period. However, I assume rates will not exceed 10% given China's demonstrated ability to control extreme occurrences.

3.1.4.3 Devaluation

Short Term Macroeconomic Outlook

WTO accession may also affect the exchange rate, especially given the macroeconomic factors characterizing China today. To begin, exports are flat or falling- China's current account

[10] Perkins, 1994, p. 43.
[11] Ziegler, 2000, p. 2.

surplus approached zero in 2000, and net exports are predicted to remain flat through 2002[12]. In addition, China's stock of foreign direct investment (FDI) has fallen steadily since 1998, and government spending has been on the rise in an attempt to prime the economy. Finally, as manifested in China's recent deflation, consumption and consumer confidence have been down[13].

Considered severally and jointly these factors have the potential to encourage China to look to the exchange rate to help stimulate growth. That is, a slight devaluation could boost export demand, relieve the need for FDI, reduce reliance on a fiscal stimulus plus enhance confidence levels and spending as a consequence of increased output.

Impact of WTO on Exchange Rate

China's WTO accession adds weight to most of the above factors. To begin, the US and other WTO members expect their exports to China to *increase* once China accedes, especially in key sectors such as automobiles and agricultural goods, thereby contributing to China's potentially imminent trade deficit. And again, competition in the private sector will begin to shift the burden of welfare from the firm to the state, thereby intensifying already considerable fiscal pressures.

Yet, WTO accession's impact on consumer spending and the influx of FDI could be mixed. A sharp rise in unemployment may curtail confidence, though by the same token should increase spending among those reaping the rewards of new and restructured enterprises. Similarly, because WTO accession should strengthen China's external economic relationships[14], FDI levels may rebound, though recent tensions between the US' Bush administration and Beijing over arms sales to Taiwan could dampen investor confidence.

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[12] EIU, 2001, pp. 13-14.
[13] Rosen, 1999, p. 12.
[14] Cheng, 1999, p. 1.

Given the foregoing, China may next year indeed "widen the band in which the renminbi is allowed to trade...to +/- 3%. However, if the trade balance moves decisively into deficit, the renminbi [Yuan] may be allowed to fall more sharply.[15]"

Impact on SEPCO

To model an increasing concern in China over maintaining the export success it has enjoyed over the past two decades, I specify in Chapter 4 and analyze in Chapter 5 the impact on new generation technology costs for SEPCO of a 20% devaluation in the Yuan.

3.2 Financial Market Reforms

Over the past several years China has taken increasing steps to reform its banking system and domestic stock markets. WTO membership is expected to catalyze this as of yet incomplete process, which has nonetheless already begun to make access to capital more competitive and merit-based for Chinese firms. This section surveys the undertaken reforms, and develops an argument that SEPCO will feel their impact in a shareholder base that wields increasing influence over management.

3.2.1 State Owned Enterprises

China's need to implement financial market reforms stems from the financial weakness of State Owned Enterprises (SOEs), fueled by heavy policy borrowing (and subsequent non-repayment) of loans from state banks. Because this soft money was allocated according to plan rather than market, much of it has gone to unproductive or 'asset-destructive' use[16]. In fact, the officially reported liabilities-to-assets ratio of China's SOEs was 85% in 1995, though Nicolas Lardy of the Brookings Institution estimates this ratio to be closer to 500%. And nearly half of medium and large SOE's posted a loss in 1998. The burden of this degree of inefficiency in state

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[15] EIU, 2001, p. 13.
[16] Steinfeld, 2000, Course Lecture.

enterprise is now born by China's state banks in the form of nonperforming loans amounting to as much as ten times the banks' capital and loss reserves. Lardy further estimates it would take $260 billion, or 27% of China's GDP to recapitalize the financial system.

3.2.2 Recent SOE and Banking System Reform

Though China's banking system has been gradually adapting to market forces since 1978, China reinvigorated the reform process in 1997 with a campaign to provide for the bankruptcy, merger or acquisition of over 2000 SOE's. This move has improved SOE performance but of course has also increased unemployment. China also issued $32.5 billion in bonds earmarked for the four state-owned banks in 1998, and began setting up asset management companies in 1999 designed to purchase and manage repayment on bad loans. To achieve this, these companies are entitled not only to collect 'dividends' (in lieu of loan payments) from debtors, but are imbued with the authority to recover original principal balances by restructuring, selling or taking the companies in question public, or by conducting debt-for-equity swaps[17].

A parallel set of banking reforms in China relates to changing credit policy in the four state-owned banks. For example, credit review procedures have been revamped at the China Construction Bank, where loans have been historically granted more on the basis of political connections than the principles of sound investment. The bank is also working to hire managers trained in credit review approaches used outside of China[18].

3.2.3 Chinese Stock Markets

The process whereby Chinese companies raise money on its domestic stock markets is dramatically different than how equity issues are done internationally. To begin, rather than letting market demand for stock dictate offerings, the State Council has historically decided on

[17] Burdekin, 2000, p. 6.
[18] Wilhelm, 1999, pp. 1-6.

how many -and oftentimes on which- enterprises would go public. The Council then allocates these plans as quotas to the provinces, whose governments in turn solicit applications from local businesses. The provinces do not apply standardized criteria in the selection process, nor is any information relating to these decisions made public.

Secondly, the state regulates offering prices in the primary market, though prices typically explode in the aftermarket. For example, secondary market prices on IPOs in Shanghai have been estimated to exceed initial prices by nine times. This practice results in the transfer of wealth rightfully belonging to the firm to a handful of strategic investors[19]. Thirdly, the failure of the current system to value or reward firms according to merit results in the practice of slack corporate governance[20]. That is, since neither firms nor shareholders are necessarily rewarded on the basis of a company's fundamentals, the engaged relationship we observe between boards and management in the west has yet to develop in China. And finally, "the nonconvertibility of the renminbi [effectively] isolates investors in Chinese stocks from the outside world.[21]"

3.2.3.1 Recent Stock Market Reforms

To address some of these issues, China is now allowing investment banks to 'groom' companies for IPO's, and is beginning to impose greater transparency on the selection process for firms applying to list. It also recently opened a Nasdaq-like exchange for newer companies in Shenzen, which should give many private firms traditionally aced out by state firms some long sought-after access to capital. And finally, China has announced it plans to begin allowing foreigners to invest directly in Chinese stocks, which could create the opportunity and perhaps the incentive for China to benchmark more directly with global standards[22].

[19] Chengxi, 1998, pp. 5-8.
[20] Financial Times, 2001, p. 2.
[21] Ibid.
[22] Ibid., p. 3.

3.2.4 WTO Impact on the Financial Markets Reform Process

Though WTO accession will far from transform Chinese businesses and banks overnight, it should work to catalyze the many financial sector reforms already underway. To begin, the simple allowance of foreign entry in the banking sector could pressure the central bank to liberalize interest rates to keep Chinese banks competitive. In addition, the introduction of international accounting standards, investment and commercial banking practices WTO will bring should begin to impose more discipline in companies' financing, capital budgeting and asset management practices. Finally, international investors should become more interested in investing in Chinese stocks, whether in China or on foreign exchanges.

Impact on SEPCO

The net effect of the reforms China has undertaken in the financial sector, in combination with WTO accession, should be an increasing shareholder orientation toward the proverbial bottom line. To model this effect, I specify in Chapter 4 and analyze in Chapter 5 the impact on SEPCO of an increasing return on equity to its shareholder base.

3.3 Electric Sector Restructuring

Over the 25-year time frame of CETP's study China's electric sector will be asked to evolve with the increasing demand and shifting load profiles a growing economy should stimulate. China is thus likely to further steps initiated in 1998 to restructure how electricity service is regulated. This section describes steps China has already taken, presents possible next steps and contemplates their probable impact on SEPCO from an operational standpoint.

3.3.1 Current Status of China's Electric Sector

As mentioned in Chapter 1, China passed an Electricity Law in 1996 that nominally separated the productive and regulatory functions of the power sector. Using this as a starting point, a May, 2000 paper by Andrews-Speed and Dow in Energy Policy describes the current state of the sector as well as explains and deconstructs China's reform objectives as it struggles with restructuring and reregulating this cumbersome industry.

Physical Characteristics

Smaller, older, less efficient and more polluting coal-fired plants dominate China's power sector, where centers of demand are located relatively far from fuel sources. Though China's installed capacity caught up with demand in the mid to late 1990's, its spinning reserve is low and ability to manage daily and seasonal peak loads marginal. In spite of the presence of enough basic generating capacity on balance, long distance and transregional transmission is hampered in China by its ten separate grids, and distribution inefficiencies within grids further limit utilities' ability to accept power from plants on an as-needed basis. Yet, the construction of Three Gorges Dam in the next decade will effectively nationalize transmission, thereby alleviating one of the system's main deficiencies.

Organizational Characteristics

China's power sector is heterogenous and complex from an organizational standpoint. SEPCO and the other provincial power companies, as fully integrated utilities, serve the preponderance of customers in China. County and municipal utilities below the provincial level are involved in distribution and supply, though generally do not participate in generating activities unless on a small scale. Some of the provincials are clustered into regional power groups which administer regional grids, and above these sits the State Power Corporation (SPC), which owns most of the T&D infrastructure plus all or part of the shares in the provincials and groups. The SPC plays a key role in planning for the provincials and manages the transfer of power across grids. However, the provincials are responsible for investing in and managing generating capacity, for constructing and maintaining local T&D infrastructure and for dispatch and load balancing. However, minority generation investment also takes place at the county and city levels, through nominally Chinese consortia of foreign IPPs and through quasi-independent domestic producers such as the Huaneng Group, as discussed in Chapter 2.

Responsibility for utility profit and loss statements is not uniform in China- in some cases the regional groups manage accounting while in others this task falls to the provincials. In SEPCO's case, though CETP has been largely shielded from access to accounting data, it appears SEPCO maintains its own P&L.

Regulatory/Legal Characteristics

Many decisions about power delivery in China require national approval, which since it is concensus-based can be time consuming. This legacy of centralization also imbues the sector with more of a direct supervisory rather than regulatory air, yet at the same time cultivates tensions between the center and provincials, many of which have gained political and economic power as they have developed. As a result, many of the provincials have tended to avoid the national approval process by building larger numbers of smaller plants.

The 1996 Electricity Law was China's critical first step in restructuring as it separated regulatory from productive functions and liberalized investment in generating assets. However, many planning, ownership and decisionmaking roles are as of yet unclear, as demonstrated in the next section.

Financial Characteristics

As demonstrated by SEPCO's unwillingness to disclose financial data, the financial status of China's power sector on the whole is opaque. However, several broad trends in power sector financing over the past two decades are identifiable. In 1980 the sector derived two thirds of investment from the state, whereas major contributors in 1995 were state banks at 50% as well as provincial and local governments at 20% with assorted foreign investors and state grants comprising the rest. Interestingly, state banks are reportedly increasing the pressure on the power sector to repay historically soft debt, in keeping with the financial reforms discussed above. In all, this financial diversification was a big factor in China's recent buildup of generating capacity.

China's complex tariffs are based on centrally approved catalog prices, with provincials levying further charges. Andrews-Speed and Dow identify the following as China's most pressing tariff-related deficiencies:

- The absence of procedures for a merit order dispatch results in a failure to incent generators to cut costs;
- Tariffs do not collect for T&D improvements;
- No mechanism exists to pass any realized reduced generating costs along to consumers and
- Industrial and commercial tariffs in large part subsidize residential and state users

Given these constraints the most profitable companies are generating groups -such as Huaneng Power- that have successfully negotiated Power Purchase Agreements (PPAs) with sufficiently high tariffs. However, apparently only PPAs struck under China's newly instituted Build-Own-Transfer (BOT) process are fully protected from being overridden by the central government.

3.3.2 Reform Objectives, Barriers and Recent Actions

In the setting created by the above characteristics, China's current reform objectives are to 1) increase the capacity to deliver power, 2) contain costs, 3) improve end use efficiency and 4) reduce environmental impacts.

T&D Effectiveness

The greatest inhibitors in China at present of T&D effectiveness are the long distances between coal supply and power demand, underinvestment in T&D, unclear procedures for power trading between provinces and insufficient numbers of peaking plants. The state has in fact begun to address these issues by constructing mine mouth power plants and allocating state funds to improve interregional transmission. However, the state disallows any other entities from these types of investments, and power trading protocols continue to remain unclear.

Cost Containment

Several conditions are necessary for allowing consumers to enjoy the benefits of reduced system costs- an independent regulatory body, transparency of system information and a transparent and equitable system for power pooling and dispatch. As mentioned above, China has established an at least nominally independent regulator. However, most of these elements are clearly not yet present. They may also be hard to establish since China's lack of standardized accounting procedures, absence of an independent judiciary and centrist tendencies in general all constitute institutional barriers to their implementation.

End Use Efficiency

Though access to information and conservation measures are also necessary conditions for enhancing energy efficiency, the greatest barrier to efficiency in China is the lack of a dynamic pricing mechanism to manipulate power usage patterns and curtail consumption levels.

Thus, though China did pass an Energy Conservation Law in 1997, it has yet to implement the comprehensive tariff reform necessary to communicate the true costs of service to the rate base.

Environmental Impacts

China is also focused on mitigating the environmental impact of the power sector. Because I model this event stream as a separate phenomenon in Chapter 5, I address the environment as a stand-alone issue in the next section of this chapter.

3.3.3 Possible Next Steps

Partial Wholesale Deregulation

Given China's priorities its first logical step would be to restructure the market by introducing competition at the level of generation, as has been done in other markets. To effectively achieve this China would also have to ensure competition in power plant construction, fuel supply, plant operation and management and dispatch. Regulations already exist in China for competitive plant construction, though fuel supply is largely captive to the state-owned rail network, which is far from free market functioning. Foreign investors are beginning to take advantage of China's new BOT regulations, though competition is largely absent from the process whereby the management structure of most plants is decided upon, as provincial power companies often make these decisions. On the last point, China has in fact conducted experiments at the provincial level with merit order dispatch. The benefits of one such experiment in Zhejiang Province included reduced plant coal consumption and an improved power trading relationship with neighboring provinces. Nonetheless, legislation has yet to be drafted that establishes a power purchasing entity or ensures fair competition among technologically disparate generators with varied ownership structures.

Given these issues the authors speculate China might incrementally begin to restructure by deregulating power sales to large customers rather than by tackling the issue of forming the corollary of an Independent System Operator (ISO) or Regional Transmission Organization (RTO) head-on.

More Complete Separation of Generation from T&D

Should incremental wholesale deregulation prove effective, China would then logically work to extend the model by more extensively unbundling generators from purchasers. In this respect the separation of the management and accounting practices of the divisions could prove difficult in a Chinese context. Therefore China may be forced to severely limit or eliminate utility ownership of generating assets.

Creation of a Purchasing Entity

Having played such a prominent role in China's power sector historically, the provincial power companies may be better equipped than the power groups to assume the roles of power purchasers and distributors.

Ensuring Effective Regulation of a Restructured Regime

Ultimately, China will have to address the issue of simplifying and concentrating all regulatory tasks under an entity that is truly independent from system ownership, planning and/or operation. That is, "the requirements for independence include: autonomy from the daily operations of government; a transparent appointment process; clearly defined objectives and sufficient legal powers and expertise to obtain information and enforce decisions.[23]"

Impact on SEPCO

Given the steps China has taken to date to restructure and reregulate the power sector, I believe it is reasonable to assume deregulation efforts will continue throughout CETP's study period. To model a fundamental step in this process, I specify in Chapter 4 and analyze in Chapter 5 the impact of basic wholesale power deregulation on SEPCO.

3.4 Stricter Environmental Monitoring and Enforcement

As mentioned above, one of the primary objectives of power sector reform in China is mitigating the local and regional environmental impacts of thermal generation. This concern by extension also puts China in a position to address the contribution of its power sector to climate change. Thus, as China strengthens its economic and diplomatic relationships with the rest of the world through the WTO mechanism it may become more receptive to this issue (however stalled Kyoto negotiations may currently be). Be that as it may, China's immediate concerns are the local and regional health and environmental impacts of coal combustion generally and of power production in particular. This section surveys the environmental impacts of coal combustion in China and explores the contribution of the power sector to these impacts. Because China already does control for particulates (as further discussed in Chapter 4) it then constructs a rationale for China to begin more strictly regulating sulfur emissions.

3.4.1 Domestic Health and Environmental Impacts of Chinese Coal Combustion

China's citizens and natural environment have borne the costs of coal's role in its provident growth. Chinese researchers ascribe 1 million of the average 1.4 million annual deaths from pulmonary disease in China to air pollution exposure. And, total GDP loss due to all types of environmental pollution exceeds 8%[24].

Particulates

An estimated 72% of all Chinese cities have an annual average Total Suspended Particulates (TSP) level above the State Environmental Protection Administration's (SEPA)

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[23] Andrews-Speed and Dow, 2000, pp. 1-15.
[24] Chandler and Logan, 1998, p. 13.

residential standard of 200 micrograms per cubic meter, most of which is coal-derived. Between 60% and 80% of TSP is comprised by "PM-10", or particles less than 10 microns in diameter. PM-10 is considered to be a serious threat among the air pollutants attributable to fossil fuel combustion, though particulate exposure from indoor rather than outdoor air pollution is now understood to be the greater health risk in China, especially among women. Because only 10% of women in China–as opposed to 75% of men- smoke cigarettes, epidemiological studies attribute the exceedingly high rates of respiratory disease among Chinese women to coal-derived particulate inhalation indoors[25].

Sulfur Dioxide

Sulfur dioxide from soft coal combustion is China's most severe regional air pollutant. Half of China's northern cities exceed SEPA's residential standard for SO_2. In addition to the elevated human health danger SO_2 exposure poses in combination with PM-10, acid deposition has damaged up to 40% of China's land area[26], and has caused extensive acidification in Taiwan, Korea and Japan[27].

3.4.2 Power Sector's Contribution to Emissions

Lawrence Berkeley Laboratories' China Energy Databook published a compendium of energy sector data from a number of Chinese and international sources in 1996. Though LBL will be publishing an updated Databook later this year, this thesis draws on the older data. As Figure Four demonstrates, coal has historically dominated China's primary energy mix, accounting for 73% of primary consumption in 1994. Oil accounted for 20%, natural gas for 2% and hydro for 5% of consumption that year.

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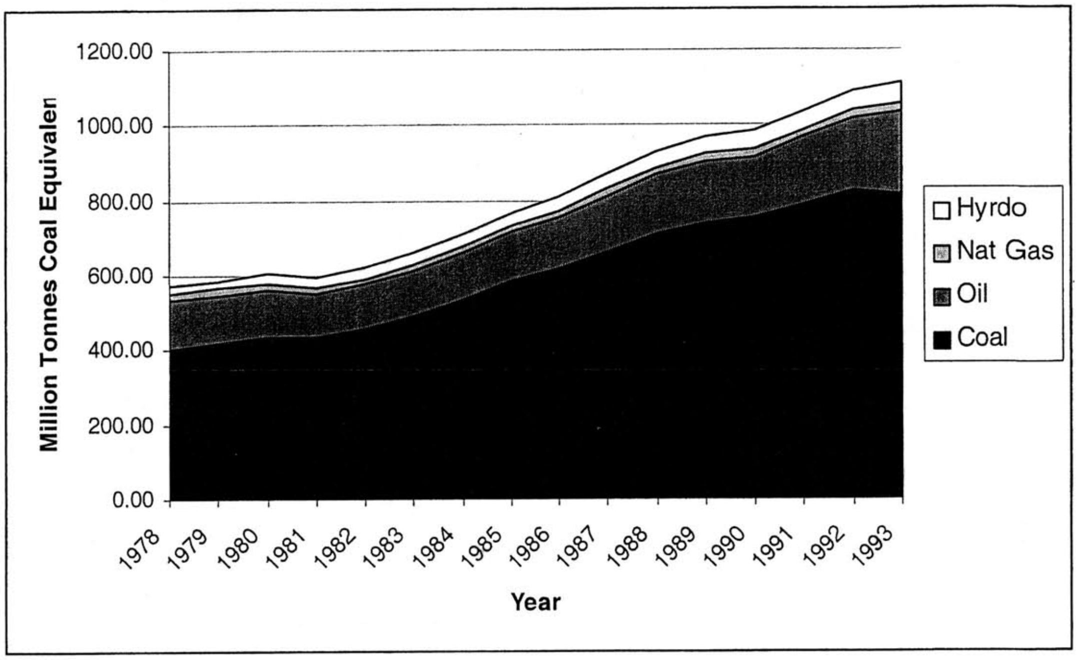
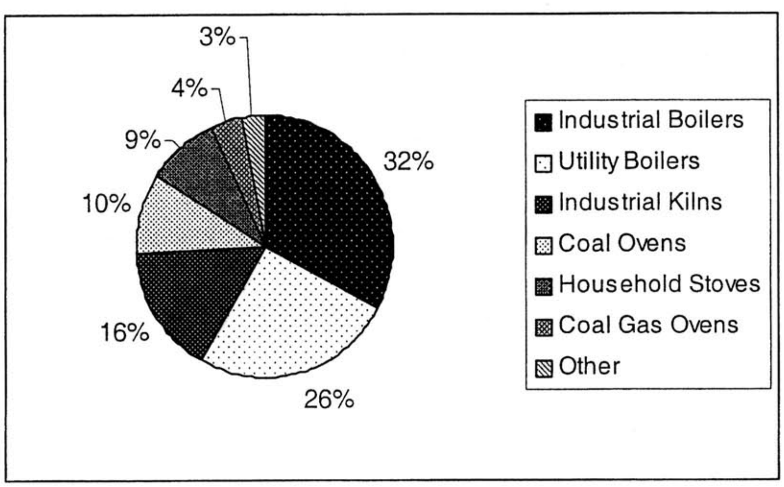
[25] US Embassy, Beijing, 1999, p. 2-4, 11.
[26] Chandler and Logan, 1998, p. II-13.

Figure Four: Primary Energy Consumption in China, 1978-1993



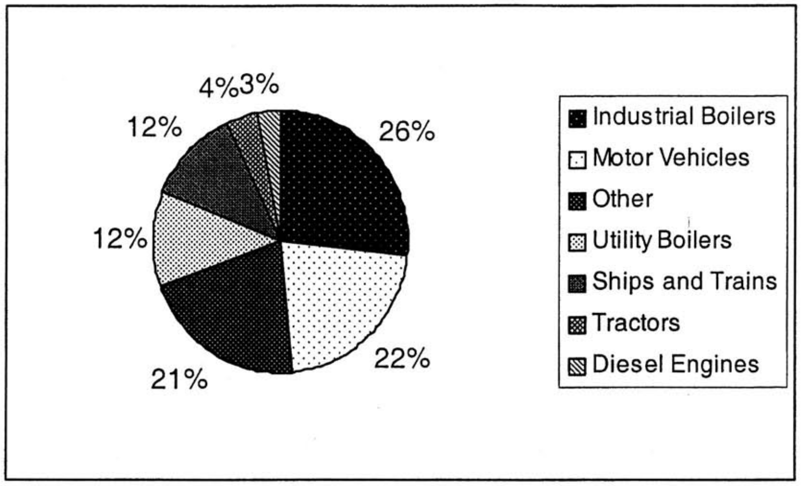
As shown below, utility boilers consumed 26% of China's coal and 12% of its oil in 1990. Roughly speaking that would attribute some 19% of China's emissions from coal combustion to the power sector, and 2.4% of emissions from oil combustion to the power sector.

Figure Five: Coal Consumption by End Use, 1990



[27] US Embassy, 1999, p. 11.

Figure Six: Oil Consumption by End Use, 1990



However, the actual sulfur and particulate emissions contributed by the power sector in 1993 were considerably higher. LBL attributes 48.6% of sulfur emissions and 28.3% of particulate emissions to the electric utilities sector. As described in Chapter 4, China already controls for particulates on both new and existing power plants. And, though it does require the installation of flue gas desulfurization equipment on new power plants, it does not currently control for sulfur on most existing plants. However, a new law in Shandong does call for scrubber installation on existing plants burning coal of greater than 1% sulfur content[28].

3.4.3 Options for Ameliorating Environmental Impacts Through Power Sector Reform

China can first and foremost reduce power sector emissions by focusing on generating, T&D and end use efficiency. However, it can also reduce emissions by employing cleaner combustion technologies, by installing additional emissions control equipment and/or by simply burning cleaner fuel. As specified in Chapter 4, CETP incorporates the ability for SEPCO to include 'clean coal' technologies in its generating portfolio, and also models the use of cleaner prepared coal. Drawing upon more detailed data presented in Chapter 4, Table compares the additional costs incurred from installing either of the cleaner coal technologies instead of a conventional pulverized coal unit to the costs of installed FGD systems on existing and new plants and to the costs of using prepared coal[29].

Table Fifteen: Cost Comparison of Sulfur Control Options

Control Method	Overnight Costs Yuan/kW
IGCC > Pcoal	4800
AFBC > Pcoal	2200
FGD Existing	126-1425
FGD New	101-1140
Washed Coal	.00072 Yuan/kWh

Due to the difference in units it is not possible to directly compare the variable costs of using washed coal with the fixed costs of installing the other generating or control technologies. Other emissions benefits of AFBC and IGCC, and of using prepared coal would also need to be weighed beyond simply comparing the options' sulfur performance. Notwithstanding these tradeoffs, the use of prepared coal is clearly viable option for reducing power sector emissions.

Impact on SEPCO

Given China's concern over domestic health and environmental issues, its objectives and plans for power sector reform, and considering the relative economic efficiency of using cleaner fuels it is reasonable to anticipate China might begin regulating sulfur content in steam coals. I therefore specify in Chapter 4 and analyze in Chapter 5 the impact on SEPCO of China's imposition of stricter sulfur controls on coals burned in existing power plants.

3.5 Chapter Summary

Chapter Three provided the necessary background and built arguments for several series of events I hypothesize will happen in China that will significantly impact the power sector and hence also SEPCO. Namely, China's accession to the World Trade Organization, ongoing

[28] SEPRI, May, 2001.

financial market reforms, deregulation of its power industry and stricter enforcement of environmental regulations will affect how the utility makes immediate operating as well as long term planning decisions. Chapter Four introduces the modeling approach and assumptions behind the ensuing analysis of these events on SEPCO.

[29] The deltas shown for the clean coal technologies are based on the differences in overnight costs for 300MW plants of comparable efficiencies. The figures for FGD range from installation in a 50MW plant to a 300MW plant. And, figure for clean coal based on cleaning costs of 5 Yuan/tonne x an average of 25GJ/tonne energy content.

Chapter Four- Description of Simulation Exercise, Modeling Assumptions and Methodologies

4.1 Description of Tool

General

CETP makes use of a software package called the Electric Generation Expansion Analysis System (EGEAS), which models how a utility dispatches its generating plants in merit order according to each unit's marginal cost of production. EGEAS thus dispatches baseload plants first, followed by intermediate and then peaking units in turn as variable costs, or [(Fuel Price x Heat Rate) + Variable O&M] rise. According to this formula variable costs are expressed in

$/kWh = Cost/Unit of thermal energy x Thermal energy/kWh + O&M costs/kWh.

