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GROWTH, UPGRADING AND EXCESS COST IN CHINA'S ELECTRIC POWER SECTOR

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Abstract

China's electricity industry has recorded immense achievements in many areas: growth, technical upgrading and innovation, improved reliability, and universal service. This record of excellence coexists with massive inefficiency. Despite China's multiple cost advantages, the unit cost of producing, transmitting and delivering electricity is at least 30 percent higher in China than in the United States. Latent potential for cost reduction clusters in coal-fired generation that supplies about two-thirds of total output. New reforms that deepen the influence of market forces will strengthen financial pressures and thus increase the likelihood of achieving potential cost reductions, perhaps increasing the output and share of coal-fired thermal plants.

Key words: China; electricity; reform; upgrading; coverage; cost; inefficiency

JEL Codes: L2, L6, O14, O25, O32

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INTRODUCTION

Electricity is the ubiquitous facilitator of modern economic activity. While typically taken for granted, the consequences of power outages quickly demonstrate that electricity truly is the indispensable resource.

This chapter reviews the recent trajectory of China's power sector, which has delivered an impressive combination of growth, technological upgrading, network expansion and improved reliability during the past several decades. These advances come at high cost. Chinese and U.S. electricity prices are similar; Chinese power providers enjoy multiple cost advantages over U.S. electric utilities, but achieve consistently weaker financial results. This combination of prices and financial results implies that the average cost of producing and delivering each unit of electricity is higher in China than in the United States.

This surprising outcome signals the presence of substantial inefficiency. Our review of the decade 2005-2015 identifies 30 percent as a lower bound for excess costs within China's electricity system. We conclude with a survey of recent reform initiatives, which fix prices for transmission and delivery of electricity, expand the scope for direct contracting between generating companies and end-users and introduce competition into retail electricity sales.

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These changes have begun to exert downward pressure on electricity prices. Falling prices will force producers to explore the potential for cost reductions. Prospects of lower costs seem concentrated in the generation and delivery of coal-fired thermal electricity. The likely outcome is an unexpected and unwelcome increase in the volume and share of coal-based electricity production.

We begin with a brief summary of features that distinguish electricity from other widely-utilized products.

Electric power is a network industry with considerable scale economies and huge fixed costs. The network element means that costs shrink and benefits multiply when the number of interconnected users expands. In China, as elsewhere, the electricity sector originated with isolated power plants, each connected to multiple customers. By the 1930s, the need to ensure timely and sufficient power supplies encouraged Japanese-controlled generating firms in China's northeast (but apparently not in Shanghai) to establish rudimentary arrangements that unified the characteristics of power from multiple generating facilities and enabled big industrial users to absorb electricity from multiple sources (Manshū kaihatsu 1964, 2: 536-539).

Networking is synonymous with scale economies, meaning that unit costs decline as the number of participants and the volume of power flow expands. The production process contributes further scale economies: the standard size of generation plants continues to rise: the share of thermal generation capacity rated at 300 MW and up rose from 17 percent in 1990 to 39 and then to 79 percent in 2000 and 2015 (Energy Report 1997, p. 58 and Table 2).

Technical factors complicate electricity markets. On the supply side, fixed costs are high, meaning that power companies incur substantial expenses regardless of sales volume. Large differences in operational flexibility as well as the split between fixed and variable cost across various power generating technologies – coal, hydro, natural gas, nuclear, wind, solar – complicate efforts to achieve high levels of operational efficiency.

The unusual combination of long lead times for expansion of generation and distribution facilities with the need for instantaneous supply response – customers expect power to flow at the flip of a switch – and wide variations in power demand according to time of day, season and economic conditions creates a potential for mismatch between shifting user requirements and available production capabilities.

Avoiding such mismatches, which can cause temporary blackouts or more serious system disruptions, requires continuous oversight to ensure smooth matching of supply and demand throughout the power grid. "Dispatch" – assigning delivery quotas to individual power plants – is a key element of system operation.

These complexities lead to universal problems of governance and management. Historically, policy-makers viewed electricity as a "natural monopoly." Customers typically had no choice of supplier, but were protected from overcharging either by public ownership or by regulatory bodies that controlled pricing and limited private utility companies' charges to levels consistent with "reasonable" profits.

During the 1990s reformers, arguing that monopoly and regulation concealed vast excess costs, initiated an agenda of "unbundling" – forcing vertically integrated utilities to divest some segments of their businesses in order to expand commercial rivalry and consumer choice. The reform agenda aimed to inject elements of market pricing in place of governmental price-setting wherever feasible. Implementation of reforms began in the United Kingdom and gradually spread across the globe.

Several decades later, results remain limited. Unusual features of the electricity industry, especially the combination of extreme reliability requirements, lack of viable means to store surplus power and absence of effective rationing mechanisms to resolve episodes of excess demand, make it difficult to implement economists' standard recommendation of "marginal cost pricing" that equates retail price with the cost of producing the final unit purchased. As in other capital-intensive sectors, there is an unavoidable tension between marginal cost pricing and the need to provide incentives for new investment.

Efforts to use auctions as a means for steering production quotas toward low-cost suppliers have stumbled into frightening episodes of instability in which temporary power shortages trigger price spikes that threaten to bankrupt suppliers or to inflate retail power prices. There is some evidence that clever participants can "game the system" and reap windfall profits from actions that magnify or even initiate such episodes.

As a result, there is no consensus on how best to organize, administer and govern the production and distribution of electricity. The current U.S. structure combining elements of regulated (via officially-imposed price controls) and deregulated (without price controls) electricity markets reflects this state of affairs. China's circumstances display similar ambiguity: despite the substantial impact of past and recent reform initiatives, the architecture of a fully reformed electricity sector remains unclear, as does the nature of concrete steps that could advantageously restructure this large and important industry.

CHINA'S ELECTRICITY INDUSTRY

Basic Elements of Industry Structure

Following several decades of rapid growth, China's electricity sector is now the world's largest. Notwithstanding rapid expansion of renewable technologies, especially wind farms (Mathews and Tan 2014), coal continues to dominate, with thermal (90 percent coal-fired) facilities accounting for 73.1 percent of 2015 production and 65.7 percent of generating capacity at year-end 2015 (Electricity Operations 2014; China Electricity Council 2016).

Industry is the largest electricity user, absorbing 71.6 percent of 2015 supply (Table 8). Household consumption occupies a far smaller share of power consumption than in the U.S. (13.2 percent in China vs. 36.2 percent in the U.S. in 2015), but continues to expand at double-digit rates, and thus seems likely to claim a rising share of China's future electricity supply.[3] Geographic imbalance is a central feature of China's energy economy. Map 1 shows that resources are concentrated in a wide arc stretching from Heilongjiang (oil) in the northeast through Inner Mongolia (coal, wind) and Shanxi (coal) in the north, Shaanxi (coal), Gansu (wind) and Xinjiang (coal, wind, sun) in the northwest and Sichuan, Chongqing, Guizhou and Yunnan (hydropower) in the southwest, while demand clusters in a diametrically opposed arc running southward along the coast from the Beijing metropolitan area through Shandong, Jiangsu, Shanghai, Zhejiang and Guangdong. Feeding the energy demand of this coastal belt requires some combination of large-scale domestic energy transport and cross-regional power transmission. In the absence of international trade in electricity or large-scale local power production from nuclear plants or offshore wind farms, massive long-distance shipments of fuel, principally coal, or of electricity itself must figure prominently in China's power system. Recent economic expansion in central provinces like Hubei, Hunan and Jiangxi has created new gaps between energy demand and local supply that intensify the pressure to build nuclear plants or expand long-distance shipments of coal or power (Jiang 2014; Zhu 2016).

Map 1 about here

The institutional evolution of China's power sector is well-understood (Xu 2002, 2004). In the pre-reform planned economy, electricity was a state-run monopoly under the Ministry of Electric Power. Once reform policies implemented from the late 1970s began to accelerate overall economic growth, and hence the growth of demand for electricity, severe shortages of electricity created a powerful incentive for reform.[4]

Early reform initiatives focused on decentralization: provincial and local governments were permitted to organize, manage and finance (sometimes with foreign investments) new power plants, actions formerly reserved for the center. This accelerated the growth of production capacity, especially in regions that had suffered the biggest supply gaps. There were significant unintended results: a proliferation of small, high-cost producers as well as the emergence of substantial *de facto* provincial and local control over power supplies, developments that increased the potential for local authorities to oppose, obstruct or simply ignore unwelcome instructions from Beijing.

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[3] Chinese data from China Electricity Council 2016 and Table 8 below; U.S. data from http://www.eia.gov/consumption/, accessed April 2, 2016.

[4] The author recalls touring factories by flashlight during the summer of 1982; one manufacturer of cashmere garments reported large losses from the destruction of yarn stranded in dyeing vats during repeated episodes of unexpected power outages.

Next came a 1998 initiative aimed at commercializing the power sector by transforming the Ministry of Electric Power into the State Power Corporation. Subsequent reforms, implemented in 2002, involved "unbundling" the formerly integrated electricity sector to roll back vertical integration, expand competition, and establish a clear demarcation between commercial enterprises and the state.