Inputs

EGEAS makes its dispatch determinations based on user inputs covering topics that include the utility's existing infrastructure, electricity demand and fuel price trajectories. The bulk of this chapter is devoted to sections discussing the full range of assumptions behind all the inputs EGEAS draws upon for CETP.

Capabilities

EGEAS uses its basic dispatch algorithm to satisfy energy demand under a load duration curve, and can model production from fully dispatchable plants (e.g. thermal plants), energy-limited plants (e.g. hydroelectric facilities from which output is not entirely deterministic), as well as from nondispatchable sources (e.g. solar and wind).

Additional EGEAS capabilities include the ability to model spinning reserves, to account for planned outages, to flag selected units as 'must-run' and to simulate electricity swaps across grid boundaries in periods of excess supply or shortage. EGEAS also models emissions, which for CETP are based on quantity and quality of fuel consumed.

Finally, EGEAS calculates a range of cost metrics such as production and capital recovery costs, into which it can incorporate the effects of taxes, depreciation, inflation, discounting, etc.

Approach

Because EGEAS optimizes dispatch and generation expansion plans according to given sets of inputs, CETP expressly exercises alternative planning strategies in EGEAS over varying futures in order to compare scenario results across changing conditions. This reflects the consortium's belief that a modeling approach which assumes planners have control over strategies but not future conditions is more realistic than one which prescribes optimized strategies for fixed futures.

4.2 Modeling Assumptions

4.2.1 New Generation Technologies

Though China's coal endowment will likely dominate its future generating technology decisions, environmental concerns and the increasing availability of alternative technologies and fuel sources will also broaden its choices. In light of these facts CETP chose to model the following new generation technologies:

- Advanced combustion turbines (CT)
- Advanced combined cycle combustion turbines (CC)
- Sub-critical pulverized coal (PC)
- Atmospheric fluidized bed (AFBC)
- Integrated gasification combined cycle (IGCC)
- Advanced light water reactors (ALWR)
- Modular high temperature gas cooled reactors (MHTGR)

Availability

Pulverized coal, ALWR, oil and diesel generators are currently available in Shandong. In accordance with client predictions CETP assumes simple cycle gas turbines will come on line in 2008 for peaking service, ALWR and AFBC in 2010 and IGCC in 2012. Table Sixteen shows CETP's assumptions regarding the availability of all modeled new technologies.

Table Sixteen: New Generation Technology Availability Assumptions

Technology	Nameplate Capacity MW	Lead Time Years	Availability in Shandong: Order Year	Availability in Shandong: On-Line Year
Pulverized Coal	300	5	1995	2000
AFBC	300	5	2005	2010
IGCC	500	6	2006	2012
Combustion Turbines	155	3	2007	2010
Combined Cycle	250	4	2011	2015
ALWR	600	8	2000	2010
ALWR	1000	8	2000	2010
MHTGR	113	4	2000	2015
Diesel	3	1	1999	2000
Oil # 6	200	5	1995	2000

Cooling Systems

CETP models the impact of two types of cooling systems on the selected generation technologies: Once Through (OC) cooling and Wet Cooling (WC). OC cooling systems, which have higher capital yet lower O&M costs, discharge waste heat into circulating water from a large nearby natural source, such as the sea. WC systems expel heat through evaporation of local water in cooling towers. Though cheaper to build, they use more water and are more expensive to operate.

CETP assumes all new coastal units use OC, as this configuration is more economical over the life cycle of a plant. And, as Shandong's river flow rates are too low to site OC inland, CETP assumes all new inland plants use WC. Table X shows the relative costs and performance of the two cooling technologies.

Table Seventeen: Comparative Cooling Tech. Performance for 300MW Coal Unit

Technology	Average Efficiency	Average Heat Rate	Overnight Cost	Fixed O&M	Variable O&M	Water Consumption
	%	kJnet/kWh	99Yuan/kW	Yuan/kW-yr	Yuan/MWh	m3/MWh
Once Through	37.0	9732	600	160	8	0.0267
Wet Cooling	36.5	9865	588	168	8	0.7593

Coal Technologies

Sub-critical existing coal units feed 97% of Shandong's current load with mostly unprepared coal and no sulfur control. CETP models 300 MW and 600 MW new sub-critical coal units assuming all are built -per current Chinese policy- with ESP and FGD. (I discuss these emissions control technologies further in the sections below.) In addition, though nitrous oxides control is not currently of great policy concern in China, CETP assumes new coal technologies installed will incorporate low NO_x burners with overfire air, as this NO_x control technique is moderately inexpensive and relatively easy to include in new plants.

CETP also models two higher efficiency clean coal technologies. AFBC uses fluidized limestone in the combustion chamber that calcinates to capture sulfur. It also, by virtue of its lower combustion temperatures, inhibits NO_x formation. IGCC gasifies coal for turbine combustion, which affords not only higher efficiencies but also easy chemical separation of impurities during gasification. Table Eighteen displays CETP's cost and performance assumptions for new coal plants.

Table Eighteen: New Coal Generation Tech. Cost and Performance Assumptions

Technology	Nameplate Capacity	Cooling Method	Average Efficiency	Average Heat Rate	Overnight Cost	Fixed O&M	Variable O&M
	MW		%	kJnet/kWh	99Yuan/kW	Yuan/kW-yr	Yuan/MWh
conventional							
pulverized coal	300	OC	36.0	10002	4800	160	8
pulverized coal	600	OC	37.0	9732	4800	152	8
clean coal							
AFBC	300	OC	38.0	9476	7200	240	32
AFBC	300	WC	37.5	9602	7040	248	32
IGCC	500	OC	45.0	8002	9600	240	8
IGCC	500	WC	44.5	8091	9600	248	8

Natural Gas Technologies

CETP models both advanced combustion turbines and combined cycle power plants, both of which afford higher availability and efficiencies, lower O&M and reduced emissions. Table X shows the cost and performance assumptions for these technologies.

Table Nineteen: Natural Gas Generation Tech. Cost and Performance Assumptions

Technology	Nameplate Capacity	Cooling Method	Average Efficiency	Average Heat Rate	Overnight Cost	Fixed O&M	Variable O&M
	MW		%	kJnet/kWh	99Yuan/kW	Yuan/kW-yr	Yuan/MWh
combustion turbine	155	CL*	38.0	9476	3200	8	24
combined cycle	250	OC	58.0	6208	4896	96	4
combined cycle	250	WC	57.5	6262	4800	112	4
combined cycle	500	OC	58.0	6208	4896	88	4
combined cycle	500	WC	57.5	6262	4800	104	4
combined cycle	750	PC	58.0	3208	4896	80	4
combined cycle	750	WC	57.5	6262	4800	96	4

*Closed loop cooling

Nuclear Technologies

CETP models two nuclear technologies. Advanced Light Water Reactors (ALWR) entail long construction periods and high capital requirements, though are attractive due to their low emissions. CETP also chose to model modular high temperature gas cooled reactors (MHTGR) -though they are not yet commercially available- as they are both considerably more efficient and safe than ALWR, and as such present an attractive future alternative for SEPCO. MHTGR's achieve higher efficiencies by super heating helium gas for turbine generation, and are safer as they use fuel encased in graphite, which lends it great stability. Reliance on natural convection for cooling contributes to MHTGR's safety, and additionally lowers capital costs due to the inherently simpler design of such 'passive' safety systems. Table Twenty depicts the comparative costs and performance of these two technologies.

Table Twenty: Nuclear Generation Tech. Cost and Performance Assumptions

Technology	Nameplate Capacity	Cooling Method	Average Efficiency	Average Heat Rate	Overnight Cost	Fixed O&M	Variable O&M
	MW		%	kJnet/kWh	99Yuan/kW	Yuan/kW-yr	Yuan/MWh
MHTGR	113	OC	45.0	8002	8000	0	0
MHTGR	113	WC	44.5	8091	8000	240	4
ALWR	600	WC	33.0	10911	12000	248	4
ALWR	1000	WC	33.0	11079	11200	328	4

Oil Fuel Generation Technologies

Though oil is available as a feedstock in increasingly limited quantity in Shandong, SEPCO does make some use of oil and diesel generators to serve peak demand. CETP thus models oil and diesel peaking generators, as shown in Table Twenty-One.

Table Twenty-One: Oil Generating Tech. Cost and Performance Assumptions

Technology	Nameplate Capacity	Cooling Method	Average Efficiency	Average Heat Rate	Overnight Cost	Fixed O&M	Variable O&M
	MW		%	kJnet/kWh	99Yuan/kW	Yuan/kW-yr	Yuan/MWh
Diesel	3	-	30.0	12000	2400	2	5
Oil	200	OC	35.0	10286	4000	15	2
Oil	200	OC	34.5	10435	4000	15	2

[1] Hansen, Chris, New Generation Technology Characteristics and Costs, MIT/CETP, 2001.

4.2.2 Sulfur Control

Regulation

Chinese environmental regulations mandate sulfur control equipment on all new and repowered coal units. They additionally call for retrofitting existing plants of size greater than 50 MW with sulfur control equipment by 2020, and for retiring sub-50 MW plants by 2003.

The older, generally smaller and less efficient units in Shandong's generating fleet tend to have higher emissions rates than its newer plants. Yet, given Shandong's heavy reliance on coal it is likewise important to control emissions in new plants. A range of measures exists for controlling sulfur emissions from both existing and new plants.

Sulfur Control Technologies

CETP models four commercially available flue gas desulfurization technologies, presented below in order of effectiveness:

1) *Wet Scrubbers (WS).* This efficient, reliable, relatively high-cost and yet most prevalent technique uses a lime and sodium-based sorbent to absorb stack sulfur. The by-product of this process- gypsum can be retrieved and sold.
2) *Sea Water Scrubbers (SW).* This new, low cost and easily maintained technique uses and discharges seawater as a sorbent, though it is practical only for coastal plants burning low sulfur coal.
3) *Spray Drying (SD).* This method captures sulfur in a lime-based sorbent mist, the by-product of which is useable if combined with pre-scrubber fly ash.

4) *Furnace Sorbent Injection (FSI).* This low-cost method absorbs sulfur in the boiler and further downstream with pulverized limestone, though it is not as effective as the preceding techniques.

Table Twenty-Two presents the characteristics of the above technologies, and describes how they are distributed through Shandong's generating fleet.

Table Twenty-Two: Characteristics and Applications of FGD Tech's in Shandong

Method	Sorbent	Performance		Cost	Space Required	Applied to Power Plants	
		Low S Coal	High S Coal			Inland	Coastal
WS	lime	high	high	high	large	>= 100 MW	>= 100 MW
SW	sea water	high	high	low	large	-	>= 50 MW
SD	lime	medium	medium to low	medium	large	>= 300MW	>= 300 MW
FSI	lime	medium	low	low	small	50-250 MW	50-250 MW

Costs

In addition to the minor cost impact induced by the need to slightly derate the efficiency and capacity of plants installed with FGD by 1%, CETP models the capital, fixed operation and maintenance (O&M) plus variable O&M costs of the technologies considered.

CETP assumes all technologies afford the same installation economies of scale in China as they do in the US, and further assumes a 20% discount on FGD installed in new vs. old units. Table Twenty-Three lists CETP's cost assumptions for the full size range of new and old units in Shandong.

Table Twenty-Three: Capital Costs of FGD Technologies in Shandong

Technology	Existing Units, Yuan/kW			New Units, Yuan/kW		
	50 MW	200 MW	>= 300MW	50 MW	200 MW	>= 300MW
US WS	2374	1188	970	2374	1188	970
Chinese WS	1425	713	582	1140	570	465
Chinese SD	902	451	368	722	361	295
Chinese SW	522	261	213	418	209	171
Chinese LSI	309	154	126	247	124	101

CETP assumes fixed and variable O&M are affected by coal quality as lower sulfur coal (<1.6% by weight content) requires more capital, labor and energy to prepare for combustion. Table Twenty-Four presents CETP's variable cost and performance assumptions for all FGD technologies modeled.

Table Twenty-Four: Cost and Performance Assumptions for Modeled FGD Tech's

FGD Retrofits	Capacity MW	% Sulfur Content	% Removal Efficiency	Fixed O&M Yuan/kWh	Variable O&M Yuan/kWh
WS	>300	any	90	0.003	0.009
WS	200	any	90	0.003	0.009
SD	>300	.1-1.5	80	0.002	0.010
SD	>300	1.6+	65	0.002	0.012
FSI	200	.1-1.5	80	0.002	0.013
FSI	50	.1-1.5	80	0.002	0.013
FSI	200	1.6+	65	0.003	0.015
FSI	50	1.6+	65	0.003	0.015
SW	>300	any	90	0.003	0.003
SW	200	any	90	0.003	0.003
SW	50	any	90	0.003	0.003
New Installations					
WS	>300	any	90	0.003	0.009
Ws	200	any	90	0.003	0.009
SD	>300	.1-1.5	80	0.002	0.010
SD	>300	1.6+	65	0.002	0.012
FSI	200	.1-1.5	80	0.002	0.013
FSI	200	1.6+	65	0.003	0.015
SW	>300	any	90	0.003	0.003
SW	200	any	90	0.003	0.003 [2]

4.2.3 Particulate Matter Control

Regulation

Though ambient standards have yet to be established in China for particulate matter (PM) levels, there is an increasing awareness -as in the US- of the health effects of smaller PM particles (less than 10 microns in size). Chinese environmental regulations do require and enforce the installation of electrostatic precipitators (ESP), a particulate

[2] Cheng, Chia-Chin. New Generation Technology Characteristics and Costs, MIT/CETP, 2001.

matter control measure, in new plants. Yet, many older plants either use less effective techniques or nothing at all.

Forms of Particulate Matter Pollution

PM attributable to the combustion process includes ash, unburned carbon and airborne flue gas PM. PM attributable to coal handling stems from coal crushing and loading, and from the handling of post-combustion ash. Most PM occurs in ash form, and some -called condensable PM- occurs via the condensation of unburned particles small enough to pass through filtering devices. Condensable PM is often used to refer to a third type, called secondary PM, which is formed via the nucleation of other flue gases such as NO_x and SO_x with particles already existing in the atmosphere. Secondary PM is thus better mitigated with sulfur rather than conventional PM controls.

PM Control Technologies

CETP models the two following seasoned PM Control technologies:

1) *Electrostatic Precipitators (ESP).* ESP filters particulate matter using an electric charge. It is popular in China as it is applicable across a wide range of systems and sizes, and as it has a negligible impact on combustion performance. ESP is effective at fine and coarse particle removal though not as effective for mid-range particle sizes.
2) *Baghouse Filters.* Baghouse uses fabric bags to trap flue gas PM and is highly effective, though it does reduce plant efficiency.

Table Twenty-Five depicts CETP's simulation inputs for PM control technologies.

Table Twenty-Five: Performance of Particulate Control Tech's in Shandong

Technology	Coal Type	% Removal Efficiency	Capital Costs Yuan/kWh	Fixed O&M Yuan/kWh
ESP				
new	raw	95	160	1.92
retrofit	raw	95	200	1.92
new	prepared	97	160	1.92
retrofit	prepared	97	200	1.92
Baghouse				1.92
new	raw	99.9	240	1.92
retrofit	raw	99.9	300	1.92 [3]

4.2.4 Coal Classification and Emissions

Coal Classification System

The makeup of a combustion fuel in large part determines the thermal and environmental performance of the unit burning it. In addition, as 97% of Shandong's generation is coal-based, it was important to develop a detailed database of the coals used in Shandong plants.

CETP developed a classification scheme for coal burned in Shandong plants based on coal type, energy content, sulfur content, geographical source and transport method. Table Twenty-Six presents these data for the steam coals burned in Shandong's major power plants.

[3] Cheng, Chia-Chin, Particulate Matter Control on Existing and New Generation, MIT/CETP, 2001.

Table Twenty-Six: Characteristics of Steam Coal Used in Shandong

Power Plant	LHV GJnet/tonne	Sulfur % weight	Primary Fuel	Fuel Source	Delivery Method
Linyi	24.6	0.44	Meager	Shanxi	Rail
Liaocheng	24.5	0.42	Meager	Shanxi	Rail
Heze	23.8	0.50	Anthracite	Shandong	Rail
Weihai	23.5	0.75	Bituminous	Inner Mongolia	Rail/Ship
Huangtai	23.4	1.48	Meager	Shanxi, Shandong	Rail
Shiheng	22.9	1.48	Bituminous	Shandong	Rail
Weifang	22.7	1.24	Meager	Shanxi, Shandong	Rail
Jining	22.6	0.61	Meager	Shandong	Rail
Zouxian	22.6	0.80	Bituminous	Shandong	Rail
Shiliquan	22.5	1.18	Bituminous	Shandong	Rail
Qingdao	22.2	2.31	Meager	Shanxi, Shandong	Rail/Ship
Yantai	22	1.62	Meager	Shanxi, Shandong	Rail/Ship
Nanding	21.9	2.00	Meager	Shandong	Rail
Laiwu	21.5	2.58	Bituminous	Shandong	Rail
Longkou	21.5	0.52	Lignite	Shandong	Mine Mouth
Huangdao	21.5	1.34	Meager	Shanxi, Shandong	Rail/Ship
Dezou	21.4	1.23	Meager	Shanxi	Rail

In order to accurately express the composition of Shandong steam coal using these metrics -which EGEAS relies upon for simulation inputs- it was necessary to reconcile the Chinese coal classification system per the above table to the prevailing US system as purveyed by the American Society For Testing and Materials (ASTM).

Whereas the Chinese system classifies coal according to its coking properties for steel manufacture, the ASTM system relies primarily on a method called Proximate Analysis to describe coal's physical makeup in properties which are more pertinent to power generation and emissions tracking, such as energy and sulfur content[4].

ASTM categories range from anthracite to lignite, which are names given to categories of coal in decreasing order of lower heating value (dry) and fixed carbon content. Table X gives heating values and Proximate Analyses for ASTM coals.

Table Twenty-Seven: ASTM Coal Categories and Properties

ASTM Coal Categories	LHV Gjnet/t	Proximate Property (% weight) Moisture	Volatiles	Fixed C	Ash
Meta-Anthracite	21.7	13.2	2.6	65.3	18.9
Anthracite	30	4.3	5.1	81	9.6
Semi-Anthracite	32.3	2.6	10.6	79.3	7.5
Low-Volatile Bituminous	33.5	2.9	17.7	74	5.4
Med-Volatile Bituminous	33.3	2.1	24.4	67.4	6.1
High-Volatile A Bituminous	32.7	2.3	36.5	56	5.2
High-Volatile B Bituminous	27.2	8.5	36.4	44.3	10.8
High-Volatile C Bituminous	25.2	14.4	35.4	40.6	9.6
Sub-Bituminous A	24.8	16.9	34.8	44.7	3.6
Sub-Bituminous B	22.4	22.2	33.2	40.3	4.3
Sub-Bituminous C	21.1	26.6	33.2	34.4	5.8
Lignite	16.3	36.8	27.8	29.5	5.9

As Table Twenty-Eight shows, Chinese coal categories range from anthracite to brown coal. Because they, as ASTM coals, are categorized in part according to low heating value, sulfur and ash content, for purposes of modeling CETP was able to calculate the balance of characteristics according to ASTM standards for the four types of coal used in SEPCO plants.

Table Twenty-Eight: Chinese Coal Characteristics

Chinese Standard Coal Categories	LHV Gjnet/t	Proximate Property (% weight) Moisture	Volatiles	Fixed C	Ash
Anthracite	26.5	9	25.8	56.6	8.6
Meager	21.4	1	12.8	56.8	29.4
Lean	24.4	5.4	11.2	57.1	26.3
Weakly Caking	29.6	9	25.8	56.6	8.6
Non-Caking	26.8	11.3	25.4	52.5	10.8
Long Flame	22.3	13.5	32	43.7	19.8
Brown	16.9	30.8	23.7	25.6	

CETP established Shandong coals' total carbon content by regressing ASTM coals' total carbon content on their lower heating values, and established fixed carbon content (a subset of total carbon) by using the same ratios in which fixed carbon appears

[4] Proximate Analysis involves a determination of a particular coal's moisture, volatile matter, ash and fixed carbon content.

in ASTM coals. CETP also established ash content in Shandong coal using regression on ASTM lower heating values, and was provided weight percent sulfur and moisture figures by SEPRI. Finally, CETP calculated weight percent volatile matter as the remaining proportion of material in the Shandong coals such that the otherwise complete set of components summed to 100%.

EGEAS also models the impact of coal preparation on emissions. Most coal preparation techniques -which involve the crushing and physical separation of coal from impurities with the assistance of air, fluid, machinery and/or chemicals- undertaken in Shandong aim to reduce ash content, though these methods also improve heating values and reduce sulfur content.

To model prepared coal in Shandong CETP applied a conventionally achievable 40% ash reduction to all categories save anthracite, which does not normally need ash reduction, and lignite, which is too low in heating value to be worth cleaning. Because much of a given coal's mineral (pyritic) sulfur content is contained in ash, CETP also ascribes a 14% reduction in sulfur content to prepared coal. All prepared coal categories also gain in heating value for purposes of simulation as a result of beneficiation. Finally, because coal ash fouls power plant boilers, CETP assumes prepared coal units enjoy fewer weeks of scheduled maintenance and lower equivalent forced outage rates (EFORs) annually than units burning untreated coal.

Emissions from Coal Combustion

EGEAS calculates sulfur dioxide, carbon dioxide and total ash emissions (including fly and bottom ash) stoichiometrically assuming complete oxidation minus 1% of total carbon and 4% of sulfur assumed to remain fixed in ash wastes.

As particulate emissions vary with unit configuration and combustion conditions, CETP assumes particulate emissions rates are representative of those for a conventional 300 MW coal unit across the various categories of Shandong coal[5].

4.2.5 Coal Costs

Background on Coal Prices in China

In a commodity market coal quality in terms of heating value and impurity content greatly impacts its cost, as do transit mode and shipping distance. Though these factors also help determine coal costs in China, an overlay of subsidies, ministerial conflicts and shifting policies tend to distort prices. Until 1994 China operated a dual production system for coal, whereby state-owned mines produced coal allocated by plan and small township mines produced free market coal, which they could sell for negotiated prices. The abolishment of this system had the effect of increasing prices for allocated coal though it also stimulated new entrants, which led late in the decade to overproduction and falling prices. China is thus currently campaigning to stem this phenomenon by closing smaller mines, yet at the same time maintains the policy position that it is moving towards a free market system for the industry.

In this environment SEPCO sources and negotiates prices for coal as it can from both within Shandong and from Inner Mongolia via rail, and from Shanxi via rail and barge. Given China's advocacy of coal market rationalization, CETP chose to model coal costs in accordance with established electric industry convention by basing them on quality, transit mode and shipping distance.

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5 Cheng, Chia-Chin, CETP/ESS: Classification of Steam Coal for ESS Scenarios, MIT/CETP, 2001.

CETP's pricing regime incorporates 1) a raw coal costs paid on the basis of low heating value (LHV), 2) preparation costs and 3) transportation costs. For the raw coal component, CETP adapted an LHV-based formula used for coal exports from China to Taiwan in 1999 to the entire range of combustion coals used in Shandong. For the preparation component CETP uses a 5 Yuan per tonne processing charge, and for the transportation component was provided information by SEPRI. Table Twenty-Nine gives the baseline raw, preparation and transit costs for the coal used in SEPCO's units.

Table Twenty-Nine: Cost Components of Shandong Coal

Coal Type	Raw Costs	Prep Costs	Transportation Costs from Shandong via Rail	Shanxi via Rail	Shanxi via Rail/Ship	Inner Mongolia via Rail
Anthracite	169	5	25	40	50	50
Meager	192	5	25	40	50	50
Bituminous	194	5	25	40	50	50
Lignite	278	5	-	-	-	-

In order to capture the range of possible impacts evolving technology, policy and general economic conditions will unquestionably have on coal prices to SEPCO over the study period, CETP also models three possible coal cost trajectories: Business as Usual (BAU) Market Stabilization and Production Innovation. The BAU case assumes prices escalate with inflation, whereas Market Stabilization assumes prices will escalate in step with further anticipated mine closures in the near term and fall again later as the market stabilizes. And, the Production Innovation case assumes that increasing adoption of mechanized mining equipment in China will reduce labor, improve productivity and drive prices down more dramatically. Table Thirty shows the annual percentage growth CETP assumes coal costs will experience for each of the trajectories. (Note the simulations will additionally incorporate inflation.)

Table Thirty: Cost Trajectories of Modeled Coal

	Cost Escalation Factors (%/year)		
Year	BAU	Stabilization	Innovation
1999	0	2	2
2000	0	2	2
2001	0	2	2
2002	0	1	1
2003	0	1	1
2004	0	0	0
2005	0	0	-1
2006	0	-1	-1
2007	0	-1	-2
2008	0	-1	-3
2009	0	-2	-3
2010	0	-2	-4
2011	0	-2	-4
2012	0	-2	-4
2013	0	-2	-5
2014	0	-2	-5
2015	0	-2	-5
2016	0	-2	-6
2017	0	-2	-6
2018	0	-2	-6
2019	0	-2	-6
2020	0	-2	-6
2021	0	-2	-6
2022	0	-2	-6
2023	0	-2	-6
2024	0	-2	-6

[6]

4.2.6 Non-Coal Fuels

Because China plans to address environmental and energy security concerns over the study period and beyond by diversifying its electric power fuel base, CETP models the use of fuel oil, diesel, natural gas and nuclear fuels. Table Thirty-One shows CETP's basic assumptions with respect to non-coal fuels, which are based on a literature review and dialogue with Chinese stakeholders.

[6] Cheng, Chia-Chin, Coal Cost Assumptions and Coal Cost Uncertainty Development, MIT/CETP, 2001.

Table Thirty-One: Basic Noncoal Fuel Characteristics and Costs

Fuel	Energy Content GJn/tonne	Base Yr. 1999 Cost Yuan/GJn	Base Yr. 1999 Cost $/GJn	Total Sulfur weight %	Total Carbon weight %	kg CO_2/ GJn
Pipeline Gas	48.84	26.0	3.25	0	73	54.8
LNG	48.84	32.0	4.00	0	75	56.3
Diesel Fuel	44.51	60.0	7.50	0.5	87	71.7
Heating Oil	39.37	36.0	4.50	1.6	85	79.2
Nuclear 3.25%	2850000	4.8	0.60	0	0	0
Nuclear 8%	3880000	5.6	0.70	0	0	0

Petroleum Fuels

As a net importer of oil China is not expected to rely on petroleum products for baseload generation. Yet, diesel and fuel oil are used in peaking and backup applications. CETP models Shandong's use of diesel (Oil2), and residual fuel oil (Oil6), which is lower grade and contains more impurities yet is less expensive.

Natural Gas

LNG's need for compression, storage and port handling makes its capital investment prohibitive for use in Shandong. Hence CETP does not model its use, though uses LNG prices as a long run upper bound for pipeline gas.

China is, however, focused on developing its natural gas pipeline infrastructure to the east-coast from Western China, Mongolia and Siberia, as mentioned in the background section. CETP assumes natural gas will be available to SEPCO's peaking units beginning in 2008, and that sufficient pipeline gas to support baseload generation will become available beginning in 2015, since industry and residences will likely have first use of gas expected to become available by 2012.

Though natural gas is more efficient and less polluting than coal, its higher cost may relegate it to a minor role in Shandong's power sector. CETP assumes the cost to SEPCO of natural gas will rise at 1percentage point over inflation once supply comes online due to the long-term increase in demand the advent of limited supply is expected to stimulate. Table Thirty-Two details CETP's cost trajectory assumptions for gas fuels.

Nuclear

CETP models the use of 3.25% U-235 enriched fuel for use in ALWR. China currently produces this fuel domestically, though CETP expects a situation of global oversupply to keep prices down throughout the study period. Alternatively, the 8% enriched U-235 fuel CETP models for use in MHTGR has not yet achieved mass production, though recent progress demonstrates the feasibility of China producing it domestically should China's energy policy embrace MHTGR. Table Thirty-Two details CETP's cost trajectory assumptions for nuclear fuels.

Table Thirty-Two: Non-Coal Fuel Cost Escalation Trajectories

Year	Inflation	Pipeline Gas	Diesel Fuel	Heating Oil	3.25% Nuclear	8% Nuclear
		---% change in cost over previous year---				
1999	0.0	0.0	0.5	0.5	0.0	0.0
2000	0.5	0.5	1.0	1.0	0.5	0.5
2001	1.0	1.0	1.5	1.5	1.0	1.0
2002	1.5	1.5	2.0	2.0	1.5	1.5
2003	2.0	2.0	2.5	2.5	2.0	2.0
2004	2.5	2.5	3.0	3.0	2.5	2.5
2005	3.0	3.0	3.5	3.5	3.0	3.0
2006	3.5	3.5	4.0	4.0	4.0	3.5
2007	4.0	5.0	4.5	4.5	4.5	4.0
2008	4.5	5.5	5.0	5.0	5.0	4.5
2009	5.0	6.0	5.5	5.5	5.0	5.0
2010	5.0	6.0	5.5	5.5	5.0	5.0
2011	5.0	6.0	5.5	5.5	5.0	5.0
2012	5.0	6.0	5.5	5.5	5.0	5.0
2013	5.0	6.0	5.5	5.5	5.0	5.0
2014	5.0	6.0	5.5	5.5	5.0	5.0
2015	5.0	6.0	5.5	5.5	5.0	5.0
2016	5.0	6.0	5.5	5.5	5.0	5.0
2017	5.0	6.0	5.5	5.5	5.0	5.0
2018	5.0	6.0	5.5	5.5	5.0	5.0
2019	5.0	6.0	5.5	5.5	5.0	5.0
2020	5.0	6.0	5.5	5.5	5.0	5.0
2021	5.0	6.0	5.5	5.5	5.0	5.0
2022	5.0	6.0	5.5	5.5	5.0	5.0
2023	5.0	6.0	5.5	5.5	5.0	5.0
2024	5.0	6.0	5.5	5.5	5.0	5.0[7]

4.2.7 Load Assumptions

Annual Electricity Demand

Shandong's electricity consumption has grown quickly in the post-Mao era, achieving annual rates between 7.5% and 17.5% through 1998. However, virtual annual demand saturation in Shandong roughly coincided with the Asian currency crisis, which had a GDP and hence demand-dampening effect throughout China. Recent electricity demand growth rates have consequently been more moderate. Though these figures were not available to CETP, we can infer they have diminished as generation growth slowed for China from 5.1% in 1997 to 2.8% in 1998[8]. Because annual demand over the study period will be influenced in Shandong by factors such as the weather, the economy, population growth as well as policy and technical change, CETP models three demand growth trajectories.

SEPCO was only able to provide busbar demand figures for 1998 and 1999. However, CETP was able to develop trajectories by extrapolating the curve formed by available historical total electricity consumption data for Shandong Province as a whole into three alternative functions extending through the study period that represent low, moderate and high growth. As Figure Seven below demonstrates, CETP represented these possibilities by extending the historical function in linear, 7% annual growth and polynomial (X^2) fashion.

Because total provincial demand is somewhat greater than that served by SEPCO, it was necessary to subtract SEPCO's expected annual busbar demand from each of these trajectories to more accurately represent strictly SEPCO-served demand. Because much of this extra-grid demand is in Shandong's stable industrial sector, CETP deemed it reasonable to simply subtract the known delta (approximately 15,000 GWh for 1998 and 1999) between the provincial and SEPCO figures in even increments for each year throughout the study period in order to model the range of demand trajectories SEPCO will face. The modeled trajectories result in 3.89% (low), 5.12% (moderate) and 7.65%(high) long-term annual growth rates.

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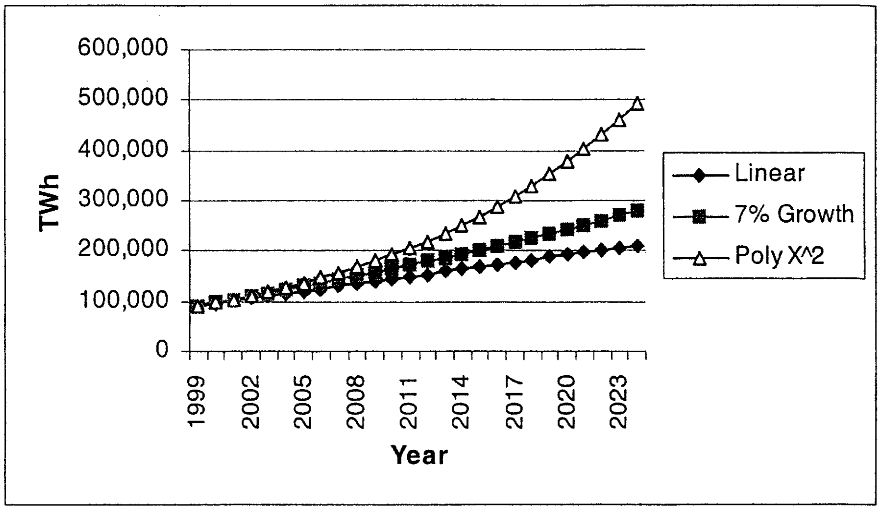
[7]Hansen, Chris, ESS/CETP: Non-Coal Fuels, Characteristics and Costs, MIT Energy Laboratory, 2001.
[8] State Electric Power Information Center, 1999.

Figure Seven: Shandong Provincial and Grid Demand Trajectories



As electricity demand in hindsight is never smooth, CETP adds a final touch of volatility to each of the above modeled demand trajectories by randomly assigning noise to each year of demand within plus and minus one standard deviation of the historical data.

Peak Load Growth

In addition to continuing to meet total annual electricity demand, SEPCO must maintain capacity in excess of annual peak load. Though historical peak load demand data for SEPCO is limited to recent years, CETP does have forecasted annual provincial demand data for Shandong by sector, provided by China's Energy Research Institute in Beijing.

CETP modeled peak load growth with this data by working from the assumption that the ratio of sectoral peak load to average annual hourly load for that sector should approximate the ratio of annual peak load to average annual hourly load for the system as a whole. Thus, CETP converted sectoral forecasts of annual demand into average hourly demand for each of the consumer classes (industrial, construction, transportation, agricultural, service and residential) by dividing those figures by the number of power generating hours in a year. CETP then derived sectoral multipliers by isolating the Sectoral Peak factor from the following relation:

Sectoral Peak / Ave. Hourly Sectoral Load = Annual Peak Load /Ave. Hourly Total Load

Hence, the anticipated Sectoral Peaks for each year =

(Ave. Hourly Sectoral Load)(Annual Peak Load) / Ave.Hourly Total Load

Finally, total peak load for each year can be approximated by aggregating the respective sectoral peaks.

It is important to consider, however, that electricity demand in Shandong's service and household sectors is growing rapidly, industry is growing more slowly and the other sectors appear stable. To account for the impact this type of differential sectoral growth may have, CETP's 'business as usual' peak load growth trajectory assumes the rate of peak load growth exceeds the growth rate of annual demand. Alternatively, CETP also builds in a 'peak management' scenario that accounts for the possibility SEPCO may implement peak load management practices by applying uniform load multipliers across all sectors. Table X shows the sectoral load multipliers used in each case.

Table Thirty-Three: Sectoral Load Multipliers

	Industrial	Construction	Transportation	Agriculture	Service	Household
Uniform	1.45	1.45	1.45	1.45	1.45	1.45
Sectoral	1.30	1.50	1.50	1.45	3.00	3.00

Finally, to account for volatility as with annual demand, CETP applies random noise to each peak load trajectory.

End-Use Efficiency

As effective implementation of an end use efficiency program could supplement any peak management efforts SEPCO undertakes, CETP incorporates three strategies SEPCO may adopt: Current, Moderate and Aggressive. The current case assumes both annual and peak demand remain unchanged. The moderate and aggressive cases assume the respective achievement of 10% and 20% reductions in electricity use for target sectors[9].

The set of scenarios I specify and analyze in chapter 5 all assume, per current practices, that SEPCO does not pursue a focused end use efficiency program.

4.3 Strategies, Futures and Scenarios

CETP represents SEPCO's choices by simulating the performance of various electricity service planning *scenarios.* Each scenario consists of a number of selected *strategies* run over varied *futures.* Using this approach, a strategy is defined as a set of choices that are under SEPCO's control, such as what types of power plants to build and fuels to use. A future, by contrast, is then an uncertainty that SEPCO may be able to somewhat predict but nevertheless cannot control. For example, SEPCO has a feel for projected electricity demand growth, but cannot control such future factors in the same way as it can exercise choice over things like generation investments.

CETP organizes strategies into three broad categories: 1) existing generation, 2) new generation and 3) end use efficiency. Futures fall into three categories as well: 1) demand growth, 2) coal costs and 3) natural gas costs. According to these categories and

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[9] Cheng, Chia-Chin. CETP/ESS: ESS Electricity Load Assumptions and Uncertainties, MIT, April, 2001.

the subcategories within them, Table Thirty-Four presents a master key of all the strategies and futures one may select from to form scenarios.

Table Thirty-Four: Master Key of Strategies and Futures for CETP

			Key
Strategies		*Existing Generation*	
	Retirement Schedule	"B"aseline	**B**
		"R"etire Some	**R**
		"S"cheduled Retirement	**S**
		"T"hirty-five Year Retirement	**T**
	Emissions Retrofits	N"O"ne Beyond Planned	**O**
		R"A"tchet Down Sulfur Content	**A**
	Fuel Type	"C"urrent Coal	**C**
		"P"repared Coal	**P**
		Prepared Coal in E"X"isting Units	**X**
		New Generation	
	New Baseload & Intermediate	"C"onventional Coal	**C**
		Coal + A"F"BC	**F**
		Coal + Co"M"bined Cycle	**M**
		Coal + Must-Run Combined Cycle	**R**
		Coal + "N"uclear	**N**
		Coal + Combined Cycle + Nuclear	**D**
		Coal + AFBC + CCycle + Nuclear	**K**
	Extra-Provincial Generation	N"O"ne by Wire	**O**
		Natural G"A"s by Wire	**A**
	Renewables	"N"one	**N**
	Peak Management	Moderate Combustion Turbines	**P**
		Active "L"oad Management	**L**
	Planning Reserve Margin	Target 20%	**A**
		Target 15% (F"I"fteen)	**I**
		Target 10% (T"E"n)	**E**
		End-Use Efficiency	
	End-Use Programs	Current "S"tandards	**S**
		"M"oderate Efforts	**M**
		A"G"gressive Efforts	**G**
Futures		*Uncertainties*	
	Electricity Demand Growth	Slow	**T**
		Moderate	**F**
		"S"trong	**S**
	Delivered Coal Costs	Business as Usual	**I**
		Prod"u"ctive	**U**
		"A"ggravated	**A**
	Natural Gas Costs	"B"ase	**B**
		Lower	**F**
		Position Reserved to IndicateROE	**B,H**

4.4 Reference Scenarios

I compare the hypothesized scenarios to two reference cases. The first case represents a baseload generation strategy that is strictly coal-based, which in effect represents SEPCO's past and current practices. Per the articulated intent of SEPCO officials with respect to the future, the second reference case incorporates some nuclear capacity into baseload as well as some natural gas capacity imported by wire from outside of Shandong. Note however that this second case only supplements SEPCO's portfolio with the new technologies and continues to rely predominantly on coal, which makes this scenario a reasonable 'alternative' reference case. Table Thirty-Five depicts the ingredients of the reference cases using elements from the key above.

Table Thirty-Five: Reference Scenarios

Conventional Coal Reference Scenario
B O C - C O N P A S - F I B
"**B**"aseline old unit retirement schedule
N"**O**" emissions retrofit beyond planned
"**C**"urrently available coal supplies
- "**C**"oventional coal baseload
N"**O**" extra-provincial generation
"**N**"o renewables
"**P**"eaking units = combustion turbines
T"**A**"rget planning reserve of 20%
"**S**"tandard end-use efficiency programs
- "**F**"uture demand growth moderate
Bu"**I**"siness-as-usual coal costs
"**B**"aseline ROE

Nuclear and Gas-by-Wire Reference Scenario

B O C - N A N P A S - F I B

"**B**"aseline old unit retirement schedule
N"**O**" emissions retrofit beyond planned
"**C**"urrently available coal supplies
- "**N**"uclear and conventional coal baseload
G"**A**"*s by wire* from outside province
"**N**"o renewables
"**P**"eaking units = combustion turbines
T"**A**"rget planning reserve of 20%
"**S**"tandard end-use efficiency programs
- "**F**"uture demand growth moderate
Bu"**I**"siness-as-usual coal costs
"**B**"aseline ROE

4.5 Comparison Scenarios

To represent each of the four hypothesized streams of events, I construct four sets of coal-based scenarios and four parallel sets of nuclear and gas-based scenarios for comparison in Chapter 5 to their appropriate base cases. The subsets for each hypothesis then differ only by generation strategy, and are otherwise identical according to the modeling methods presented below.

4.5.1 World Trade Organization Set

The World Trade Organization (WTO) scenarios first introduce a letter S in the twelfth position, as in BOC-CONPA*S*-SIB and BOC-NANPA*S*-SIB, in order to represent "S"tronger economic growth than in the base case. WTO also incorporates an inflation trajectory that peaks and falls in five to seven year increments as it has in China's post-Mao period- whereas the base case assumes a flat 5% annual inflation after 2005. Finally, WTO models slightly higher imported technology component costs as a result of a moderate devaluation in the Yuan. To reiterate- so as to simulate conditions of greater economic expansion, more volatile inflation and a freely floating currency as a consequence of China's accession to the WTO, the WTO scenarios reflect:

1) Substitution of an "S" in the twelfth position to represent a "S"trong economy at 7% annual electricity demand growth.

2) As shown in Table Thirty-Six, substitution of the following 'noisier' inflation trajectory for the reference case's assumption of 5% annual inflation. Because it is not possible to directly represent this new trajectory by substituting a single letter in any position, for these scenario it is embedded in the technology cost, fuel cost plus fixed and variable O&M data tables EGEAS draws upon to execute.

Table Thirty-Six: WTO Inflation Trajectory

Year	Inflation %	Year	Inflation %
1999	**N/A**	**2012**	**10**
2000	0	**2013**	**6**
2001	1.5	2014	4
2002	2.5	2015	2.5
2003	4	2016	4
2004	**7**	**2017**	**6**
2005	5	**2018**	**7**
2006	3	**2019**	**10**
2007	2	**2020**	**8**
2008	2	2021	5
2009	4	2022	5
2010	**6**	2023	4
2011	**8**	2024	3

3) Incorporation of the effect on new generation technology costs of a 20% devaluation in the Yuan. As the various new gentechs SEPCO will select from contain differing proportions of imported components, devaluation would impact costs to a greater extent as foreign content increases. For modeling purposes, then, costs escalate for each technology the greater proportion of that technology must be purchased from overseas. For example, were the Yuan to devalue by 20%, the cost to purchase a technology of former price X with 100% foreign components would be X/.8. To represent how purchase costs would escalate for a range of generating technologies containing foreign components in varying

proportions, I grossed up the reference case's overnight costs using the divisors in Table Thirty-Seven.

Table Thirty-Seven: New Generation Technology Devaluation Divisors

Technology	WTO Devaluation Divisor
Diesel Generators	0.95
Single Cycle Combustion Turbines	0.85
Combined Cycle Combustion Turbines	0.85
Conventional Coal Technologies (Subcritical)	0.95
Clean Coal Technologies	0.95
Pebble Bed Reactors	0.85
Advanced Light Water Reactors	0.85

4.5.2 Return on Equity Set

To model the operational impact of ongoing and pending Chinese financial market reforms on SEPCO, this set simulates increasing shareholder demands for a return on equity commensurate with risk. As for example in BOC-CONPAS-FI*H* and BOC-NANPAS-FI*H* it thereby introduces an H in the fourteenth position to represent a "H"igh return on equity, or ROE.

For these scenarios in order to model increasing shareholder power and consequent higher returns, I recalculated SEPCO's weighted average cost of capital (WACC) using a set of ROE's ranging from 4% to a "H"igh bound of 13%.

Some select SEPCO financial statement data were made available to CETP, though not enough to properly calculate the company's WACC. However, as discussed in Chapter 2, Huaneng Power International's recent acquisition of SEPCO generating assets makes it a reasonable and opportune 'comparable' company for purposes of approximating SEPCO's WACC. Figures Eight through Ten depict Huaneng Power International's most recent financial statements, which I drew upon for this process as described below.

Figure Eight: Huaneng Power International, Balance Sheet (000's)

ASSETS	12 Months Ended 12/31/2000	
Noncurrent Assets	RMB	$US
Net PPE	32,219,595.00	$ 3,892,149.00
Other long-term assets	185,664.00	$ 22,428.61
Current Assets		
Cash and cash equivalents	1,988,373.00	$ 240,199.69
Short term investments	354,925.00	$ 42,875.69
Accounts receivable	1,196,072.00	$ 144,488.04
Materials and supplies	563,741.00	$ 68,101.11
Other receivables and assets	5,958,578.00	$ 719,808.89
Due from HIPDC	0.00	
Total current assets	10,061,689.00	$ 1,215,473.42
Total assets	42,466,948.00	$ 5,130,097.61
LIABILITIES		
Current Liabilities		
Short-term bank loans	1,300,000.00	$ 157,042.76
Current portion long term loans from founding shareholders	218,995.00	$ 26,455.06
Current portion long term loans from Nanjing Investment	58,123.00	$ 7,021.38
Current portion lt bank loans	1,431,713.00	$ 172,953.97
Accts payable & accrued liabs	2,717,957.00	$ 328,334.98
Payble to Nanjing Investment	141,641.00	$ 17,110.53
Taxes payable	529,661.00	$ 63,984.17
Staff welfare and bonus payable	542,355.00	$ 65,517.64
Dividend payable	130,158.00	$ 15,723.36
Total current liabilities	7,070,603.00	$ 854,143.88
Noncurrent Liabilities		
Convertible notes	1,393,388.00	$ 168,324.23
Long term loans from SH	782,825.00	$ 94,566.92
Long term note fr Nanjing Inv	174,368.00	$ 21,064.03
Long term bank loans	8,885,634.00	$ 1,073,403.48
Accrued put premium for convertibles	380,395.00	$ 45,952.52
Total noncurrent liabilities	11,616,610.00	$ 1,403,311.19
Total liabilities	18,687,213.00	$ 2,257,455.06
SHAREHOLDERS EQUITY		
Total shareholders equity	23,779,735.00	$ 2,872,642.55
Liabilities and SH equity	42,466,948.00	$ 5,130,097.61

Figure Nine: Huaneng Power International, Income Statement (000's)

	12 Mos Ended 12/31/00	
	RMB	$US
Net Operating Revenue	12,553,254.00	$ 1,516,459.77
Operating Expenses		
Fuel	(3,840,690.00)	$ (463,963.52)
Maintenance	(670,994.00)	$ (81,057.50)
Depr & amort	(2,666,949.00)	$ (322,173.11)
Labor	(669,916.00)	$ (80,927.28)
Transmission fees	(17,094.00)	$ (2,064.99)
Service fees to HIPDC	(310,742.00)	$ (37,538.29)
Other	(469,971.00)	$ (56,773.50)
Total Operating Exp	(8,646,356.00)	$ (1,044,498.19)
EBIT	3,906,898.00	$ 471,961.58
Financial (expenses) income		
Interest expense	(944,930.00)	$ (114,149.55)
Interest income	0.00	$ -
Exchange (losses) gains	(34,936.00)	$ (4,220.34)
Pretax Income	2,927,032.00	$ 353,591.69
Income taxes	(411,202.00)	$ (49,674.08)
Net Income	2,515,830.00	$ 303,917.61

Figure Ten: WACC and CAPM Calculations

WACC and CAPM Inputs Defined		Inputs Used	
Tc = tax rate	14.05%	Tc	14%
Rd = return on debt	6.57%	Rd	6.50%
Empirical D/V = debt to value	0.44	D/V	0.66
US Electric Industry D/V	0.66	Re	4%-13%
Empirical Re = return on equity	3.48%	E/V	0.34
CAPM-Predicted Re	13.33%		
Empirical E/V = equity to value	0.56	Modeled WACC Range	
US Electric Industry E/V	0.34	Re	Implied WACC
Average beta for 1996-1998	0.92	4%	5.05%
Risk-Free rate	6.00%	5%	5.39%
Market risk premium	8.0%	6%	5.73%
		7%	6.07%
Formulae		8%	6.41%
WACC		9%	6.75%
= (1-Tc)Rd(D/V) + Re(E/V)		10%	7.09%
		11%	7.43%
CAPM		12%	7.77%
Re = Rf + Beta(Rm-Rf)		13%	8.11%

Using figures from the statements and tables above I calculated the various inputs for WACC according to the following conventional formulae (in which "Re" = ROE):

WACC = (1-Tc)D/V(Rd) + (E/V)Re, where

Tc = the annual corporate tax rate

D/V = the firm's debt to value (debt plus equity) ratio

Rd = the firm's return on debt, or average interest rate paid on short and long term debt outstanding

E/V = the firm's equity to value ratio (also 1-D/V) and

Re = the firm's return on equity

Note: Re is calculated using the Capital Asset Pricing Model (CAPM),

Re = Rf + β(Rm + Rf), where

Rf = the prevailing risk-free rate, usually the rate on an equivalent maturity US Bond

β = the sensitivity of the firm's stock price to aggregate market movements

Rm = the historical return on the US stock market

I calculated the appropriate WACC and CAPM inputs for the above as follows:

Tc = Income taxes paid/Pretax income[10]

D/V and E/V= the average debt to value ratio for firms in the US electric utility industry[11]

Rd = interest paid in 2000/(outstanding principal balance of loans)

Re = 13% according to the CAPM

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[10] Huaneng Power International, Income Statement, March 2001

The CAPM predicts a ROE for Huaneng of 13%. However, the firm's empirical ROE since going public in 1997 is just 4%[12]. Because the CAPM is a contested measure of return even in western corporate finance, in light of the discrepancy in this case it is reasonable to conclude that several of the CAPM's components may simply not be applicable to how Chinese capital markets currently function. For example, there is no record of the betas of Chinese stocks. Nor would the historical risk premium in China (Rm - Rf) be meaningful as a) heavy capital controls tend to artificially suppress Rf, b) the young age of the market yields a less meaningful Rm time series and c) firms have historically gone public in China by virtue of political ties rather than financial viability per se[13], meaning Rm is not necessarily commensurate with risk or performance in this system.

Both reference scenarios therefore incorporate Huaneng's empirically demonstrated 4% ROE for this and all comparisons. However, to test the impact of a stronger shareholder base as a result of ongoing stock market rationalization and reform in China, I ran the "ROE" scenarios using the CAPM-predicted 13% as the high case.

4.5.3 Market Power Set

To represent a SEPCO increasingly captive to the market power of wholesale generators, this set models high wholesale electricity costs in periods within which SEPCO's reserve margin dips below its baseline target of 20%. This is done by respectively substituting the letters I and E in the ninth position, as in BOC-CONP*I*S-FIB and BOC-CONP*E*S-FIB, also as in BOC-NANP*I*S-FIB and BOC-NANP*E*S-FIB. These scenarios thus model a SEPCO buying from wholesale generators at auction, and is as a

[11]Finance.yahoo.com, March 1, 2001
[12]Finance.yahoo.com, March 1, 2001.

consequence operating in an environment with a considerably lower target reserve margin -respectively f"I"fteen and t"E"n- than would prevail in a regulated setting. To simulate this effect -and assuming deregulation takes several years to evolve in China- beginning in year 2005 variable O&M for both scenarios increases by 25% for every percentage point decrease in actual reserve margin below the reference case's 20%, as Table Eleven demonstrates.

Table Thirty-Eight: Target Reserve Margins and Variable O&M Multipliers

	Target Reserve Margin for BOC-CONP S-FIB where			Variable O&M Multipliers			Inflation		Multipliers with Inflati		
Year	A = 20%	I = 15%	E = 10%	A = 20%	I = 15%	E = 10%	Percent	Multiplier	A = 20%	I = 15%	E = 1
	Actual Reserve Margin										
2000	42.0	42.0	42.0	1.0	1.0	1.0	0.0	1.0000	1.0000	1.0000	1.0
2001	26.0	26.0	26.0	1.0	1.0	1.0	0.5	1.0050	1.0050	1.0050	1.0
2002	**18.0**	**18.0**	**18.0**	**1.5**	**1.5**	**1.5**	1.0	1.0151	**1.0151**	**1.0151**	**1.0**
2003	**12.0**	**12.0**	**12.0**	**3.0**	**3.0**	**3.0**	1.5	1.0303	**1.0303**	**1.0303**	**1.0**
2004	**11.0**	**11.0**	**11.0**	**3.3**	**3.3**	**3.3**	2.0	1.0509	**1.0509**	**1.0509**	**1.0**
2005	21.0	**15.0**	**10.0**	1.0	**2.3**	**3.5**	2.5	1.0772	1.0772	**2.4236**	**3.7**
2006	**19.0**	**13.0**	**9.0**	**1.3**	**2.8**	**3.8**	3.0	1.1095	**1.1095**	**3.0510**	**4.1**
2007	31.0	26.0	21.0	1.0	1.0	1.0	3.5	1.1483	1.1483	1.1483	1.1
2008	43.0	37.0	31.0	1.0	1.0	1.0	4.0	1.1942	1.1942	1.1942	1.1
2009	39.0	33.0	27.0	1.0	1.0	1.0	4.5	1.2480	1.2480	1.2480	1.2
2010	30.0	25.0	**19.0**	1.0	1.0	**1.3**	5.0	1.3104	1.3104	1.3104	**1.6**
2011	40.0	34.0	28.0	1.0	1.0	1.0	5.0	1.3759	1.3759	1.3759	1.3
2012	43.0	37.0	31.0	1.0	1.0	1.0	5.0	1.4447	1.4447	1.4447	1.4
2013	33.0	28.0	23.0	1.0	1.0	1.0	5.0	1.5169	1.5169	1.5169	1.5
2014	45.0	38.0	32.0	1.0	1.0	1.0	5.0	1.5928	1.5928	1.5928	1.5
2015	41.0	34.0	29.0	1.0	1.0	1.0	5.0	1.6724	1.6724	1.6724	1.6
2016	43.0	37.0	31.0	1.0	1.0	1.0	5.0	1.7560	1.7560	1.7560	1.7
2017	37.0	31.0	25.0	1.0	1.0	1.0	5.0	1.8438	1.8438	1.8438	1.8
2018	40.0	34.0	28.0	1.0	1.0	1.0	5.0	1.9360	1.9360	1.9360	1.9
2019	24.0	20.0	**14.0**	1.0	1.0	**2.5**	5.0	2.0328	2.0328	2.0328	**5.0**
2020	25.0	21.0	**16.0**	1.0	1.0	**2.0**	5.0	2.1345	2.1345	2.1345	**4.2**
2021	32.0	26.0	21.0	1.0	1.0	1.0	5.0	2.2412	2.2412	2.2412	2.2
2022	26.0	21.0	**15.0**	1.0	1.0	**2.3**	5.0	2.3532	2.3532	2.3532	**5.2**
2023	22.0	**17.0**	**12.0**	1.0	**1.8**	**3.0**	5.0	2.4709	2.4709	**4.3241**	**7.4**
2024	24.0	**19.0**	**14.0**	1.0	**1.3**	**2.5**	5.0	2.5944	2.5944	**3.2431**	**6.4**
										(4 yrs)	(8 y

Beginning in 2005
If RM >=20 ... Multiplier = 1
if RM < 20 ... Multiplier = ((20-RM)* 0.25) +1

[13] Ed Steinfeld, MIT Sloan School of Management, Course Lecture, April, 2000.