The new structure eliminated the State Power Corporation, transferring its regulatory authority to a new body, the State Electricity Regulatory Commission (SERC) and assigning its generation and grid equipment to newly created companies. Massive resources were poured into five huge generating companies, while two immense grid management firms were assigned to transmit and distribute electricity. These five generating firms, which now produce nearly half of China's electricity, own and operate power plants on a nationwide scale, ensuring some degree of commercial rivalry. Map 2 shows the territories served by the two main grid firms: China Southern Grid, which spans five provinces in the south and southwest, and the much larger State Grid Corporation, which manages power networks elsewhere. The two do not compete directly, but create the potential for performance comparison.[5]

Map 2 about here

Further reform plans produced extensive discussion, but, until recently, little action. Reform stalled through a combination of institutional resistance to unbundling, transparency, and marketization, priority for eliminating chronic power shortages, and difficulties revealed in experimental reform pilots.

The resulting system combines elements of plan and market. Substantial competition (as well as lobbying) surrounds the construction and equipping of new generation facilities, typically involving rivalry among giant state-controlled generation, construction and machine-building enterprises. Generating companies face single buyers – all power goes to the local grid company, which acts as a monopoly seller of electricity in its service territory, a circumstance that recent reforms, discussed below, have begun to change.

Three prices dominate the finances of these firms: the wholesale or "on-grid" tariff that generating firms receive from the grid, the retail price that the grid charges to end-users, and the price of coal, the main component of variable cost for China's predominantly coal-fired power producers. Table 1 lays out the trajectory of these prices since 2003.

Table 1 about here

Two of these prices, the on-grid and retail tariffs, are controlled by the National Development and Reform Commission (NDRC), which sets basic tariffs. These vary according to power source (low on-grid tariffs for hydropower and for western thermal plants, higher feed-in tariffs for thermal plants in coastal regions and for nuclear, wind and solar power) and user (low retail

[5] Smaller grid companies manage power networks in western Inner Mongolia and parts of Shaanxi.

prices for households and for agriculture, higher prices for industry and commerce). A blizzard of taxes, fees and subsidies, many imposed by provincial and local governments, surrounds these reference prices, resulting in a labyrinth of charges – more than 300 in Beijing alone (Huo 2013).

Table 1 includes two coal price indexes: a domestic series that tracks mine-mouth prices and a more volatile indicator reflecting Asian regional coal prices. Gradual domestic marketization and growing Chinese participation in global coal markets makes the latter index increasingly relevant to the finances of Chinese power producers; the domestic index clearly understates the volatility of coal costs during the past decade.

This combination of official price regulation, with its slow and politically charged adjustments, and an increasingly volatile coal market has created a financial roller coaster for China's power sector. Coal price spikes in 2008 and 2011 pushed up generation costs, whereupon inflexible on-grid tariffs splashed red ink over large segments of the power generating sector. Falling coal prices have the opposite effect. A mechanism linking coal costs and power prices, adopted in 2004, has worked poorly, as NDRC officials have blocked prompt implementation of supposedly automatic price changes for electricity in the wake of coal price fluctuations (Huang and Yu 2014; Bie 2014).

Prior to the latest reforms, grid company revenues came from the spread between the on-grid tariffs paid to generation companies and the retail prices collected from end-users (Table 1). Until recently, the grid companies' refusal to provide detailed cost information – State Grid famously classified up to 31 percent of its costs under the opaque heading "other" (其他 *qita*) - prevented regulators from calibrating grid charges to actual costs (Power Prices 2014; Yu 2014).

Financial volatility originating in the coal market has also affected the grid companies. In 2009, for example, NDRC raised on-grid tariffs to give generation companies some relief from higher coal prices, while imposing a slight reduction in average retail prices (Table 1). This resulted in an unexpected drop in the grid companies' price-cost differential that eliminated profits until compensating adjustments in the following year sharply increased grid company margins.

Table 1 uses standard currency exchange rates to convert average Chinese retail prices, as well as the prices charged to "large industrial users" (大工业) into U.S. dollars. The comparison shows that the average price of electricity in China has risen in recent years to match comparable U.S. figures. For large industrial users, average Chinese retail tariffs consistently exceed U.S. industrial electricity prices, with Chinese costs outrunning corresponding U.S. prices by 50 percent or more beginning in 2011. This observation contradicts claims, for example by Haley and Haley (2013), that Chinese manufacturers enjoy cheap electricity supplies; while regional and local governments may lower prices for favored sectors, Table 1 shows that power prices charged to industrial users are consistently higher in China than in the U.S.