4.5.4 Stricter Sulfur Set

The Stricter Sulfur (SS) scenarios model increasingly stringent sulfur dioxide emission controls in Shandong. By substituting the letter A in the second position, as in BAC-CONPAS-FIB and BAC-NANPAS-FIB, they represents a r"A"tcheting downward of sulfur controls for existing units, which are forced in these scenarios to use coal with no greater than .75% sulfur content. Such a mandate would presumably also drive up demand and hence transit costs for lower sulfur coal. Hence, SS also substitutes the letter A in the thirteenth position, as in BOC-CONPAS-FAB and BOC-NANPAS-FAB to incorporate the effect of higher, or "A"ggravated transit costs for coal imported from Shanxi province as a result of growing railway congestion. The far righthand column of Table Thirty-Eight shows the impact aggravated costs would have on coal shipments.

Table Thirty-Eight: Coal Transit Cost Uncertainties for Aggravated Case[14]

		Transp. Cost (no Infl.)	Transp. Cost (w/Infl.)	Transp. Cost (no Infl.)	Transp. Cost (w/Infl.)	Shanxi Rail/Ship			Delivered Coal Cost Aggravated Transp. Case	
		Rail	Rail	Ship	Ship	Rail	Ship	Rail+Ship	no Infl.	w/I nfl.
Year	Inflation	%/yr	%/yr	%/yr	%/yr	¥/Tonne			¥/Tonne	¥/Tonne
1999						40.0	10.0	50.0	190.3	190.3
2000	0.0	0.0	0.0	1.0	1.0	40.0	10.1	50.1	190.4	190.4
2001	0.5	0.0	0.5	1.0	1.5	40.2	10.3	50.5	190.5	191.5
2002	1.0	0.0	1.0	1.0	2.0	40.6	10.5	51.1	190.6	193.5
2003	1.5	15.0	16.5	1.0	2.5	47.3	10.7	58.0	196.7	202.6
2004	2.0	15.0	17.0	1.0	3.0	55.3	11.0	66.4	203.7	213.8
2005	2.5	15.0	17.5	1.0	3.5	65.0	11.4	76.5	211.8	227.6
2006	3.0	0.0	3.0	1.0	4.0	67.0	11.9	78.9	211.9	234.5
2007	3.5	0.0	3.5	1.0	4.5	69.3	12.4	81.7	212.0	242.8
2008	4.0	0.0	4.0	1.0	5.0	72.1	13.0	85.1	212.1	252.7
2009	4.5	0.0	4.5	1.0	5.5	75.3	13.8	89.1	212.2	264.2
2010	5.0	0.0	5.0	1.0	6.0	79.1	14.6	93.7	212.3	277.5
2011	5.0	0.0	5.0	1.0	6.0	83.1	15.5	98.5	212.4	291.6
2012	5.0	0.0	5.0	1.0	6.0	87.2	16.4	103.6	212.5	306.3
2013	5.0	0.0	5.0	1.0	6.0	91.6	17.4	108.9	212.6	321.8
2014	5.0	0.0	5.0	1.0	6.0	96.2	18.4	114.6	212.7	338.0
2015	5.0	0.0	5.0	1.0	6.0	101.0	19.5	120.5	212.9	355.1
2016	5.0	10.0	15.0	1.0	6.0	116.1	20.7	136.8	219.1	383.2
2017	5.0	10.0	15.0	1.0	6.0	133.5	21.9	155.4	225.9	414.1
2018	5.0	10.0	15.0	1.0	6.0	153.6	23.2	176.8	233.4	448.4
2019	5.0	0.0	5.0	1.0	6.0	161.2	24.6	185.9	233.5	471.1
2020	5.0	0.0	5.0	1.0	6.0	169.3	26.1	195.4	233.6	494.9
2021	5.0	0.0	5.0	1.0	6.0	177.8	27.7	205.4	233.7	519.9
2022	5.0	0.0	5.0	1.0	6.0	186.6	29.3	216.0	233.8	546.1
2023	5.0	0.0	5.0	1.0	6.0	196.0	31.1	227.1	234.0	573.7
2024	5.0	0.0	5.0	1.0	6.0	205.8	33.0	238.7	234.1	602.7

4.5.5 Consolidated Set

This set consolidates the above four hypothesized event streams so as to represent them as concurrent phenomena. For example, the coal-based scenario BAC-CONPES-SAH represents r"A"tcheted sulfur controls and a t"E"n percent target reserve margin under conditions of "S"trong economic growth with "A"ggravated coal costs and a "H"igh (i.e. the CAPM- predicted 13%) return on equity. Figure Eleven shows the ingredients of both consolidated scenarios.

[14] Cheng, Chia-Chin, ESS Coal Cost Assumptions and Coal Cost Uncertainty Development, CETP, April,

Figure Eleven: Consolidated Scenarios

Conventional Coal Consolidated Scenario

B A C - C O N P E S - S A H

"**B**"aseline old unit retirement schedule
R"**A**"tchet down to ***stricter sulfur*** content
"**C**"urrently available coal supplies
- "**C**"oventional coal baseload
N"**O**" extra-provincial generation
"**N**"o renewables
"**P**"eaking units = combustion turbines
T"**E**"n % target reserve under ***Market Power***
"**S**"tandard end-use efficiency programs
- "**S**"trong demand under ***WTO***
"**A**"ggravated Coal Costs
"**H**"igh ***ROE***

Nuclear and Gas-by-Wire Consolidated Strategy

B A C - N A N P E S - S A H

"**B**"aseline old unit retirement schedule
R"**A**"tchet down to ***stricter sulfur*** content
"**C**"urrently available coal supplies
- "**N**"uclear and conventional coal baseload
G"**A**"***s*** *by wire* from outside province
"**N**"o renewables
"**P**"eaking units = combustion turbines
T"**E**"n % target reserve under ***Market Power***
"**S**"tandard end-use efficiency programs
- "**S**"trong demand under ***WTO***
"**A**"ggravated Coal Costs
"**H**"igh ***ROE***

2001, p. 10.

4.6 Methodologies

I begin examining scenario results with a multi-attribute tradeoff analysis of general scenario cost and emissions performance. I then further investigate scenario performance by comparing additional metrics relevant to the respective event streams simulated.

4.6.1 Multi-Attribute Tradeoff Analysis

This technique is a decision-enabling methodology that plots scenario performance two attributes at a time. Attributes are simply performance metrics that stakeholders to the process have identified as important. For example, two relevant attributes to SEPCO in this study are total costs of electric service and cumulative sulfur emissions.

Because tradeoff analysis affords visual comparison, it helps gauge scenario performance relative to others. For example, using tradeoff analysis we may see how a large number of scenarios comprised by varying generation buildout strategies and end-use efficiency strategies performs over alternative futures with respect to cost and emissions.

4.6.2 Preliminary Attributes of Interest

I use tradeoff analysis to examine the rough performance of each scenario subset across the following four basic attributes:

1) Total Regional Costs (TRCn)

This figure represents the present value of all costs Shandong incurs over the study period for providing electric service. It includes capital recovery on existing and new generation, all T&D system maintenance and upgrades, fuel costs, fixed and variable

O&M costs, general and administrative costs, and the cost of end-use conservation and peak load management programs.

2) Cumulative Sulfur Emissions (SO_2t)

This figure represents the cumulative amount of sulfur dioxide emissions from SEPCO power plants over the study period, in thousands of metric tonnes.

3) Cumulative Particulate Emissions ($PM_{10}t$)

This figure represents the cumulative amount of small particulate matter emissions from SEPCO plants over the study period, in thousands of metric tonnes.

4) Cumulative Carbon Dioxide Emissions (CO_2t)

This figure represents the cumulative amount of carbon dioxide emissions from SEPCO plants over the study period, in millions of metric tonnes.

As the tradeoff analysis is a preliminary look at the data, I chose the total regional costs attribute as a coarse indicator of cumulative long-range scenario performance. Hence, in the further analyses I conduct for each subset I use finer metrics, such as costs normalized to electricity generated. I focus in particular throughout on sulfur and particulate emissions as Shandong's most immediate health and environmental concerns are upper respiratory disease and acid rain. I added carbon as the global environmental community's concern with China has more to do with climate change. And, I excluded nitrous oxides as Shandong is not particularly focused at present on urban smog mitigation via either combustion or stack NO_x abatement measures[15].

[15] Connors, 2001.

4.6.3 Other Methods

After using tradeoff analysis up front I further compare subset scenarios to the reference cases by looking at some additional aggregate attributes for the full study period, and at some simple differences in time series behind the aggregate figures. Specific attributes examined and the time series feeding into these attributes differ according to the subset at hand.

4.6 Chapter Summary

Chapter Four described the software used for the simulation exercise, and introduced scenario planning with a description of the strategies and futures it uses as building blocks. It also defined the two reference scenarios that serve as benchmarks for Chapter 5's analysis, and presented the process whereby I constructed four scenario subsets to model the impact on SEPCO of the hypotheses developed in Chapter 3 coming to pass. It then defined the consolidated scenarios used for the concluding analysis, and introduced the methodologies I subsequently employ for all comparisons in Chapter 5.

Chapter Five- Analysis

5.1 WTO Set

5.1.1 WTO Tradeoff Analysis

In Figures Twelve, Thirteen and Fourteen WTO represents movement from the coal-based reference case to WTO accession for the coal-based strategy. And, WTO2 represents movement from the nuclear-and-gas by wire reference case to WTO accession for the nuclear and gas strategy. Scenario performance is parallel for each of the emissions types: the stronger electricity demand stimulated by WTO membership leads to higher cumulative emissions and higher total costs over the study period.

Figure Twelve: WTO- Cumulative Sulfur Emissions vs. Total Costs

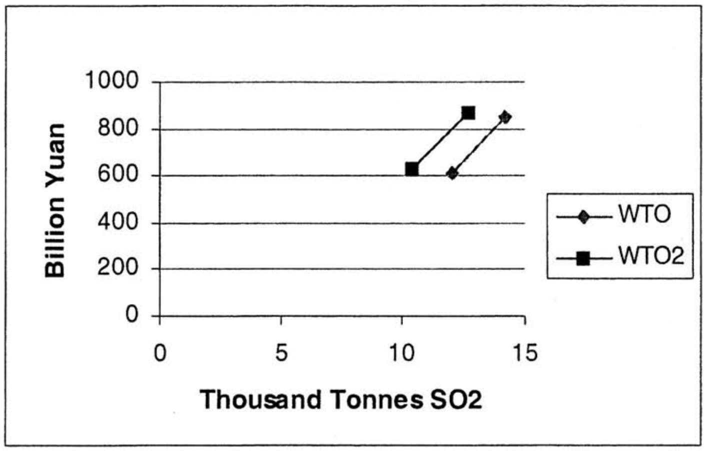


Figure Thirteen: WTO- Cumulative Particulate Emissions vs. Total Costs

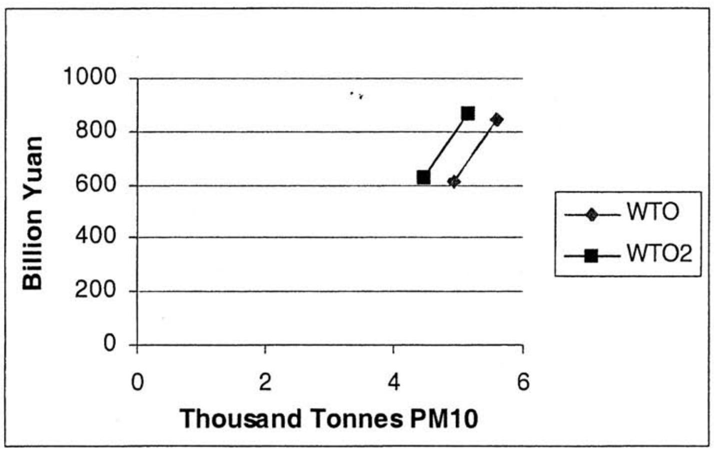
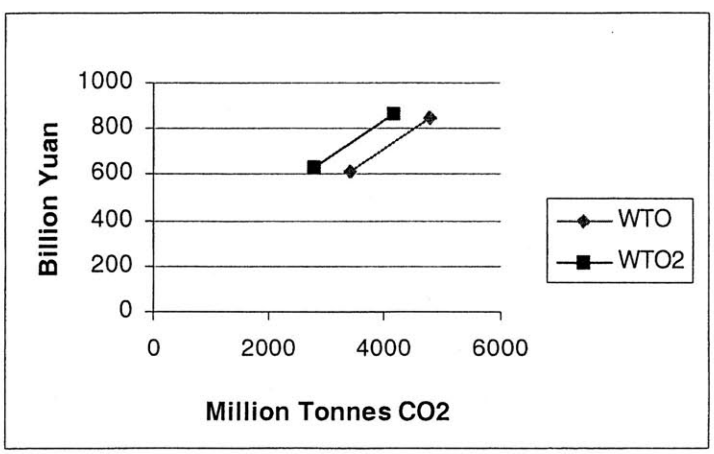


Figure Fourteen: WTO- Cumulative Carbon Dioxide Emissions vs. Total Costs



5.1.2 WTO vs. Coal Reference Case

I also compared the following parameters between WTO and the coal reference case: A) annual demand and peak load, B) the unit cost of electricity, C) new technology investments, D) inflation's impact over the study period and E) emissions.

A. Demand and Annual Peak Load

As one would expect with stronger economic growth, at-meter demand and annual peak load both increase significantly from reference to WTO, as Figures Fifteen and Sixteen show.

Figure Fifteen: Annual Demand- WTO vs. Coal Reference Case

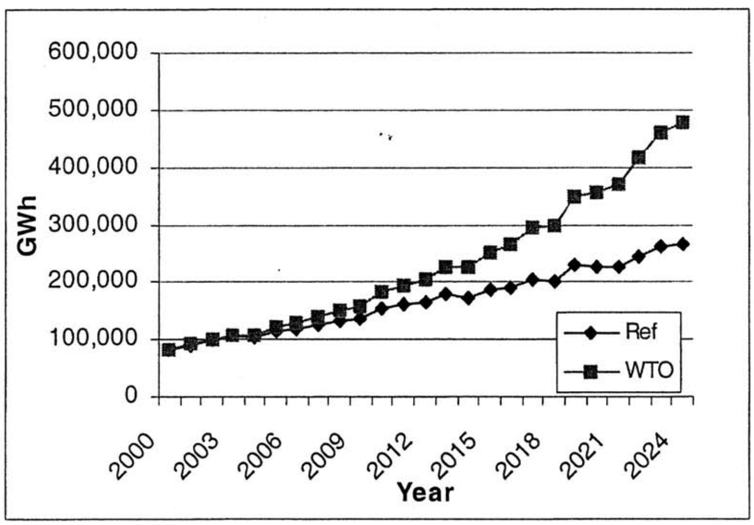
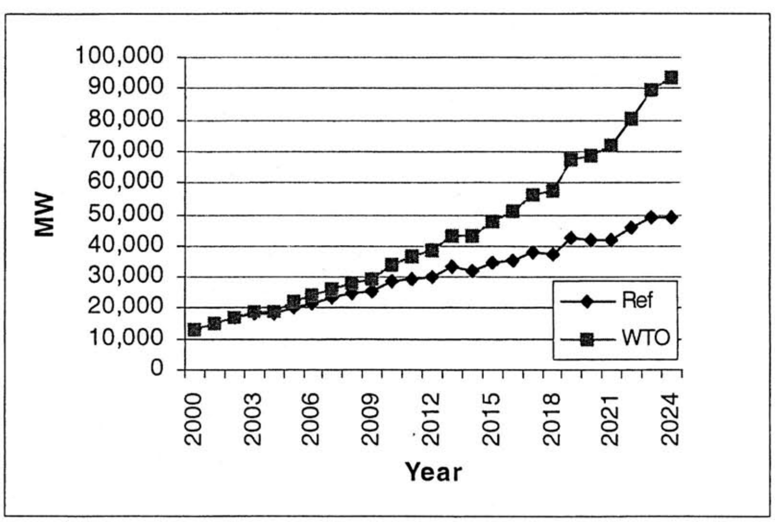


Figure Sixteen: Annual Peak Load- WTO vs. Coal Reference Case



In addition, peak load grows at a higher compounded annual growth rate than demand for both the reference case and WTO, as Table Thirty-Nine shows. Thus SEPCO's load becomes 'peakier', which would naturally result from increasing incomes and shifting electricity consumption habits.

Table Thirty-Nine: Compounded Annual Growth Rates, WTO vs. Coal Reference Case

	Ref	WTO
Annual Peak Load	6%	9%
Annual Demand	5%	8%

B. Unit Cost of Electricity

Trends in unit customer charges give an indication of whether SEPCO will be able to control costs under conditions of increasing demand and peak load. Figure Seventeen shows unit cost trends for both scenarios in future cents/kWh, and Figure Eighteen shows the same trend in base year cents/kWh. Because the reference and WTO cases incorporate different inflation trajectories, looking at future year series affords a comparison of their performance relative to one another, whereas the base year series show each scenario's performance over time relative to its own beginning value.

As Figure Seventeen shows, WTO is the more expensive of the two- exceeding Ref at an accelerating pace throughout the period, ending at $.1287 vs. Ref's future year cost of $.1094. And, as Figure Eighteen shows, base year costs for both scenarios decrease in real terms from an initial shared value of $.0563/kWh in 2000 to respectively reach $.0422/kWh and $.0403/kWh in 2024. Again note it is the relative values at the beginning and ending points for each series on this graph that are important.

Figure Seventeen: Future Unit Cost of Electricity- WTO vs. Coal Reference Case

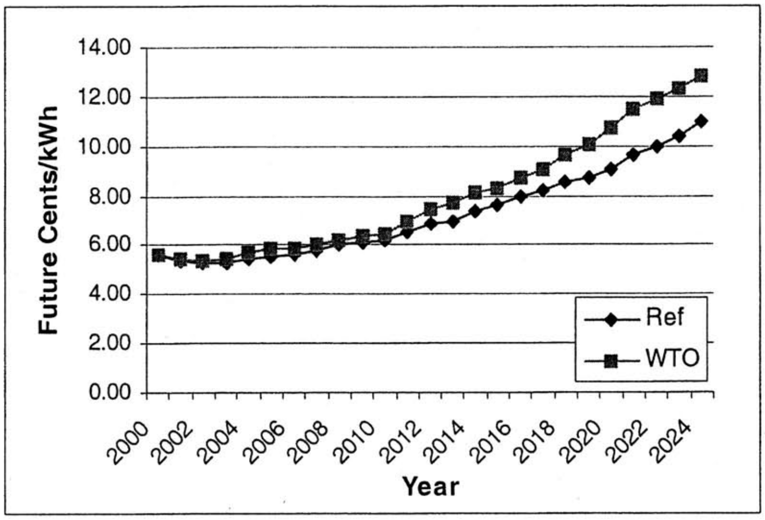
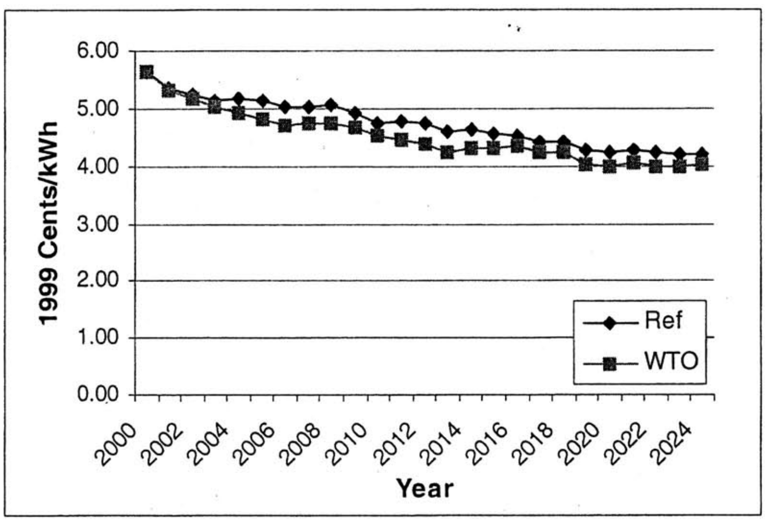
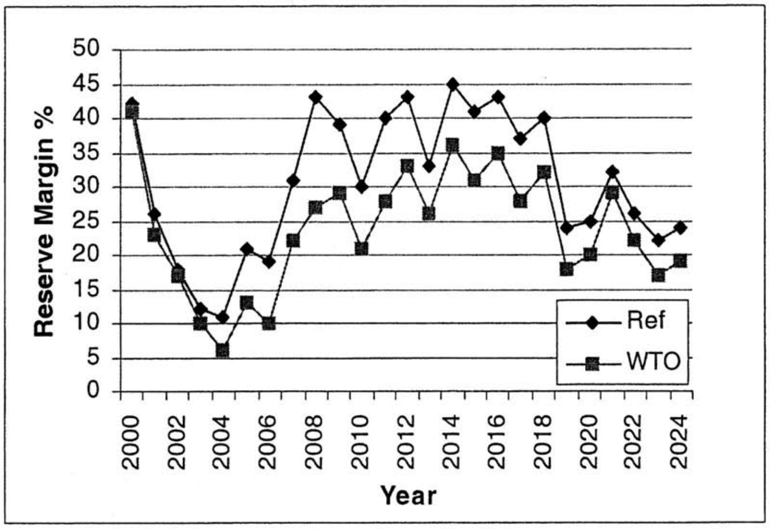


Figure Eighteen: Base Year Unit Cost of Electricity- WTO vs. Coal Reference Case



One element driving WTO's decreasing unit costs, however, might be a slight 'undercapitalization', which would result if SEPCO's new capacity construction schedule were to slip behind the pace of demand growth under WTO accession. Looking at the relative reserve margins between the two cases confirms that SEPCO does indeed operate with a thinner margin under WTO, as Table Forty shows.

Table Forty: Comparative Reserve Margins- WTO vs. Coal Reference Case



Even so, reserve levels under WTO are within reason from a reliability standpoint, with the exception of year 2004, which is attributable to the fact that currently planned units don't begin coming on line until 2005. SEPCO thus appears poised to maintain decreasing unit costs over both futures by virtue of the cost efficiencies derived from replacing its generating stock with new, more efficient pulverized coal units. In addition to this effect, decreasing costs under WTO indicate that serving a larger rate base with a slightly leaner planning reserve margin has a positive cost impact from an individual customer perspective.

C. Impact of Devaluation on New Technology Investments

Indeed, WTO calls for 90 GW in new installed capacity over the study period- 2.27 times more than the reference case's 40 GW. To satisfy greater demand, 82 GW or 91% of WTO's total is in new coal baseload, while 9% of new units are simple-cycle natural gas peaking turbines. Figures Nineteen and Twenty show the two scenarios' new capacity installation schedules.

Figure Nineteen: New Capacity Installations, Coal Reference Case

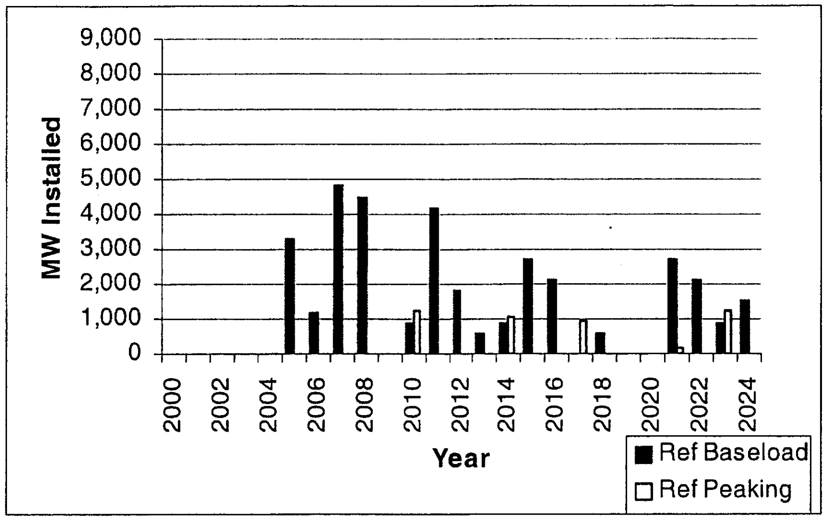
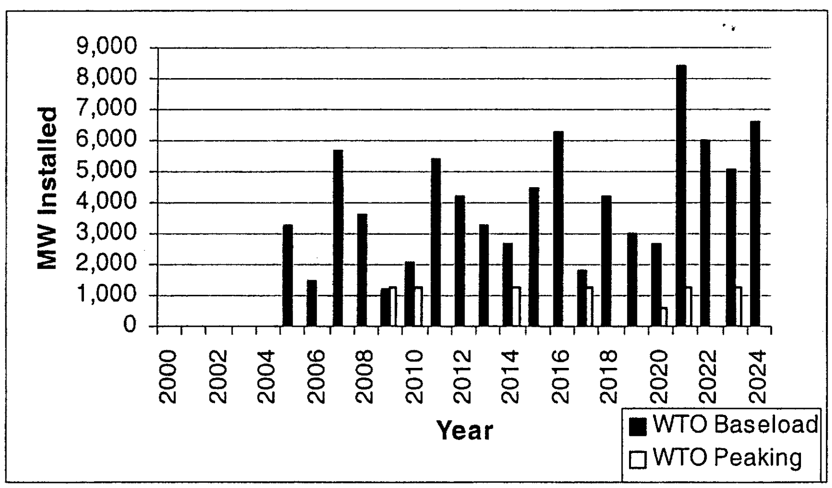


Figure Twenty: New Capacity Installations, WTO



Though SEPCO's higher cost of service under WTO is indeed driven by the need to capitalize a greater number of new plants, the impact of higher new generation technology costs as a result of Yuan devaluation appear to be small. That is, devaluation causes a 5.3% increase in new generation investment for WTO over the reference case. The impact is slight because only conventional coal units -whose foreign component content is low- get built.

D. Inflation's Impact on Cost of Service

Because inflation cascades through several cost trajectories in EGEAS, it is also worth looking at whether inflation and future cost of service track each other, especially in the WTO case which assumes more volatile inflation. Table Forty-One shows they may not necessarily work together for Ref, as cost of service rises at a varying rate while inflation is steady. For WTO unit costs' rate of change does appears to perhaps track inflation for some years of over 5% inflation. Inflation's impact on cost of service under WTO may therefore be modest.

Table Forty-One: Inflation and Future Unit Cost of Electricity, Coal Ref. Case and WTO

	Reference Scenario				WTO Scenario			
Year	Inflation %	%chg	Cents/kWh	%chg	Inflation %	%chg	Cents/kWh	%chg
2000	0	n/a	5.63	n/a	0	n/a	5.63	n/a
2001	0	0	5.39	-4%	1.5	n/a	5.41	-4%
2002	0	0	5.32	-1%	2.5	67%	5.39	0%
2003	0	0	5.30	0%	4	60%	5.43	1%
2004	0	0	5.43	2%	**7**	**75%**	**5.69**	**5%**
2005	5	n/a	5.54	2%	5	-29%	5.85	3%
2006	5	0	5.60	1%	3	-40%	5.90	1%
2007	5	0	5.79	3%	2	-33%	6.05	3%
2008	5	0	6.04	4%	2	0%	6.17	2%
2009	5	0	6.16	2%	4	100%	6.35	3%
2010	5	0	6.22	1%	**6**	**50%**	**6.48**	**2%**
2011	5	0	6.56	5%	**8**	**33%**	**6.93**	**7%**
2012	5	0	6.84	4%	**10**	**25%**	**7.46**	**8%**
2013	5	0	6.95	2%	**6**	**-40%**	**7.69**	**3%**
2014	5	0	7.37	6%	4	-33%	8.13	6%
2015	5	0	7.62	4%	2.5	-38%	8.29	2%
2016	5	0	7.97	5%	4	60%	8.73	5%
2017	5	0	8.18	3%	**6**	**50%**	**9.02**	**3%**
2018	5	0	8.56	5%	**7**	**17%**	**9.62**	**7%**
2019	5	0	8.69	1%	**10**	**43%**	**10.04**	**4%**
2020	5	0	9.08	5%	**8**	**-20%**	**10.73**	**7%**
2021	5	0	9.62	6%	5	-38%	11.50	7%
2022	5	0	10.00	4%	5	0%	11.92	4%
2023	5	0	10.41	4%	4	-20%	12.33	3%
2024	5	0	10.94	5%	3	-25%	12.87	4%

E. Emissions

As a consequence of greater demand and increased capacity, cumulative sulfur dioxide particulate and carbon dioxide emissions are respectively 18%, 14% and 16% higher for WTO than for the reference case over the study period. Because under WTO SEPCO's rate base would be growing more quickly than under the reference case, it is worth looking at demand-normalized emissions. Interestingly, some of the compounded annual growth rates for annual emissions and annual emissions normalized to demand in these three categories are negative, as shown in Table Forty-Two.

Table Forty-Two: Annual and Demand Normalized Emissions- WTO vs. Coal Ref

	SO_2 (KT)		PM_{10} (KT)		CO_2 (MT)	
	Ref	**WTO**	**Ref**	**WTO**	**Ref**	**WTO**
Total Annual Emissions	-1.77%	-0.01%	-0.05%	1.29%	5.74%	8.42%
Emissions per GWh	-6.50%	-7.11%	-4.85%	-5.91%	0.66%	0.71%

The observed negative differences in ending vs. beginning annual emissions rates are likely the result of an increasingly cleaner capital stock on the whole as SEPCO adds new units through time. And, negative CAGRs for normalized emissions would naturally result from spreading emissions over a growing rate base whether under conditions of reference or WTO-stimulated growth. For both of these cases, the negative rates resulting from smoothing growth nonetheless mask the fact that *cumulative* emissions for sulfur, particulates and carbon are still higher over the study period for WTO vs. the reference case. Moreover, cumulative, annual and normalized emissions for carbon are all positive in spite of the newer capital stock and growing rate base effects.

5.1.3 WTO2 vs. Nuclear and Gas-by-Wire Reference Case

Demand and peak load for the nuclear and gas-based scenario comparison are the same as they are for the conventional set. As one would expect, however, A.) unit cost of service, B.) new technology investments and C.) emissions results differ somewhat.

A. Unit Cost of Electricity

Figure Twenty-One shows future unit costs for the nuclear and gas strategy under WTO would outstrip reference costs early, as would be expected given the former's higher expenses under greater demand. And, Figure Twenty-Two confirms -as with the coal cases- that unit costs decrease for both the nuclear and gas-based cases in an absolute sense to \$.0453/kWh and \$.0421/kWh in 2024. SEPCO may thus also be able to maintain decreasing unit costs with a nuclear and gas strategy regardless of accession, again presumably by virtue of cleaner units.

Figure Twenty-One: Future Year Unit Cost of Electricity- WTO2 vs. Ref2

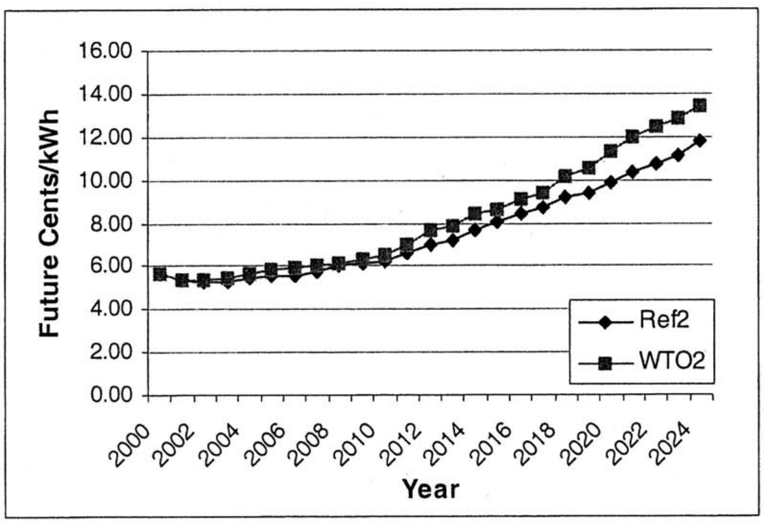
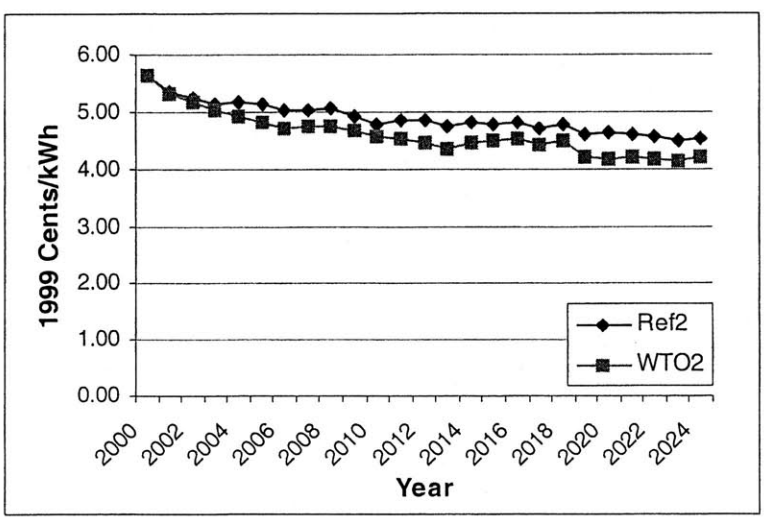


Figure Twenty-Two: Base Year Unit Cost of Electricity- WTO2 vs. Ref2



B. Devaluation's Impact on New Technology Investments

SEPCO begins introducing advanced light water reactors and combined cycle gas turbines in 2010 for both of the above cases, but to meet the stronger growth under WTO2 must build more to suit demand in that case. However, Figures Twenty-Three and Twenty-Four demonstrate that SEPCO builds the same amount of nuclear and gas units for both Ref2 and WTO2, satisfying extra demand under accession with more coal capacity.

Figure Twenty-Three: New Capacity Installations, Nuclear and Gas Reference Case

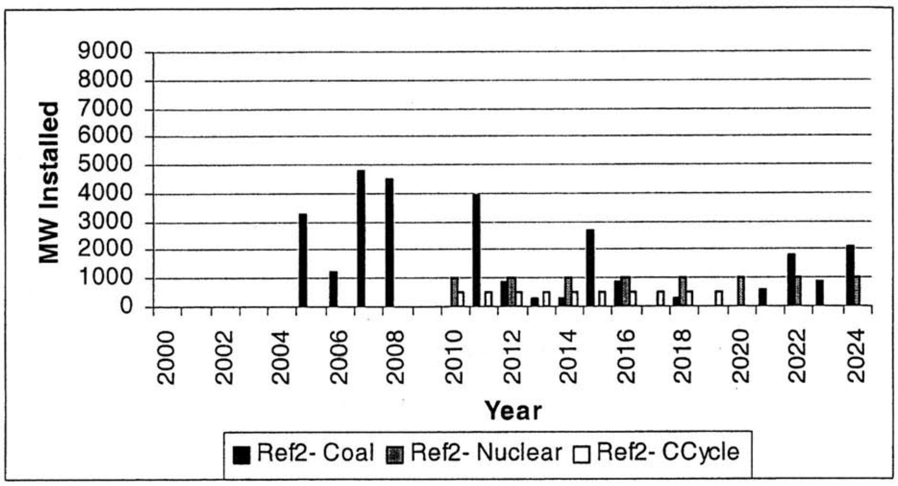
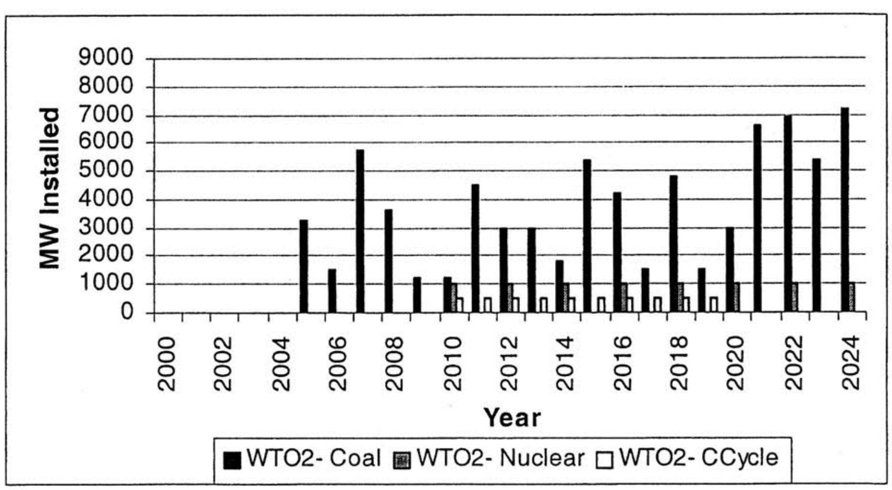


Figure Twenty-Four: New Capacity Installations, WTO2



Because inflation as modeled affects the same trajectories here as with the coal-based cases, I assume here its impact, if any, would be modest. However, due to the higher foreign component content of combined cycle and nuclear vs. conventional coal plants, the impact of devaluation is significantly higher in the nuclear and gas cases. New generation investment under WTO2 exceeds the investment required for the nuclear and gas reference case by 17.6%. Yet, the impact of potentially higher nuclear and gas capital costs as a result of devaluation is not sufficient to change the relationship between Ref2 and WTO2 unit costs.

C. Emissions

Cumulative sulfur, particulate and carbon emissions are respectively 22%, 15% and 48.6% higher for WTO2 than for Ref2. And, as with the conventional set yet more so, Table Forty-Three shows that many of the compounded annual growth rates for annual and demand-normalized emissions fall. As with the conventional set, negative CAGRs for annual emissions would reflect an increasingly cleaner capital stock, whereas negative CAGRs for demand-normalized emissions would reflect that the rate base is growing faster than emissions. And again, cumulative emissions are higher for WTO2 in all categories. Of particular note is the large percentage change in cumulative carbon dioxide emissions from Ref2 to WTO2. This would be attributable to the fact that SEPCO satisfies additional demand under WTO2 with conventional coal plants.

Table Forty-Three: Annual and Demand Normalized Emissions- WTO2 vs. Ref2

	SO_2 (KT)		PM_{10} (KT)		CO_2 (MT)	
	Ref2	**WTO2**	**Ref2**	**WTO2**	**Ref2**	**WTO2**
Annual Emissions (KT)	-3.66%	-1.04%	-1.12%	0.54%	3.90%	7.48%
Emissions per GWh	-8.29%	-8.08%	-5.87%	-6.61%	-1.09%	-0.16%

5.2.0 ROE Set

5.2.1 Tradeoff Analysis

In Figures Twenty-Five, Twenty-Six and Twenty-Seven, ROE represents movement from the coal-based reference case to a future of increasing ROEs resulting from greater shareholder power for the coal-based strategy. And, ROE2 represents movement from the nuclear-and-gas reference case to higher ROEs for the nuclear and gas strategy. As with WTO, tradeoff results on the ROE set are also very straightforward: payments to equity holders simply increase with shareholder power, thereby affecting costs but not emissions.

Figure Twenty-Five: ROE- Cumulative Sulfur Emissions vs. Total Costs

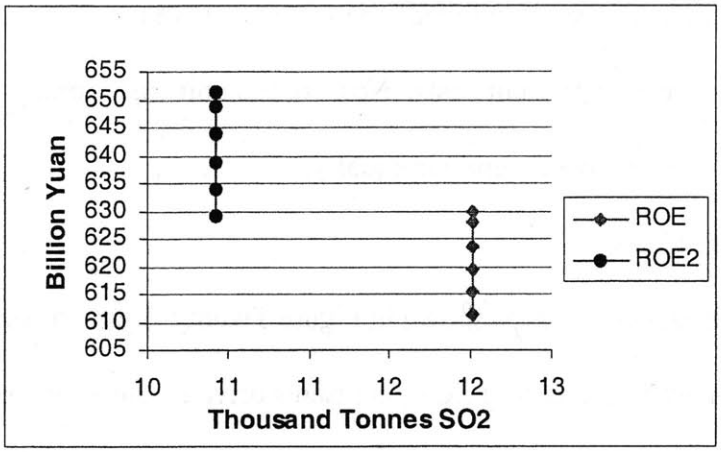


Figure Twenty-Six: ROE- Cumulative Particulate Emissions vs. Total Costs

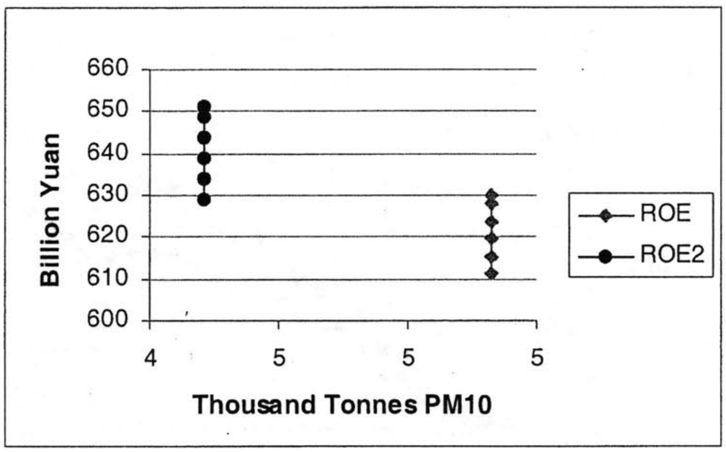
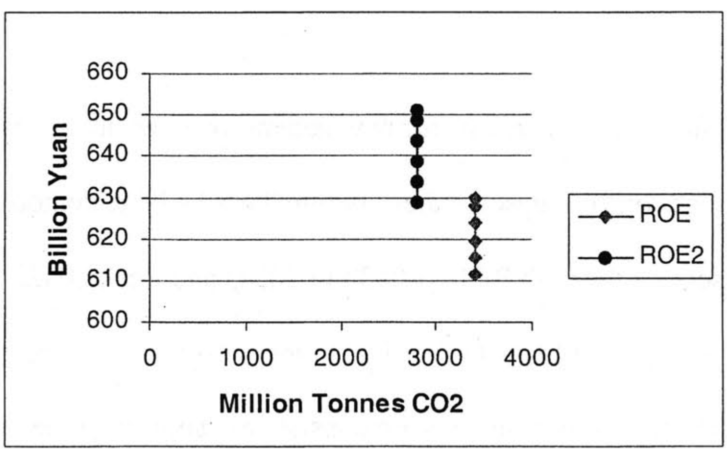


Figure Twenty-Seven: ROE- Cumulative Carbon Dioxide Emissions vs. Total Costs



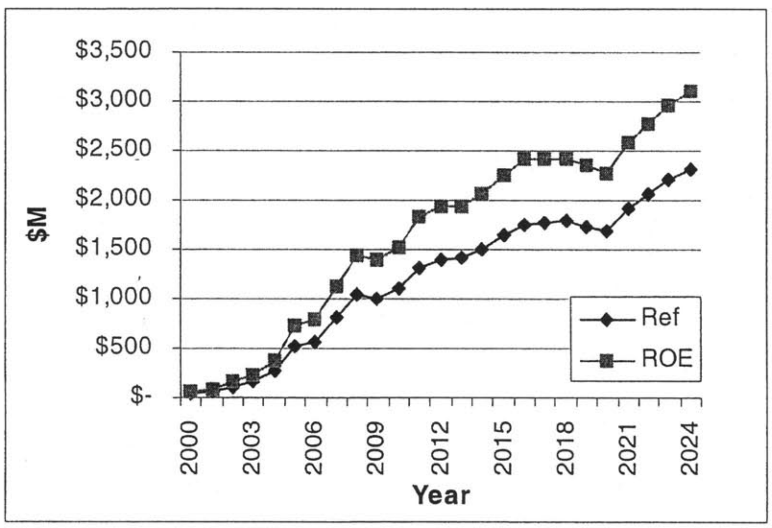
5.2.2 ROE vs. Coal Reference Case

I also compared A.) the capital recovery on new generation parameter between ROE and the reference case, as well as B.) unit costs. Note for the unit costs comparison I use base year costs since inflation affects these scenarios equally.

A. Capital Recovery Costs

As would be expected and as shown in Figure Twenty-Eight, the higher dividends payable to shareholders an increasing ROE represents drive up amortized payments to recover for new generation investments by 34% in 2024 for WTO vs. Ref.

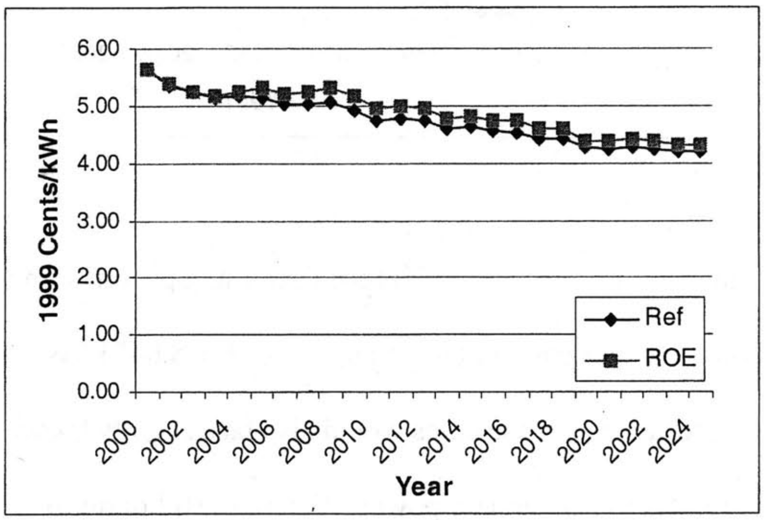
Figure Twenty-Eight: Capital Recovery for New Generation Investments- ROE vs. Ref



A.) Unit Costs

The greater increase in payments for new generation does not appear to substantially increase cost of service for this subset, either. Figure Twenty-Nine demonstrates the steady decrease in cost of service for both ROE ($.0433 in 2024) and Ref ($.0422 in 2024), which is presumably due to the fact that SEPCO uses less higher cost units as time goes by. However, unlike with the WTO set, in this case rates are consistently slightly higher for ROE than for Ref, even though they fall on the whole. It thus appears ratepayers would be better off were SEPCO's shareholders to remain passive (which in turn presumes SEPCO could maintain sufficient access to capital were that the case). Nonetheless, ratepayers would still enjoy decreasing unit costs throughout the study period regardless of whether shareholders assert more control. However, SEPCO would be more pressed to contain operating costs under circumstances of increasing ROEs given their impact on capital recovery payments.

Figure Twenty-Nine: Unit Cost of Electricity, ROE vs. Coal Ref



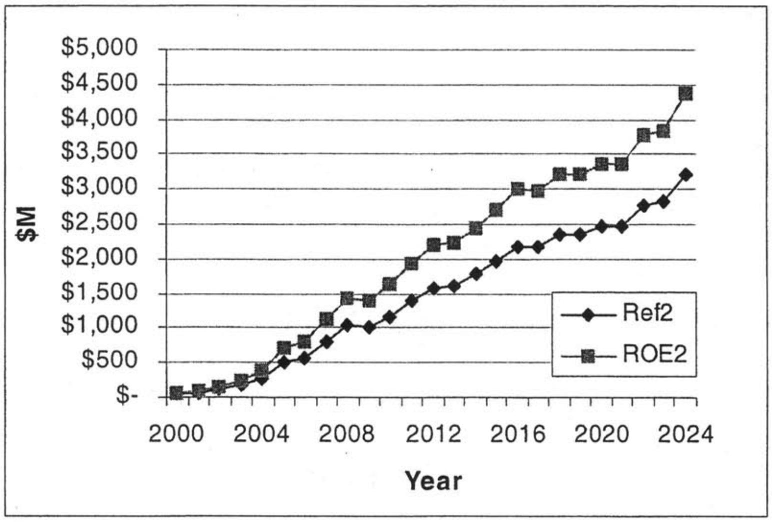
ROE's emissions do not differ from the reference case's, as the only difference between the scenarios is in the WACC calculation. Thus, no specific cost/environment tradeoff is at play here, only the issue of greater shareholder claims leading to higher capital recovery costs for SEPCO, and to slightly elevated (though still diminishing) ratepayer costs.

5.2.2 ROE2 vs. Nuclear and Gas-by-Wire Reference Case

A. Capital Recovery Costs

As with the coal-based set, ROE2 reflects the same effect of an increasing return on equity in the gas and nuclear cases. Subsequently and as shown in Figure Twenty-Nine, the higher ROE drives up recovery for new generation investments to an even higher level than for the coal-based WTO case.

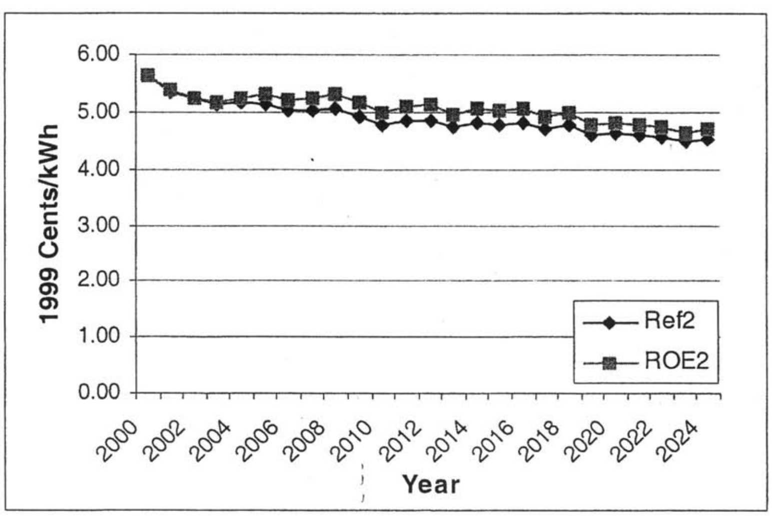
Figure Twenty-Nine: Capital Recovery for New Generation Investments- ROE2 vs. Ref2



B. Unit Costs

Finally, unit costs for this case reflect the decreasing pattern seen with the coal reference. Figure Thirty shows that unit costs fall to end up in 2024 at $.0453/kWh and $/.0470/kWh respectively. So, ratepayers in these cases would also face slightly higher unit costs across the board were shareholders to gain greater power. Yet, rates still diminish overall regardless. And as above, capital recovery costs rising with shareholder demands would create an even greater need for SEPCO to contain costs if it were to pursue the more expensive high-technology future.

Figure Thirty: Unit Cost of Electricity- ROE2 vs. Ref2



5.3.0 Market Power Set

5.3.1 Tradeoff Analysis

In Figures Thirty-One, Thirty-Two and Thirty-Three, MPow represents movement from the coal-based reference case's 20% target reserve margin to 15% and 10% targets in an increasingly deregulated environment. And, MPow2 represents movement from the 20% nuclear and gas-by-wire reference case to lower margins for the nuclear and gas strategy. As the figures show, costs go up for both MPow and MPow2 as SEPCO becomes increasingly captive to wholesale generators under low reserve margins. Cost magnitudes are also greater, as one would expect, for the nuclear-and-gas case since its nuclear component generally requires more capital investment. Emissions are all, as would be expected, lower in the nuclear-and-gas case. Interestingly, however, sulfur and particulate emissions *increase* as reserve margins get lower for both the coal and nuclear-and-gas cases. I investigate this further below.

Figure Thirty-One: Market Power- Cumulative Sulfur Emissions vs. Total Costs

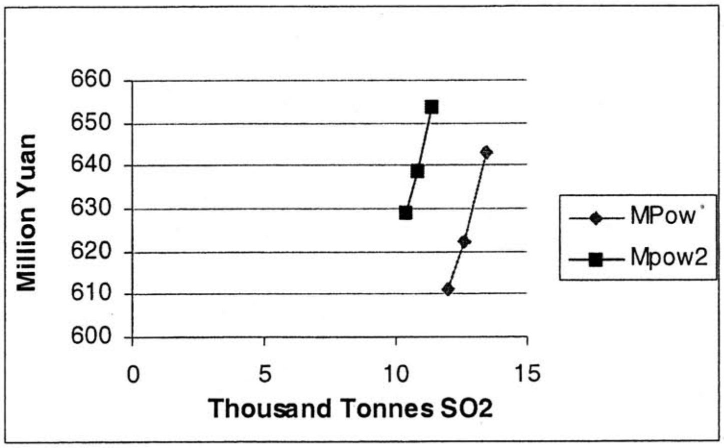


Figure Thirty-Two: Market Power- Cumulative Particulate Emissions vs. Total Costs

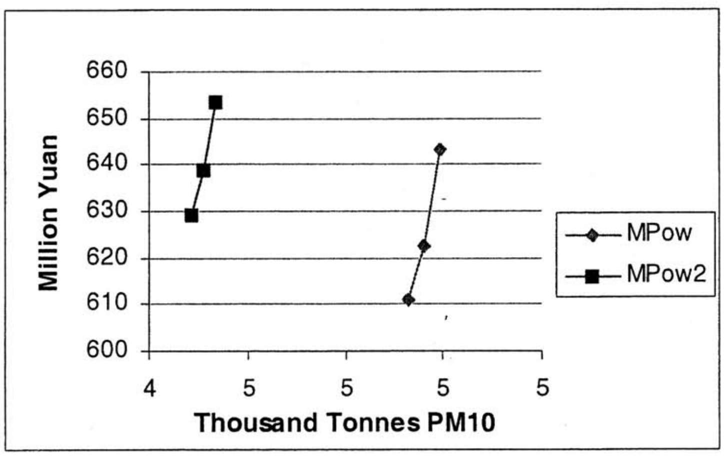
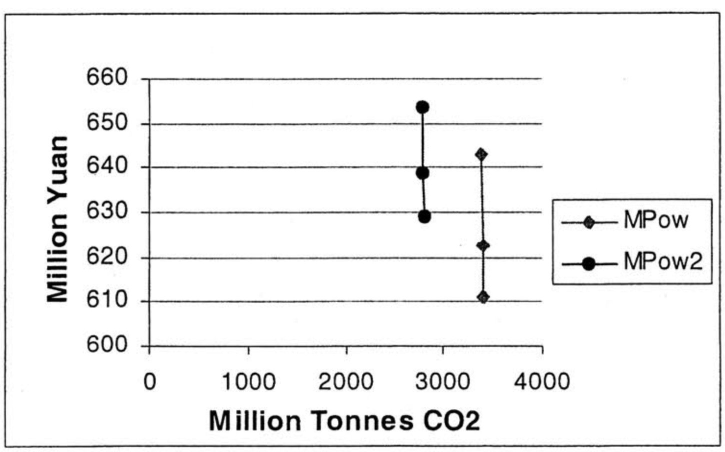


Figure Thirty-Three: Market Power- Cumu. Carbon Dioxide Emissions vs. Total Costs



5.3.2 Market Power vs. Coal Reference Case

I looked more closely at A.) the base year unit cost of service, B.) dispatch costs, C.) generation patterns by fuel type and D.) emissions to further examine this set.

A. Base Year Unit Cost of Electricity

As Figures Thirty-Four and Thirty-Five show, unit costs for both the 15% and 10% reserve margin scenarios track the reference case with the exception of during periods when actual reserve margin drops. The first jump for both graphs, in years 2003 to 2006, represents the fact that deregulation is not assumed to go into effect until 2005, which is also the year that most of the new capacity SEPCO has presently planned begins to come on line. Thus the system appears to be caught lagging when wholesale restructuring hits. SEPCO is however able to reestablish equilibrium through 2019 for the 15% case and through 2017 for the 10% case, at which point the utility again becomes captive to wholesale price spikes in a more mature deregulated environment. Note the more exaggerated impact on unit costs for the 10% vs. the 15% case. Note also that in both cases unit costs along each trajectory for the final year are lower than they were initially. However, they are slightly higher in the deregulated setting vs. the reference case- for example ending under the 10% future at respectively $.0472 and $.0422.

Figure Thirty-Four: Base Year Unit Cost of Electricity- 15% Margin vs. Reference Case

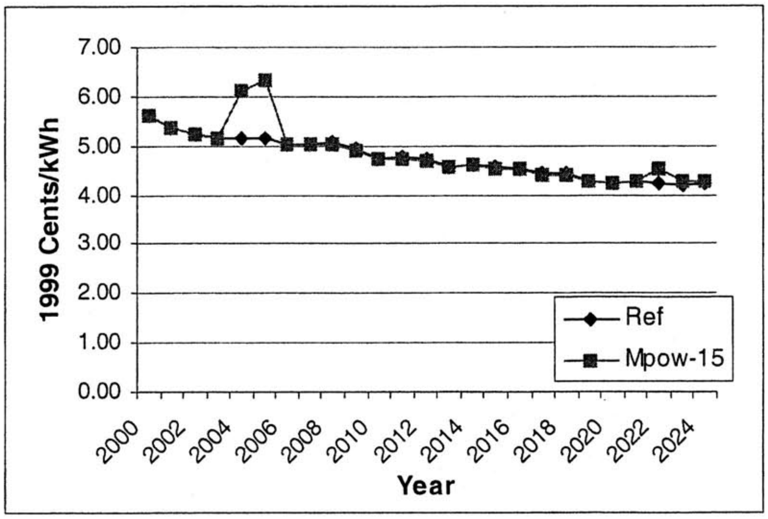
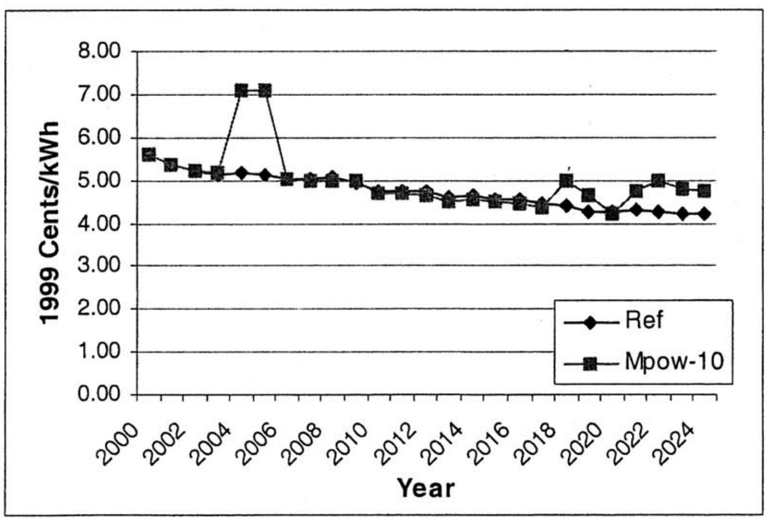


Figure Thirty-Five: Base Year Unit Cost of Electricity- 10% Margin vs. Reference Case



B. Dispatch Costs

To return to the unusual result of higher sulfur emissions in such periods, examining dispatch patterns may help explain why emissions rise when SEPCO is forced to purchase more expensive power under circumstances of lower reserve margins.

SEPCO serves (or buys) electricity from generating units on a lowest dispatch cost basis, where dispatch cost = fuel plus variable O&M. SEPCO thus seeks to minimize dispatch costs via either of these parameters. Variable O&M's modeled response to smaller reserves is clear in Figures Thirty-Six, Thirty-Seven and Thirty-Eight, though fuel costs appear to be constant.

Figure Thirty-Six: Dispatch Costs for Coal Case- 20% Margin (Reference)

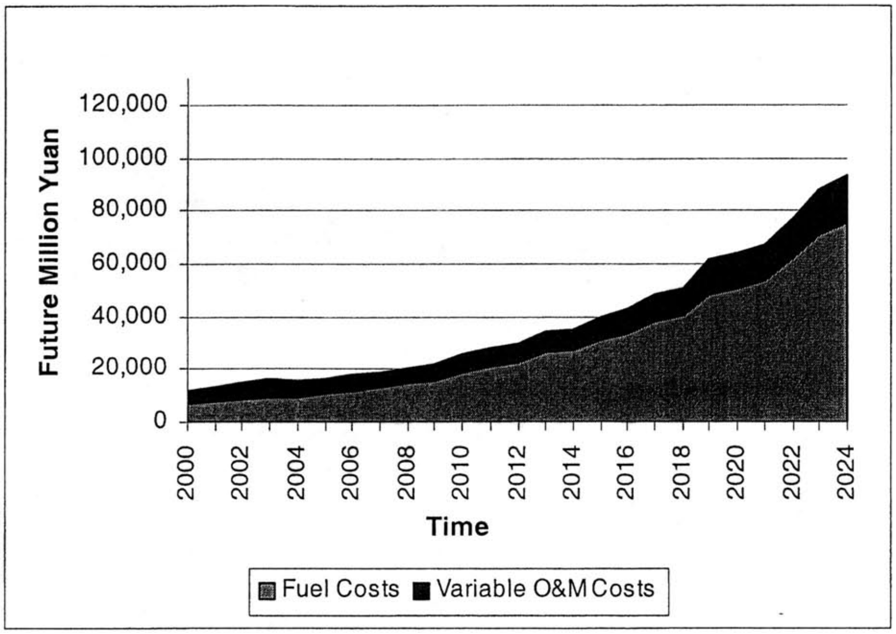


Figure Thirty-Seven: Dispatch Costs for Coal Case- 15% Margin

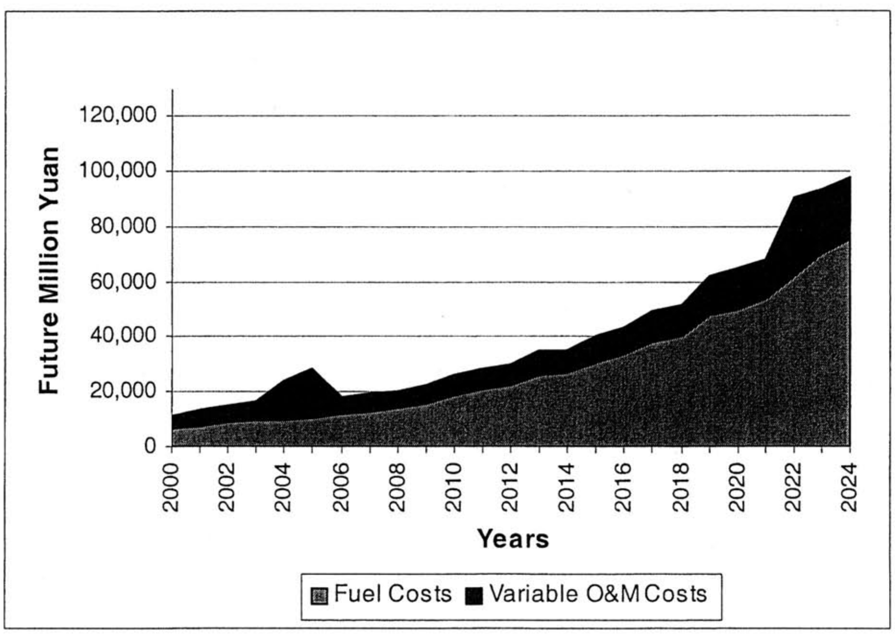
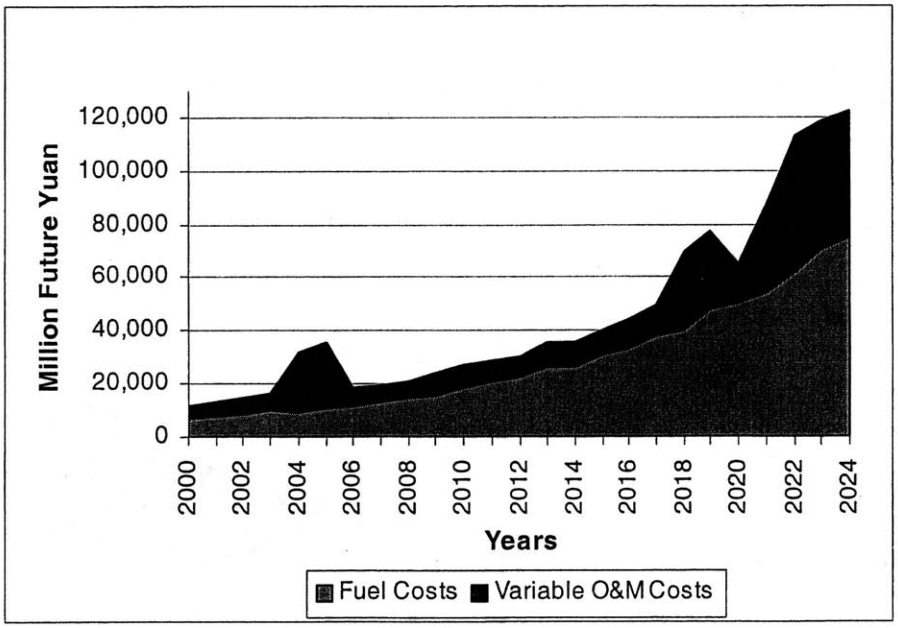


Figure Thirty-Eight: Dispatch Costs for Coal Case- 10% Margin



However, upon closer inspection, fuel costs are not constant. Table Forty-Four shows the differences throughout the study period for the coal case between fuel, variable O&M and total dispatch costs across the range of target reserves.

Table Forty-Four: Dispatch Cost Deltas for Coal Case Across Target Reserve Margins

	mmYuan Cost Differences Between 15% & 20% Target Reserve Cases			mmYuan Cost Differences Between 10% & 20% Target Reserve Coal Cases		
Year	Fuel	Var O&M	Dispatch	Fuel	Var O&M	Dispatch
2000	0.00	47.00	47.00	0.00	47.00	47.00
2001	0.00	79.00	79.00	0.00	79.00	79.00
2002	0.00	86.00	86.00	0.00	86.00	86.00
2003	0.00	121.00	121.00	0.00	121.00	121.00
2004	51.00	7,905.00	7,956.00	97.00	15,667.00	15,764.00
2005	162.00	11,651.00	11,813.00	275.00	18,931.00	19,206.00
2006	56.00	510.00	566.00	136.00	746.00	882.00
2007	**-30.00**	488.00	458.00	**-50.00**	821.00	771.00
2008	**-76.00**	574.00	498.00	**-124.00**	886.00	762.00
2009	**-80.00**	636.00	556.00	**-120.00**	2,661.00	2,541.00
2010	**-72.00**	761.00	689.00	**-98.00**	1,132.00	1,034.00
2011	**-77.00**	623.00	546.00	**-158.00**	1,022.00	864.00
2012	**-83.00**	670.00	587.00	**-167.00**	1,046.00	879.00
2013	**-84.00**	662.00	578.00	**-179.00**	1,145.00	966.00
2014	**-85.00**	670.00	585.00	**-179.00**	1,138.00	959.00
2015	**-92.00**	781.00	689.00	**-150.00**	1,150.00	1,000.00
2016	**-80.00**	779.00	699.00	**-142.00**	1,128.00	986.00
2017	**-99.00**	954.00	855.00	**-174.00**	1,389.00	1,215.00
2018	**-61.00**	741.00	680.00	**-10.00**	18,970.00	18,960.00
2019	**-74.00**	921.00	847.00	**-84.00**	16,350.00	16,266.00
2020	**-77.00**	962.00	885.00	**-156.00**	1,602.00	1,446.00
2021	**-113.00**	1,129.00	1,016.00	**-2.00**	20,389.00	20,387.00
2022	**-9.00**	13,454.00	13,445.00	**-3.00**	35,751.00	35,748.00
2023	**-133.00**	6,137.00	6,004.00	**-13.00**	31,069.00	31,056.00
2024	**-131.00**	5,118.00	4,987.00	**-2.00**	29,366.00	29,364.00
Totals	**-1,187.00**	56,459.00	55,272.00	**-1,303.00**	202,692.00	201,389.00

C. Generation by Fuel Type

Having established that SEPCO may be sourcing fuel differently in order to minimize dispatch costs as thinning reserve margins put pressure on wholesale costs, we can also look at generation by fuel type over the study period. Figures Thirty-Nine, Forty and Forty-One show SEPCO's generation fuel mix for each of the reserve margin cases. Though extra-provincial coal is sourced in growing amounts for all three cases, it is substituted more *slowly* for Shandong coal as reserve margins shrink. This makes sense as Shandong coal, being closer, is also cheaper to obtain. However, as demand grows over time the graphs show SEPCO is forced to buy coal from Shanxi as Shandong's stock is limited[1]. The state's ongoing campaign to close smaller private mines and concentrate coal mining in the more productive provinces would tend to reinforce this trend.

Figure Thirty-Nine: Generation by Fuel Type- 20% Margin

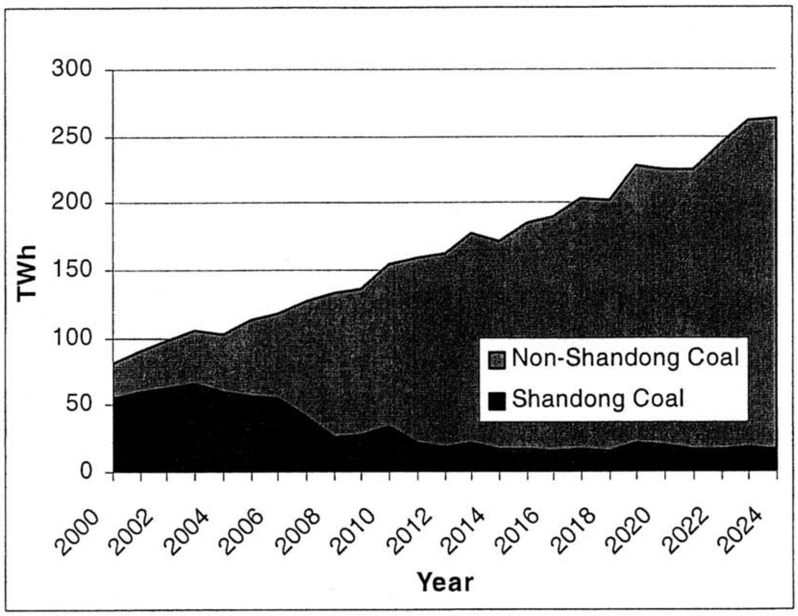
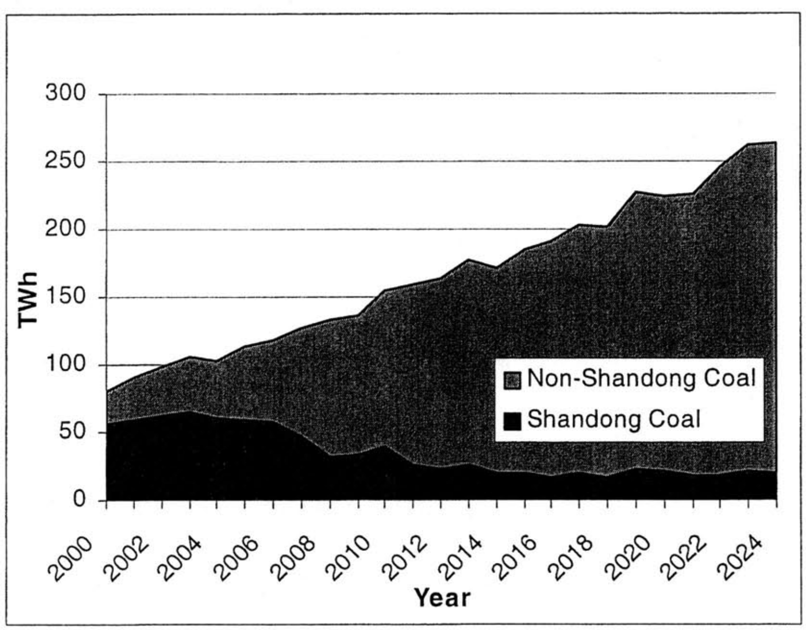


Figure Forty: Generation by Fuel Type- 15% Margin



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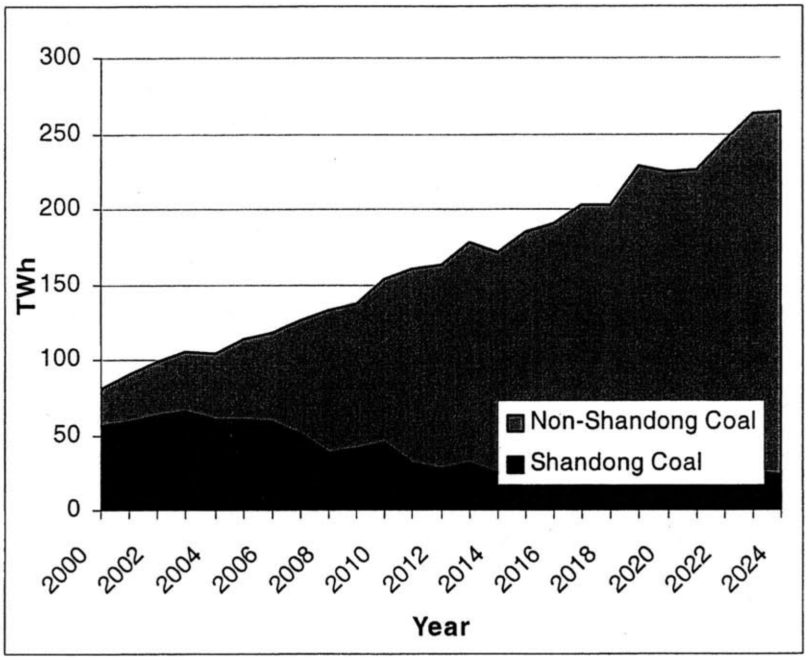
[1] SEPCO Officials, March, 2001.

Figure Forty-One: Generation by Fuel Type- 10% Margin



But how would SEPCO's increasing substitution of closer, cheaper coal translate into higher emissions when in fact Shandong coal is no dirtier than Shanxi coal? A look at the dispatch patterns shown in Table Forty-Five reveals that SEPCO in fact shifts more generation to existing units over the study period, which would explain the additional sulfur and particulate emissions observed for the lower reserve margin cases.

Table Forty-Five: Generation by Unit Type Across Target Reserve Margins

	GWh Generated		
	RM = 20%	RM = 15%	RM = 10%
Existing	1,138,257	1,246,828	1,398,439
New	3,040,422	2,931,883	2,780,241
Total	4,178,679	4,178,711	4,178,680

But what, if any, is the connection between this behavior and SEPCO's move to source local fuel? When queried further, SEPCO officials revealed that the system's older units are relegated to using Shandong coal, whereas new units had established purchase contracts with

Shanxi mines, again from which transportation costs are higher[2]. Though no further comment was offered, we may hypothesize that from a political standpoint it is easier for SEPCO to shift generating patterns rather than to acquire local coal for new units that have established sourcing relationships with larger state-owned mines outside of Shandong. This makes further sense in light of China's campaign to stabilize coal prices by closing smaller, privately-owned mines. Interestingly, the perverse result of this situation is an increase in sulfur and particulate emissions.

D. Emissions

Though sulfur and particulate emissions do increase slightly as SEPCO moves in the face of high wholesale prices to control costs by shifting generation to older units, cumulative levels do not rise drastically. Tables Forty-Six and Forty-Seven show cumulative emissions and percent differences across the target reserve margin cases. As shown, cumulative sulfur emissions respectively rise 5% and 12% from the reference case to the 15% and 10% reserve margin cases. And, particulate emissions rise close to 1% from the reference case to both the 15% and 10% cases. Carbon emissions drop slightly, though carbon and criteria pollutant emissions do not necessarily track one another given the potential within a system for alternative sulfur and particulate control technologies. For example, FGD reduces sulfur emissions but also derates unit efficiency, which may result in increased carbon emissions given the consequent need to burn more fuel to attain required power output.

[2] SEPCO Officials, March, 2001.

Table Forty-Six: Cumulative Emissions Across Target Reserve Margins

	RM = 20% (Ref)	RM = 15%	RM = 10%
SO_2 (kt)	12017	12619	13440
PM_{10} (kt)	4931	4960	4997
CO_2 (mt)	3408	3396	3380

Table Forty-Seven: Percent Differences in Cumulative Emissions Across Reserve Margins

	15%-Ref	10%-Ref
SO_2 (kt)	5.01%	11.84%
PM_{10} (kt)	0.59%	1.34%
CO_2 (mt)	-0.36%	-0.82%

5.3.2 Market Power2 vs. Nuclear and Gas-by-Wire Reference Case

A. Base Year Unit Cost of Service

Actual reserve margins rarely dip below 20% in either the 15% or 10% target reserve cases for the nuclear and gas-based strategy. This is attributable to the long lead times and large capacity installations associated with nuclear power, which influence a system which tends towards higher average reserve margins. Variable O&M costs, therefore, do not increase as much for the nuclear-and-gas cases as for coal when subject to greater captivity to generator market power. Figures Forty-Two and Forty-Three demonstrate this effect on unit costs. The initial jump is, as with the coal cases attributable to the advent of deregulation. Reference and market power costs tend to subsequently track each other under the 15% case though do diverge when margins thin to 10%. Aside from this slightly observable impact of market power, unit costs for both the 15% and 10% cases diminish over time as with the coal cases. Reference and market power unit costs respectively end at $.0453, $.0454 and $.0479 for the reference, 15% and 10% cases.

Figure Forty-Two: Unit Cost of Electricity- 15% Margin vs. Nuclear and Gas Ref

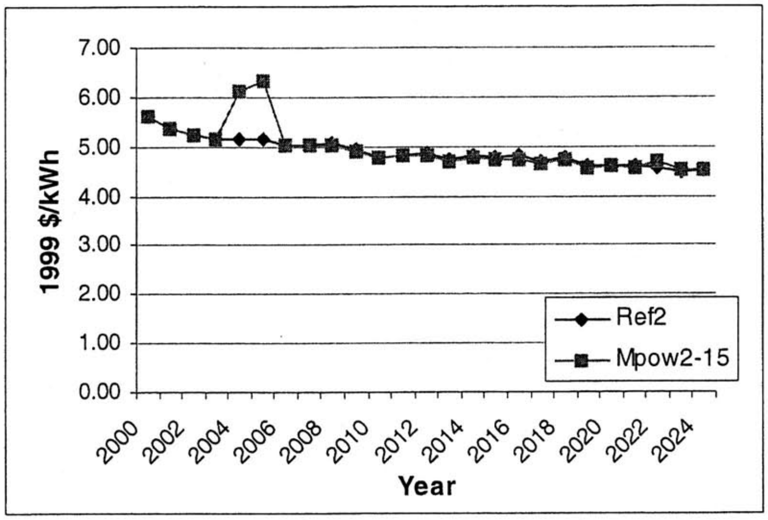
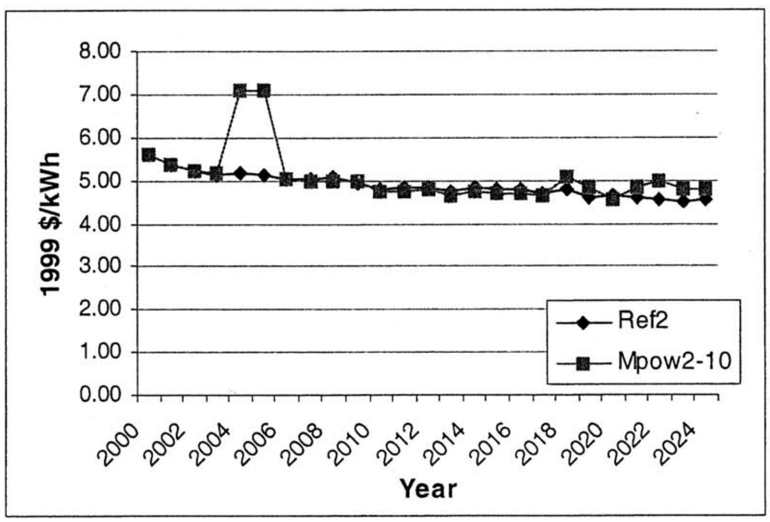


Figure Forty-Three: Unit Cost of Electricity- 10% Margin vs. Nuclear and Gas Ref



B. Dispatch Effect on Emissions

Sulfur and particulate emissions likewise increase slightly in the nuclear and gas-base case, though less so than with the coal case, as Tables Forty-Eight and Forty-Nine demonstrate.

Table Forty-Eight: Cumulative Emissions Across Reserve Margins- Nuclear and Gas Case

	RM = 20% (Ref)	RM = 15%	RM = 10%
SO_2 (kt)	10421	10855	11390
PM_{10} (kt)	4485	4510	4534
CO_2 (mt)	2802	2794	2785

Table Forty-Nine: Percent Differences in Cumulative Emissions Across Reserve Margins- Nuclear and Gas Case

	15%-Ref	10%-Ref
SO_2 (kt)	4.16%	9.30%
PM_{10} (kt)	0.54%	1.08%
CO_2 (mt)	-0.27%	-0.62%

The lesser increase in emissions in this case is attributable to the absence of as strong a market signal to contain costs given the lower installed capacity in coal plants and hence higher reserve margins. That is, SEPCO does not seek as strongly in this case to contain dispatch costs. Nonetheless, the fact that both sulfur and particulate emissions increase at all indicates that SEPCO does make a small shift to burning cheaper, provincial coal in existing units even in the nuclear and gas case.

5.4 Stricter Sulfur/Higher Coal Set

5.4.1 Tradeoff Analysis

In Figures Forty-Four, Forty-Five and Forty-Six below, SS represents movement from the coal-based reference case to stricter sulfur emissions limits on existing plants. SS2 represents the same effect for the nuclear-and-gas case. The SS+HCC and SS+HCC2 series represent the additional incorporation of higher coal transit costs due to the need to invest in, and recover for increased coal transportation infrastructure. The behavior of all of these scenarios follows the labels on the first figure[3]. As shown, migration from **1)** the reference case to **2)** stricter sulfur regulations on existing plants for both the coal and nuclear-and-gas cases predictably impacts sulfur emissions considerably and particulate emissions in small part but does not impact carbon emissions. For neither case does this movement substantially impact

[3] Note also that the 'Stricter Sulfur' and 'Stricter Sulfur plus Higher Coal' scenarios for both the coal and nuclear and gas-by-wire cases graph on top of one another in the last figure- i.e. their performance with respect to carbon emissions is the same.

costs. However, the incorporation of **3)** greater coal costs does introduce a cost impact. Interestingly, this element also results in a significantly smaller emissions impact than if coal prices were to remain constant. I explore this phenomenon below.

Figure Forty-Four: Stricter Sulfur/Higher Coal- Cumulative Sulfur Emissions vs. Total Costs

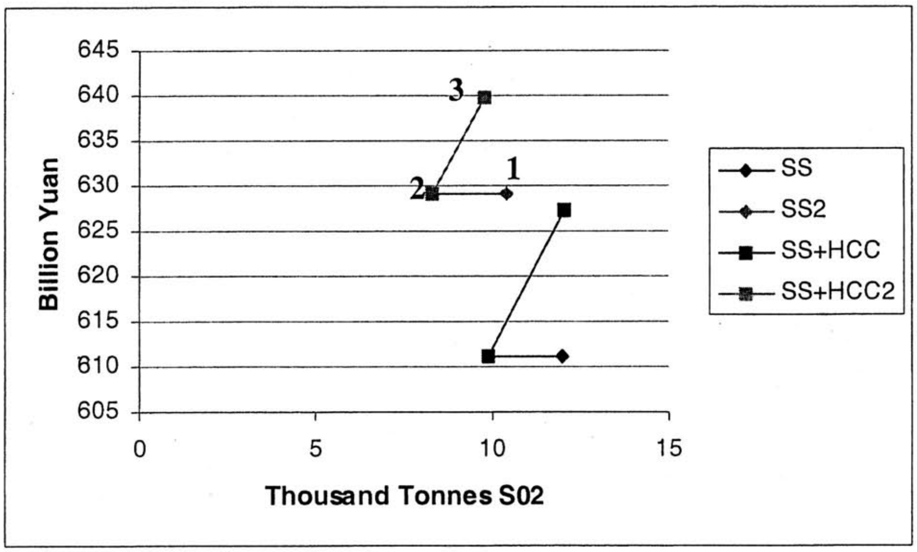


Figure Forty-Five: Stricter Sulfur/Higher Coal- Cumulative Particulate Emissions vs. Total Costs

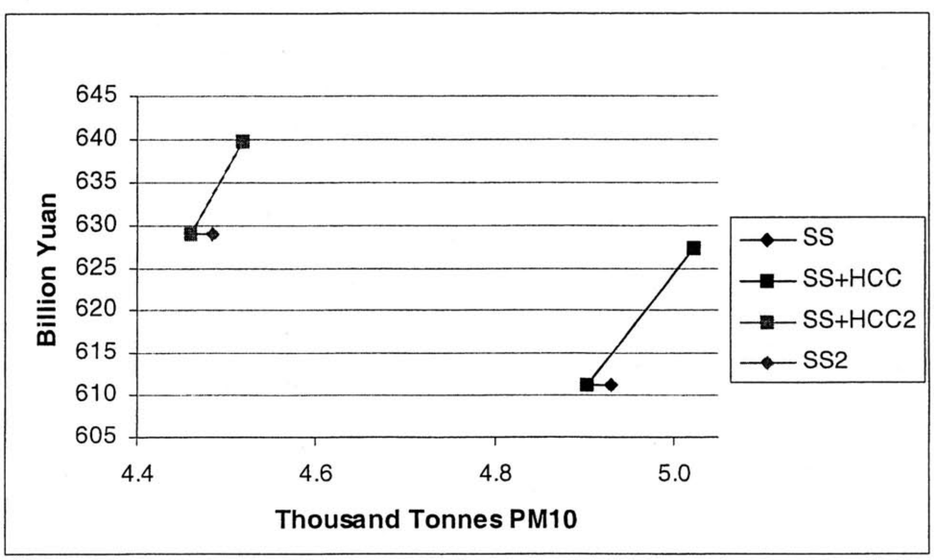
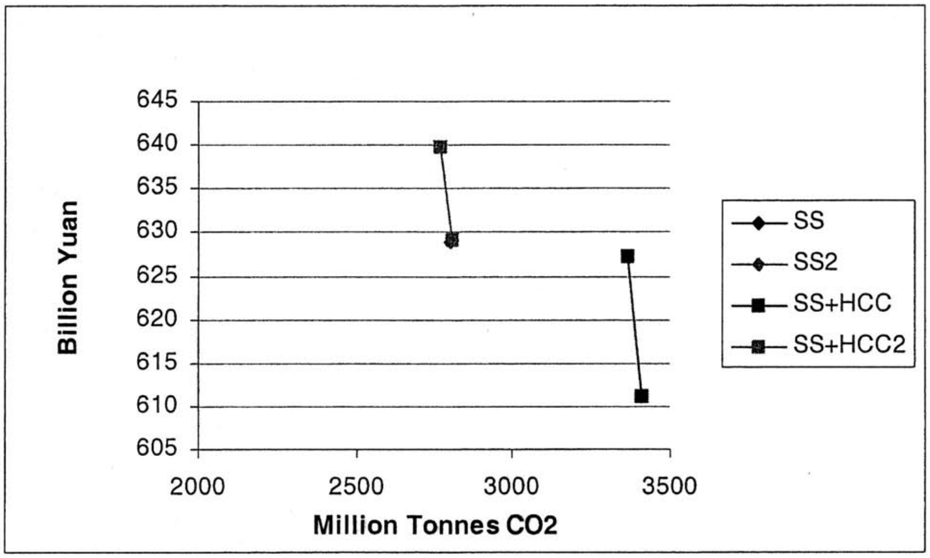


Figure Forty-Six: Stricter Sulfur/Higher Coal- Cumulative Carbon Dioxide Emissions vs. Total Costs

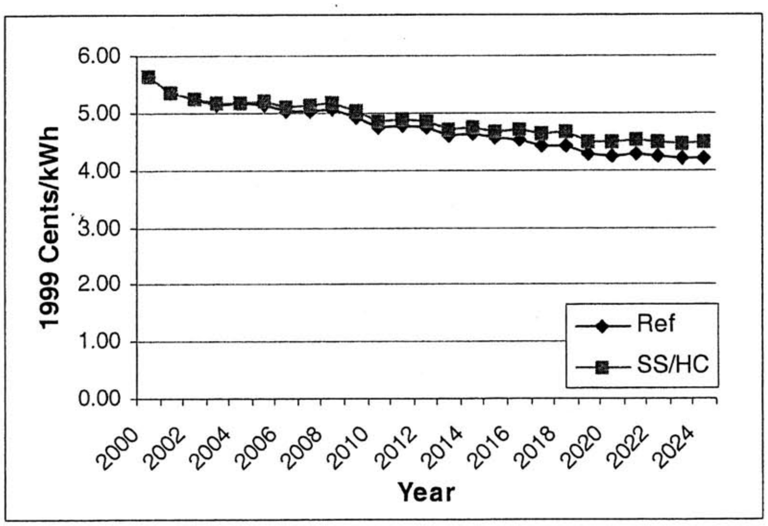


5.4.2 Stricter Sulfur/Higher Coal Costs vs. Coal Reference Case

A. Base Year Unit Costs

Before exploring the emissions results described above in this section, I briefly look at unit costs. As Figure Forty-Seven shows, unit costs decrease throughout the study period for both cases, though the stricter sulfur/higher coal costs set begins to exceed reference costs early, and end up higher at $.0448/kWh vs. the reference case's ending value of $.0422/kWh.

Figure Forty-Seven: Base Year Unit Cost of Electricity- SS/HC vs. Coal Ref



B. Emissions

As with the Market Power cases, SEPCO's lowest-cost dispatch approach applies here. Just as when faced with tightening reserve margins, Figures Forty-Eight and Forty-Nine show how in the event of stricter sulfur regulations and higher coal costs SEPCO strives to source cheaper Shandong coal.

Figure Forty-Eight: Generation by Fuel Type- Coal Reference Case

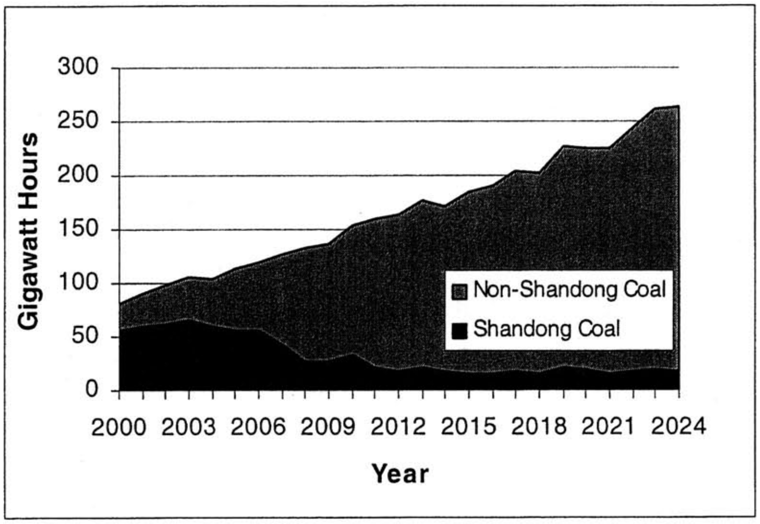
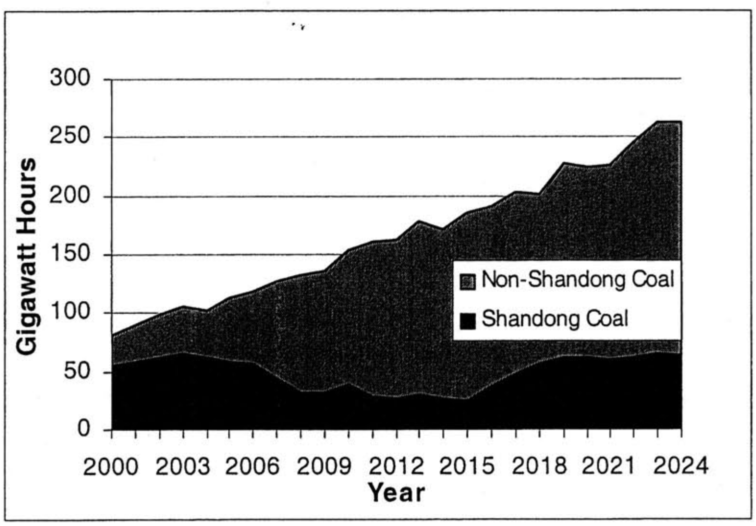


Figure Forty-Nine: Generation by Fuel Type- Stricter Sulfur/Higher Coal Costs Case



Once again, however, sourcing cheaper coal from within Shandong to the extent it is available does not in and of itself explain higher emissions. However, as Table Fifty shows, when faced with stricter sulfur emissions SEPCO reverts to running older, less efficient equipment. Thus, even though these plants are forced to burn cleaner coal, due to their lower efficiencies they must use more fuel than would have to burn were they serving the same load with newer units, which also have the advantage (if they are run, that is) of FGD.

Table Fifty: Generation by Unit Type- SS/HC vs. Reference Case

	Generation in GWh	
	Ref	SS/HC
Existing	1,138,257	1,572,135
New	3,040,422	2,606,545
Total	4,178,679	4,178,680

Tables Fifty-One and Fifty-Two show the emissions impact of this shift.

Table Fifty-One: Cumulative Emissions- SS/HC vs. Reference Case

	Ref	SS/HC
SO_2 (kt)	12017	12063
PM_{10} (kt)	4931	5022
CO_2 (mt)	3408	3365

Table Fifty-Two: Percent Differences in Cumulative Emissions- SS/HC vs. Ref

	SS/HC - Ref
SO_2 (kt)	0.38%
PM_{10} (kt)	1.85%
CO_2 (mt)	-1.27%

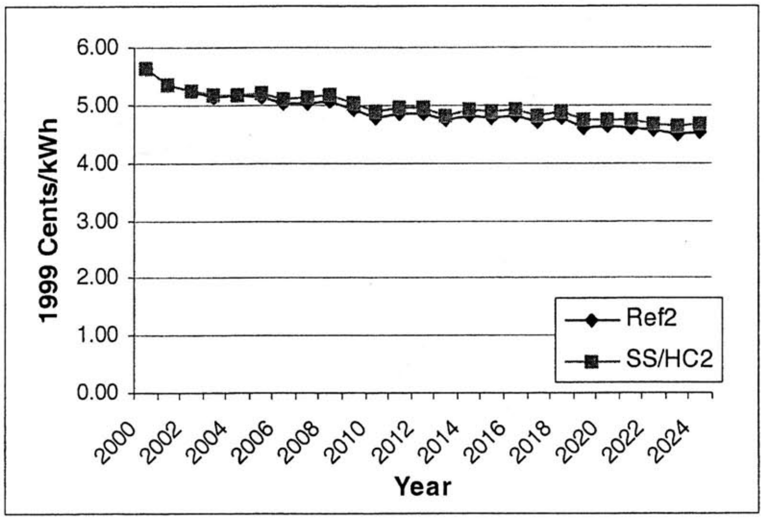
Even though the consequent increase in sulfur and particulate emissions is not great in magnitude, it is interesting nonetheless. Also noteworthy is the comparative impact of this future on costs vs. emissions: unit costs still go up for an unintended result of nearly identical cumulative emissions levels. Thus, SEPCO may be saving slightly on fuel costs -and be saving face with Shanxi coal suppliers- by changing its generating mix, though it appears to be doing so at the expense of customers and the environment in this instance.

5.4.3 Stricter Sulfur/Higher Coal Costs2 vs. Nuclear and Gas-by-Wire Reference Case

A. Base Year Unit Costs

As Figure Fifty shows, the nuclear-and-gas case exhibits the same cost patterns as does the coal case when faced with stricter sulfur regulations and higher coal costs for older units. Costs fall steadily to levels of \$.0466/kWh for the strict case and \$.0453/kWh for the reference case.

Figure Fifty: Base Year Unit Cost of Electricity- SS/HC2 vs. Nuclear and Gas Reference



B. Emissions

As shown in Table Fifty-Three, the stricter sulfur policy appears effective in this case since sulfur emissions fall. However, particulates rise, though just slightly.

Table Fifty-Three: Cumulative Emissions- SS/HC2 vs. Nuclear and Gas Reference Case

	Ref	SS/HC
SO_2 (kt)	10421	9753
PM_{10} (kt)	4485	4519
CO_2 (mt)	2802	2767

Table Fifty-Four: Percentage Differences in Cumulative Emissions- SS/HC2

Nuclear and Gas Reference Case

	SS/HC - Ref
SO_2 (kt)	-6.41%
PM_{10} (kt)	0.75%
CO_2 (mt)	-1.24%

Although the stricter sulfur policy appears to enjoy greater success in the nuclear and gas case, Table Fifty-Five shows that on closer inspection SEPCO still shifts some generation to older units.

Table Fifty-Five: Generation by Unit Type- SS/HC2 vs. Nuclear and Gas Reference Case

	Generation in GWh	
	Ref2	SS/HC2
Existing	1,061,114	1,341,181
New	3,117,614	2,837,595
Total	4,178,728	4,178,776

5.5.0 Consolidated Set

The event streams hypothesized and discussed above would in reality occur in concert. For example WTO accession should hasten financial market reform, which via shareholder empowerment should stimulate utilities to control costs, optimize asset bases and introduce western management practices to serve WTO-induced larger and peakier loads. As a consequence, Chinese electricity providers may find themselves developing more sophisticated risk management practices to handle shifting peak profiles and greater merchant risk in a restructured regime. And, because electricity deregulation in an (expectedly) expansive economy will necessitate even greater attention to China's already serious environmental issues, power providers must also anticipate an eventual transition to more effective emissions monitoring and enforcement.

As described in Chapter 4, I combined the elements of the preceding scenarios to form two consolidated scenarios, as specified in Table Fifty-Six. (Note both "Kitchen Sink" scenarios represent use of a 10% target reserve margin.) This section compares the consolidated scenarios to the reference cases.

Table Fifty-Six: Consolidated Scenarios

Conventional Coal Consolidated Scenario

B A C - C O N P E S - S A H

"**B**"aseline old unit retirement schedule
R"**A**"tchet down to ***stricter sulfur*** content
"**C**"urrently available coal supplies
- "**C**"oventional coal baseload
N"**O**" extra-provincial generation
"**N**"o renewables
"**P**"eaking units = combustion turbines
T"**E**"n % target reserve under ***Market Power***
"**S**"tandard end-use efficiency programs
- "**S**"trong demand under ***WTO***
"**A**"ggravated Coal Costs
"**H**"igh ***ROE***

Nuclear and Gas-by-Wire Consolidated Strategy

B A C - N A N P E S - S A H

"**B**"aseline old unit retirement schedule
R"**A**"tchet down to ***stricter sulfur*** content
"**C**"urrently available coal supplies
- "**N**"uclear and conventional coal baseload
G"**A**"***s*** *by wire* from outside province
"**N**"o renewables
"**P**"eaking units = combustion turbines
T"**E**"n % target reserve under ***Market Power***
"**S**"tandard end-use efficiency programs
- "**S**"trong demand under ***WTO***
"**A**"ggravated Coal Costs
"**H**"igh ***ROE***

5.5.1 Tradeoff Analysis

The figures below show that the coarse results of all the hypothesized events acting in concert are not surprising: total costs go up as a result of higher growth, increasing shareholder demands, merchant exposure and stricter environmental enforcement. Emissions rise as well, which by virtue of the preceding analysis we may guess happens as a result not only of growth but by the system's tendency to run cheaper, older units whenever possible.

Figure Fifty-One: Kitchen Sink- Cumulative Sulfur Emissions vs. Total Costs

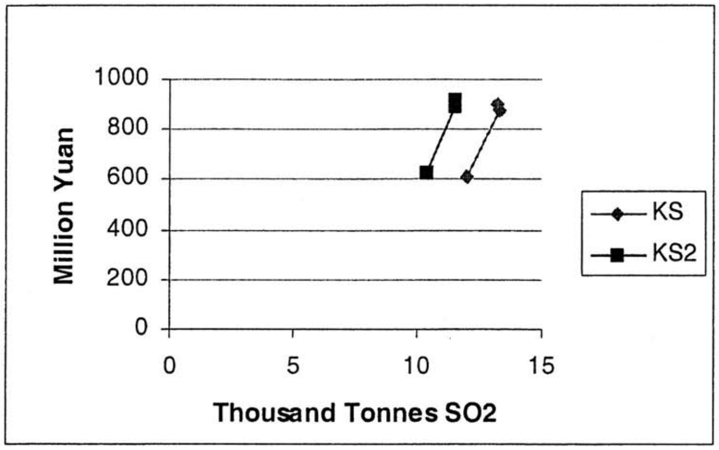


Figure Fifty-Two: Kitchen Sink- Cumulative Particulate Emissions vs. Total Costs

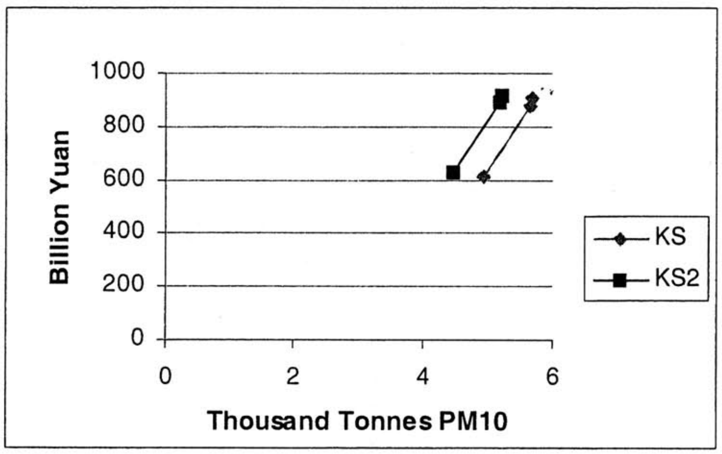
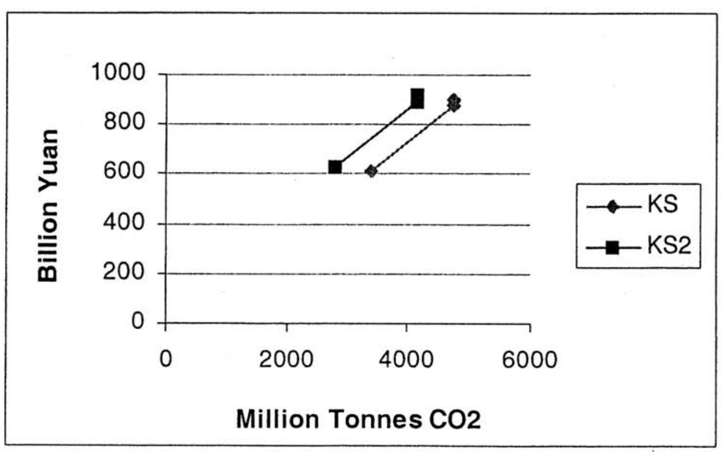


Figure Fifty-Three: Kitchen Sink- Cumulative Carbon Dioxide Emissions vs. Total Costs



5.5.1 Kitchen Sink vs. Coal Reference Case

Taking key results from the foregoing sections to heart, this section explores the following additional elements of the consolidated coal scenario: A.) future and base year unit costs, B.) annual demand vs. peak load growth, C.) Reserve Margin, D.) capital recovery on new generation, E.) generation by unit type and F.) emissions.

A. Unit Costs

Figure Fifty-Four indicates future costs would exceed reference costs for all years of the study period, and shows the series particularly diverge in later years. And, Figure Fifty-Five shows unit costs for the reference and kitchen sink (KSink) scenarios do fall in an absolute sense over the study period, albeit very slightly in the latter case. The reference case starts at $.0563 and ends at $.0422, whereas KSink starts at $.0563/kWh and ends at $.0555/kWh in real terms. Moreover, both the future and base year comparisons show the KSink case is marked by periods of volatility, which is as demonstrated the likely impact of captivity to merchant generators.

Figure Fifty-Four: Future Year Unit Cost of Electricity- Kitchen Sink vs. Coal Ref

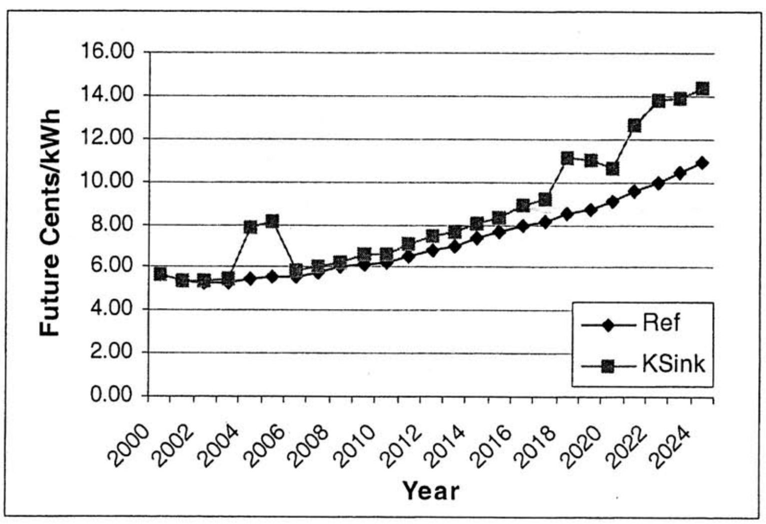
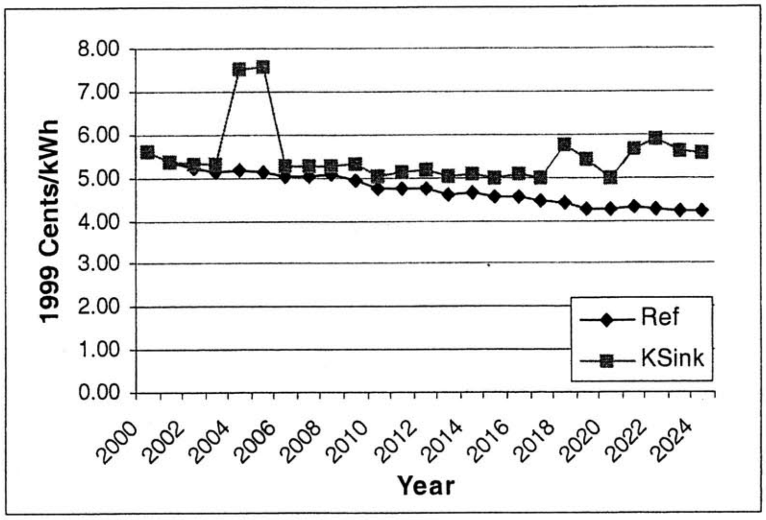


Figure Fifty-Five: Base Year Unit Cost of Electricity- Kitchen Sink vs. Coal Ref



B. Demand vs. Peak Load Growth Rates

As Table Fifty-Seven shows, both demand and peak load for KSink grow at a faster rate than they do for the reference case, just as under WTO.

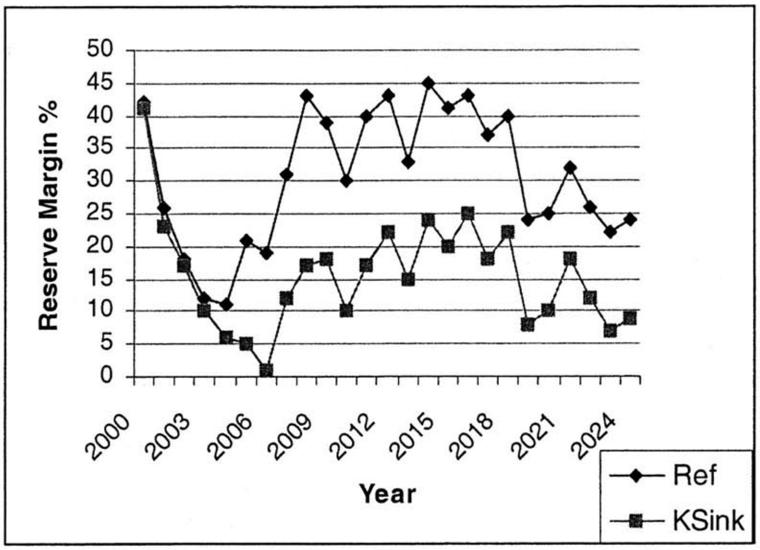
Table Fifty-Seven: Compounded Annual Growth Rates- Kitchen Sink vs. Coal Ref

	Ref	Ksink
Annual Peak Load	5.65%	7.65%
Annual Demand	5.05%	8.51%

C. Reserve Margins

KSink's reserve margins are narrower in a deregulated environment, as shown in Figure Fifty-Six. They also drive a large initial spike in unit costs when they drop to zero in 2007.

Figure Fifty-Six: Comparative Reserve Margins- Kitchen Sink vs. Coal Reference Case



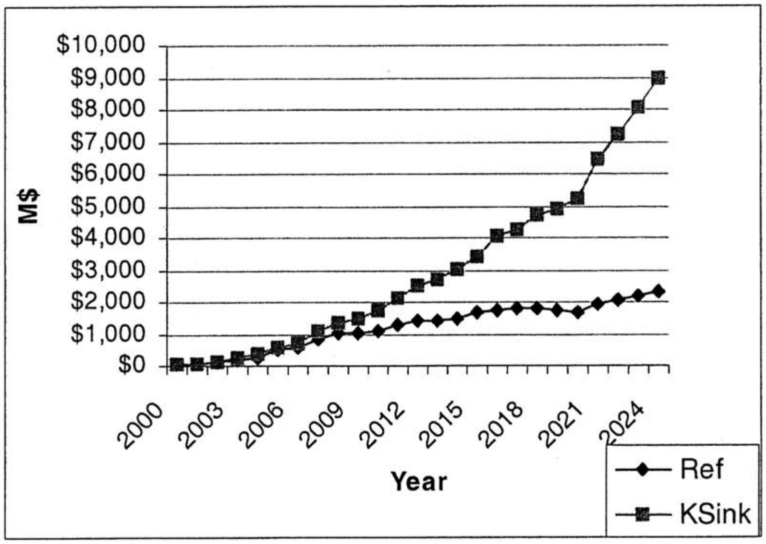
Unlike the WTO set wherein undercapitalization contributed to lower unit costs on the whole, the lower reserve margins in this case are driving higher unit costs due to SEPCO's captivity to merchant market power. We in fact have recently witnessed this phenomenon demonstrated in California.

D. Capital Recovery on New Generation

As Figure Fifty-Seven shows, the greater returns due to KSink's stronger shareholders drive up generation recovery payments by 287% in 2024 over the reference case. This dramatic increase must then represent stronger demand growth under WTO plus the impact of a higher ROE.

Figure Fifty-Seven: Capital Recovery for New Generation Investments-

KSink vs. Coal Reference



E. Generation by Unit Type

Table Fifty-Eight confirms SEPCO's tendency to source cheaper Shandong coal for use in older units under Ksink relative to the reference case. In this case SEPCO's actions are driven by the market power of generators in a deregulated environment as well as by China's imposition of stricter sulfur regulations.

Table Fifty-Eight: Generation by Unit Type- Ksink2 vs. Ref2

	GWh Generated	
	Ref	KSink
Existing	1,138,257	1,409,297
New	3,040,422	4,351,277
Total	4,178,679	5,760,574

F. Emissions

As Tables Fifty-Nine, Sixty and Sixty-One show, cumulative emissions levels over the study period rise nearly 10%, 15% and 40% for sulfur dioxide, particulates and carbon dioxide from the reference case to Ksink. The smoothed rates of change for annual emissions of sulfur and particulates climb slightly under conditions of a progressively cleaner generating stock yet also higher demand. Annual carbon emissions climb at a smoothed rate of over 8%. Demand-normalized emissions for sulfur and particulates fall as the rate base grows, though this metric for carbon likewise grows slightly.

Table Fifty-Nine: Cumulative Emissions- KSink vs. Coal Ref

	Ref	Ksink
SO_2 (kt)	12017	13197
PM_{10} (kt)	4931	5675
CO_2 (mt)	3408	4753

Table Sixty: Percentage Differences in Cumulative Emissions- KSink vs. Coal Ref

	KSink-Ref
SO_2 (kt)	9.82%
PM_{10} (kt)	15.10%
CO_2 (mt)	39.47%

Table Sixty-One: Compounded Annual Growth Rates for Annual and Demand Normalized Emissions- KSink vs. Coal Ref

	SO_2 (KT)		PM_{10} (KT)		CO_2 (MT)	
	Ref	Ksink	Ref	Ksink	Ref	Ksink
Annual Emissions	-1.77%	0.88%	-0.05%	1.36%	5.74%	8.40%
Emissions per GWh	-6.50%	-6.29%	-4.85%	-5.85%	0.66%	0.69%

5.5.2 Kitchen Sink2 vs. Nuclear and Gas-by-Wire Reference Case

A. Future and Base Year Unit Costs

Figure Fifty-Eight shows the consolidated nuclear and gas-by-wire based scenario to be more expensive to SEPCO's customers than the reference case. And, as Figure Fifty-Nine shows, base year unit costs for the nuclear and gas case move from $.0563/kWh to $.0560/kWh in 2024. In both graphs the consolidated scenarios are additionally susceptible to merchant market power.

Figure Fifty-Eight: Future Year Unit Cost of Electricity- Kitchen Sink2 vs. Nuclear and Gas Reference Case

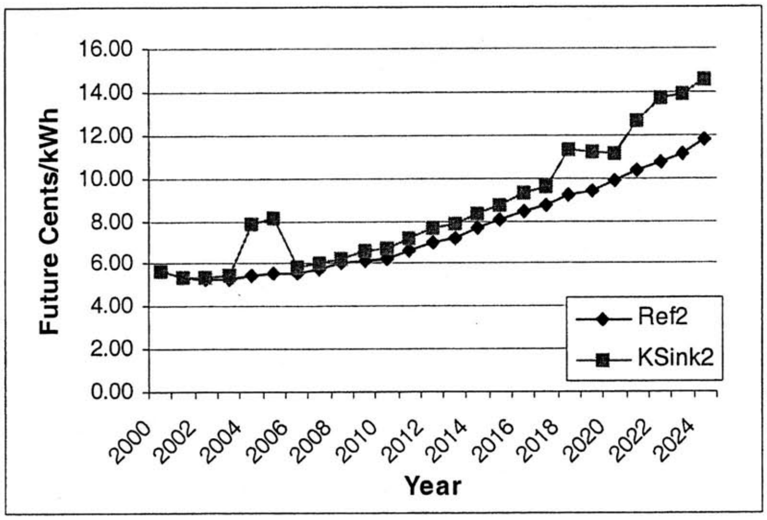
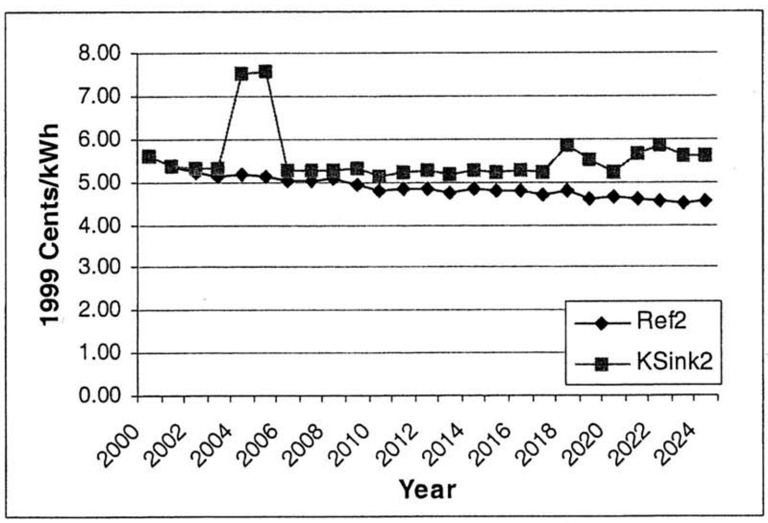


Figure Fifty-Nine: Base Year Unit Cost of Electricity- Kitchen Sink2 vs. Nuclear and Gas Reference Case



A. Demand vs. Peak Load Growth Rates

As Table Sixty-Two shows, demand and peak under this strategy have not changed from the coal case since the hypothesized future for both strategies is the same.

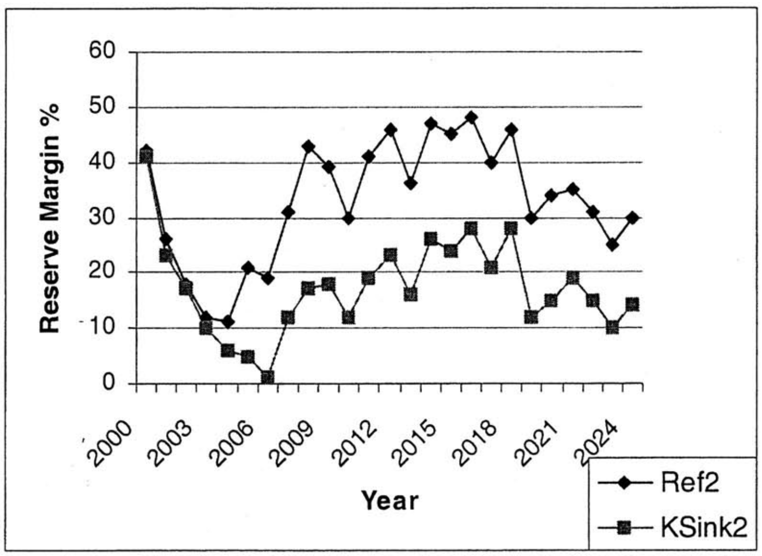
Table Sixty-Two: Compounded Annual Growth Rates- Kitchen Sink2 vs. Ref2

	Ref2	Ksink2
Annual Peak Load	5.65%	7.65%
Annual Demand	5.05%	8.51%

B. Reserve Margins

Reserve margins in this case do not narrow as much as in the coal case due to the presence of nuclear. However, margins certainly drive wholesale costs when below 20%.

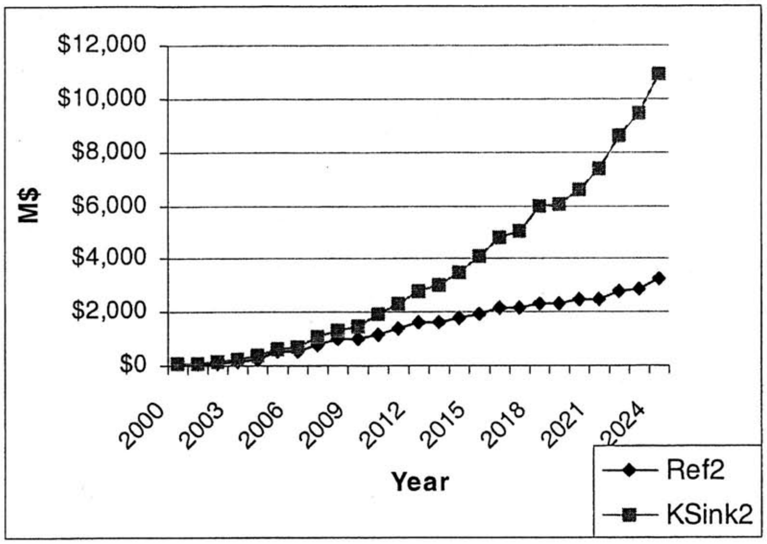
Figure Sixty: Comparative Reserve Margins- KSink2 vs. Ref2



C. Capital Recovery on New Generation

As Figure Sixty shows, capital costs for the nuclear and gas case higher in magnitude than for the coal case, though the increase in Ksink2 over Ref2 is relatively lower, at 239% in 2024.

Figure Sixty: Capital Recovery for New Generation Investments- KSink2 vs. Ref2



D. Generation by Unit Type

Table Sixty-Three confirms SEPCO's tendency to rely more on existing stock in the nuclear and gas case also.

Table Sixty-Three: Generation by Unit Type- KSink2 vs. Ref2

	GWh Generated	
	Ref	KSink
Existing	1,061,114	1,337,477
New	3,117,614	4,423,035
Total	4,178,728	5,760,512

E. Emissions

As Tables Sixty-Four through Sixty-Six show, cumulative emissions levels for the nuclear and gas case are lower than for the coal case, though the percentage differences from Ref2 to Ksink2 are higher than for the coal case. The smoothed rate of change for annual sulfur emissions falls slightly, though grows in this case for particulates and carbon. Demand-normalized emissions fall across all categories due to the presence of nuclear and to increased demand.

Table Sixty-Four: Cumulative Emissions- KSink2 vs. Ref2

	Ref2	Ksink2
SO_2 (kt)	10421	11569
PM_{10} (kt)	4485	5219
CO_2 (mt)	2802	4144

Table Sixty-Five: Percentage Differences in Cumulative Emissions- KSink2 vs. Ref2

	KSink2-Ref2
SO_2 (kt)	11.01%
PM_{10} (kt)	16.36%
CO_2 (mt)	47.91%

Table Sixty-Six: CAGRs for Annual and Demand Normalized Emissions- KSink2 vs. Ref2

	SO_2 (KT)		PM_{10} (KT)		CO_2 (MT)	
	Ref2	Ksink2	Ref2	Ksink2	Ref2	Ksink2
Annual Emissions	-3.66%	-0.32%	-1.12%	0.60%	3.90%	7.46%
Emissions per GWh	-8.29%	-7.40%	-5.87%	-6.55%	-1.09%	-0.18%

5.6 Chapter Summary

Chapter 5 sequentially compared each of the subsets formed to represent the hypothesized events to their appropriate reference cases. It began the comparisons using tradeoff analysis, and on the basis of those results explored each case in more depth. Chapter 6 recapitulates the results gleaned from this exercise, and offers pertinent recommendations.

Chapter Six- Conclusion and Recommendations

Before offering a consolidated set of conclusions and recommendations, this chapter presents findings and opportunities relevant to each individual hypothesis.

6.1 Conclusions Regarding WTO Accession

In aggregate, the stronger demand stimulated by WTO accession in China should contribute to increased total costs through 2024. Inflation would not appear to impact costs much, though higher costs for foreign technologies would impact expenses in the nuclear and gas case should the Yuan devalue.

Nonetheless, SEPCO should be able to achieve steadily decreasing *unit* costs in real terms throughout this period as newer, more efficient generation gets installed, regardless if it pursues a strictly coal or nuclear and natural-gas based generating strategy (though the nuclear unit costs are the higher of the two). WTO unit costs for both strategies are in addition consistently lower than reference case costs, though this is likely driven by the undercapitalization of the WTO scenarios relative to the reference scenarios. Even so, SEPCO should be able to reliably maintain lower reserve margins and pass those savings on to customers, though given rising incomes and changing consumption habits should at the same time plan for increasing peak loads.

Cumulative emissions would undoubtedly rise under WTO accession for sulfur dioxide, particulates and carbon dioxide, though most annual and demand normalized emissions for sulfur and particulates would appear to fall given an increasingly efficient capital stock and a growing rate base. Nevertheless, annual emissions rates for carbon would grow were China to pursue either a strictly coal-based or nuclear and gas strategy, a fact which might alarm the environmental community outside of China.

6.1.1 Related Recommendations

It is encouraging to know China may further its economic expansion through WTO without experiencing higher unit electricity costs. However, given the virtual inevitability of greater aggregate emissions levels in this case, China's options for ameliorating its already severe health and environmental problems (at least through electric sector measures) are limited. Implementing aggressive end-use efficiency programs may therefore be its only option in this respect. Such measures would also help to contain new generation investment costs in the event of devaluation, though the general tariff lowering effect of WTO may mitigate this need somewhat.

Peak load management should also become increasingly important. To this end, SEPCO might consider introducing industrial and commercial time of use rates, and implementing other demand side management measures. Granted, these steps would be difficult in the absence of regulatory and tariff reform in the electric sector, though as demonstrated these events may be on the horizon.

6.2 Conclusions Regarding Financial Market Reform

China's ongoing endeavor to reform its financial markets should impact costs but not emissions in the power sector. That is, a growing and increasingly empowered shareholder base should require higher returns as markets liberalize. Though SEPCO should be able to maintain decreasing unit costs, it would nonetheless grow more beholden to shareholder demands in terms of both cost containment and asset management under these circumstances.

6.2.1 Related Recommendations

As with WTO accession, China should simply plan to avoid new generation investment via diligent conservation so as to keep capital recovery payments in check. In addition, SEPCO should plan to experience pressure with regard to adopting western management practices in order to increase its return on assets. To this end SEPCO might seek to better understand the industry's evolution abroad, and to incorporate best practices. These may range from emerging risk management techniques to revised organizational structures to new knowledge transfer mechanisms and more dynamic human resource management approaches.

6.3 Conclusions Regarding Electric Sector Restructuring

In the event China implements electric sector restructuring without further policy reforms it should experience increasing total costs and slightly higher cumulative emissions levels. Yet, it should also enjoy decreasing unit costs, though unit costs under restructuring would be more volatile than under the current regime. And, should SEPCO opt for a nuclear and gas-based generation strategy the higher average reserve margins this type of capital stock yields would have a dampening effect on unit cost volatility. Nonetheless it is important to note that unit costs for the nuclear and gas-based strategy are generally higher than the coal-based case anyway.

A perverse result of the increasing captivity SEPCO may experience to wholesale generators in periods of low reserve margin in the event of deregulation is a tendency to shift generation to older units in an attempt to control costs. This behavior would result in increased sulfur and particulate emissions. However, as it appears to be the result of the desire on SEPCO's part to maintain positive relations with state owned coal mines in Shanxi by running plants served by them less (rather than by using cheaper coal in them), it may be amenable to a policy solution.

6.3.1 Related Recommendations

As with the above hypotheses, SEPCO would be well-advised to investigate aggressive end-use efficiency programs as China deregulates, which would help to keep costs down as its operating environment gets more competitive. And, given SEPCO's potential for increasing exposure to wholesale price fluctuations it should also look into adopting risk management practices like binding power purchase agreements (PPAs), metrics such as value-at-risk and tolling arrangements with generators which allow the purchase of both fuel and the converted electricity forward.

Resolving SEPCO's apparent obligation to source coal for new plants from more distant, state-owned mines may be more problematic. Because this situation may be the result of China's policy at a national level to buoy coal costs and support this historically strategic state owned industry, it may be out of SEPCO's hands, especially since its incentive would be to continue using older units to the extent it can. Even so, to the extent this phenomenon may repeat itself in other provinces China must be aware of the need to enforce not only the construction but actual utilization of newer and cleaner generating technologies.

6.4 Conclusions Regarding Stricter Sulfur Regulations and Higher Coal Costs

Should China successfully pass stricter regulations on sulfur content for steam coal, coal costs will likely rise, thereby contributing to higher total costs over the study period. And, though emissions in this case should decrease, if SEPCO's demonstrated dispatch behavior goes unchecked the resulting levels of achieved emissions reduction may not be worth the costs incurred. That is, just as in the market power cases, SEPCO tends to source cheaper Shandong coal and hence to run existing capital stock more in the face of rising fuel costs. Though unit costs still decrease over time as SEPCO's generating portfolio churns, the slightly higher unit costs under the stricter sulfur scenario may be for naught given the fact that this policy as implemented does next to nothing for emissions.

6.4.1 Related Recommendations

As with the above events SEPCO's best insurance in an increasingly restrictive economic environment is to implement systems and programs that help its customers save electricity. And, because coal costs drive SEPCO's generating response -and consequently the system's emissions- in this case it is another argument for SEPCO to look into fuel forwards. Finally and again as above, given SEPCO's incentives to focus more on cost than emissions containment, it may be China's larger responsibility to look into reforms that encourage the use of newer and cleaner units, even if stricter regulations on sulfur content in coal are successful.

6.5 Conclusions Regarding Concurrence

None of the events I have hypothesized would or will occur in a vacuum. Though they should chronologically begin to permeate China's institutions, economy and society in the order presented, their effects should also overlap. As a result of their concurrence China should additionally expect a great degree of interplay and catalysis among them.

Unit Cost of Electricity

The unit cost of electricity may be anticipated to <u>decline</u> slightly in real terms for the first quarter of the century, regardless if China pursues a strictly coal-based or nuclear and natural gas-based generating strategy. Though unit costs would appear to be a bit more volatile under a coal-based strategy due to naturally thinner reserve margins -and consequent captivity to market fluctuations- in these circumstances, in tradeoff costs would be somewhat higher over the study period were SEPCO to opt for a nuclear and gas-based strategy. Be that as it may, it is encouraging to note that China may look to power the economic expansion WTO is expected to stimulate at lower per-kWh costs in 25 years as a result of replacing its older generating stock with newer, more efficient and cleaner technologies.

Peak Load Growth

In any event, peak load may become a concern as incomes rise and habits change. For example, the increasing adoption of air conditioning and more appliances in homes and commercial businesses as reform-induced growth continues could impact the profile and magnitude of SEPCO's peak load.

Reserve Margins

Similarly, SEPCO may anticipate shrinking reserve margins throughout the study period for both strategies, though margins would not be as thin for a nuclear and gas case. This trend is nonetheless important to be aware of as it could influence SEPCO's degree of captivity to wholesale prices as well as its ability to serve its customers reliably.

Capital Recovery on New Generation

Capital recovery payments should be higher in an environment of rising shareholder expectations and influence.

Management of Old and New Generating Stock

Because SEPCO will continue to operate according to the least-marginal-cost dispatch rule, it should be continually aware of the pervasive incentive to run older plants. This phenomenon appears to be especially driven by fuel costs, and is therefore complicated by SEPCO's possibly state-imposed obligation to supply its new plants with coal from the larger mines in Shanxi.

Emissions

Cumulative emissions over the study period will undoubtedly be higher in a China which continues to implement reforms that enhance economic growth, even if environmental regulations begin to become more strictly enforced. Yet, annual sulfur and particulate emission rates may only rise slightly as cleaner stock comes online. Even so, it is important to keep in mind that the current health and environmental impacts of these pollutants are already serious. Moreover, carbon emissions should rise dramatically regardless of whether SEPCO selects a strictly coal-based or partially nuclear and natural gas-based strategy, on account of its quite probable continued reliance on predominantly coal-fired generation going forward.

6.5.1 Consolidated Recommendations

I present the consolidated recommendations in the order in which they seem relevant across multiple issues SEPCO may face should all the events discussed come to pass in concert. They accordingly appear in order as they have more cross-cutting potential. However, because this has been a primarily firm-level analysis, I use the extent to which SEPCO can take direct action as a second-order way of organizing the section. Following this logic, I leave the higher level, more complex and/or multi-actor recommendations to the end.

Focus on Efficiency

SEPCO should relentlessly pursue ways to increase energy efficiency on both the supply and demand sides. China's track record with impressively diminishing energy intensity is encouraging in this respect. Yet, because SEPCO's most viable generating strategies already incorporate supply side efficiency gains, it should focus in particular on reducing demand. Should electric sector restructuring hasten issues such as tariff reform and the availability of more sophisticated metering technologies, demand side efforts will be more effective. Regardless, an earnest pursuit of greater efficiency can have a cross-cutting impact on all the cost and emissions containment challenges SEPCO faces.

Adopt Peak Load Management Strategies

SEPCO should also be installing more natural gas-fired units as in any case its load will get peakier. And again, as with SEPCO's imperative to conserve, it should focus on managing the peak behavior of its customers by implementing measures like time of use rates.

Incorporate Risk Management Practices

As China's economy becomes stronger and more dynamic and its electric sector liberalizes SEPCO must also increasingly manage risk on an active basis. For example, it can address exposure to fuel and wholesale risk by respectively using forward contracts and power purchase agreements. Though no futures market for fuel commodities currently exists in China, a facility with forwards will serve SEPCO well in the event one evolves. An option for addressing the contractual risk of plant downtimes is to purchase outage insurance -especially in any strategy that incorporates nuclear- which may become more widely available by virtue of the insurance sector reforms WTO will bring. And, SEPCO should also look at using firm-level risk management tools like value-at-risk or profitability-at-risk, which would have the additional benefit of helping it align management practices with corporate strategy.

Focus on Operational, Organizational and Managerial Efficiencies

SEPCO will likely be called upon to reengineer how it operates its assets to achieve maximum return as these events unfold. As this happens, SEPCO might also consider reevaluating its organizational structure and managerial routines, as technology is ultimately only as effective as the human systems within which it functions. A devolution of power from top corporate levels and a freer flow of company information, for example, can help to make enhance employee investment, effectiveness and accountability.

Facilitate InstitutionalChange Beyond Shandong

Finally, SEPCO officials should engage the larger issue of the market distortions created by China's incongruous coal, railway and power sector policies. This is obviously more easily said than done, though could be initiated, for example, by strengthening physical and political connections with neighboring provinces towards a vision of further nationalizing intraprovincial power sales and transfer. Resultant larger and more coordinated coalitions of provincial grid operators could over time wield more influence over policy formation at the national level.

Implement Coal and Railway Industry Reform

As it proceeds, SEPCO should also be attuned to efforts on China's part to harmonize power sector, fuel and rail sector policy. Though a desire to buoy prices is understandable since China hopes to increasingly export coal, its perverse result is a bias towards running older generating stock at the provincial level. This issue is however problematic since it is both beyond SEPCO's control and symptomatic of some of the larger institutional issues China is facing such as SOE reform and balance of power issues between the center and the more modern provinces.

Whatever incremental steps SEPCO can unilaterally take, the greater economic freedoms, more rational capital flows and increasing transparency of information China is poised to enjoy should over time work in favor of SEPCO's ability to deliver more efficient and reasonably-priced electricity service. At the same time SEPCO can better attain these goals by pursuing efficiency gains, ensuring system reliability, actively managing risk and consciously evolving its corporate structure to support these functions. Just as importantly, continued efforts on China's part to further several formidable institutional changes already underway can help to ensure that SEPCO's service is as environmentally sustainable as it is economically sound.

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