The run-up to the 13th Five Year Plan (2016-2020) brought a push to revive electricity reform, partly to curb the power of the State Grid Corporation, which has strenuously resisted official regulatory efforts,[6] and particularly to implement the Xi Jinping administration's mandate to elevate market forces to a "dominant role" in China's mixed economy.

The new wave of reforms focuses on three issues, discussed further below: audits of grid company costs leading to imposition of fixed grid charges; expansion of direct power transactions between end-users and generating companies, initially confined to large industrial purchasers with the intention of full marketization within several years; and replacing the former grid company monopoly of retail electricity sales with a competitive regime that will allow new entrants, including private operators, to establish retail sales companies.

DEVELOPMENT AND INNOVATION IN CHINA'S POWER SECTOR

Growth

The central task for any electrical system is to supply customers with power on demand. With overall economic growth approaching, and annual increments to power consumption often exceeding 10 percent, fulfilling this basic function posed a huge challenge. Figure 1 illustrates the protracted, and finally successful response that enabled power supply to catch up with demand.

This supply surge pushed China past the United States as the world's largest producer and consumer of electricity, with 2016 power consumption reaching 151 percent of the comparable U.S. figure. In 1990, China's power use was a mere 22 percent of the U.S. total. Figure 1 demonstrates the magnitude of subsequent Chinese investment: beginning in 2005, annual increments to generating capacity consistently exceeded 57 GW, the peak annual increment to U.S. capacity achieved in 2002. In 2010, and again in 2014-2016, new Chinese generating capacity more than doubled the historic U.S. peak.[7]

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[6] Thus when the National Energy Administration, responding to complaints that large-scale spillage of wind power was hampering efforts to raise the share of renewables in China's electricity mix, "ordered grid companies 'to plug in all renewable power sources'," State Grid's leader promptly demurred, insisting that "'the approval process for wind power and for the grid are different'" (Shepherd and Hornby 2016).

[7] Chinese output and capacity data for 2015-2016 accessed March 22, 2017 from http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2017-01-20/164007.html; Data for 2014 are from China Electricity Council 2016. For earlier years, data on Chinese generation capacity is from http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2015-11-30/146012.html , accessed December 19, 2015; annual data on Chinese power consumption is from Fifty Years (2000, p. 279), Energy Statistics (1997-99, p. 143; 2006, pp. 110-111; 2011, pp. 124-125; 2015, pp. 122-123), and from Yearbook 2016, Table 9-6. U.S. electricity output from various issues of U.S. EIA Monthly, Table 7.1; U.S. electric power industry generating capacity from U.S. EIA 2015b.

Figure 1 about here

As the addition of new power plants and grid connections began to shrink the gap between power demand and available supply, China's grid operators implemented pre-announced rotating power blackouts; this reduced the costs associated with power shortages.[8] The initial decade of the current century brought a general balance between demand and supply, despite the persistence of regional and seasonal shortages (State Grid 2012, pp. 32, 157).[9] Most recently, continued investment together with an unexpected and steep fall-off in the growth of electricity demand have created a new problem: widespread excess capacity, which has sent utilization rates for generation facilities into a downward spiral: on average, thermal plants operated for only 4165 hours during 2016, the lowest figure since 1964 ((Table 3).

Scale

Rather than replicating existing facilities, expansion of China's power industry has pursued the scale economies characteristic of electricity generation and distribution by increasing the average size of individual facilities.

Table 2 summarizes a massive shift toward large-scale thermal generation plants. Between 2000 and 2015, the number of generating stations with capacity of 600 MW and up rose from 22 to 609, and their share in overall capacity jumped from 5 to 43 percent. Table 2 also tracks a parallel, but less rapid extension of the length and voltage of power transmission lines – an essential component of China's energy economy due to rail system's limited coal-carrying capacity as well as growing dissatisfaction with the environmental costs of coal-burning generation facilities in coastal cities.

Table 2 about here

This shift to larger facilities brings multiple benefits. Standard technical indicators increasingly resemble outcomes observed in advanced market economics. Table 3 documents a steady decline in coal consumption per KWh of electricity, which, thanks to large numbers of new

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These comparisons ignore slight differences among different Chinese data sources and in the measures used to tabulate U.S. and Chinese electricity output.

[8] During the 1990s, the 15-storey office building of the Chinese Academy of Social Sciences in downtown Beijing had a regular schedule of Friday power outages. In 2005, an invitation to visit a Beijing-area machine tool plant came with the proviso that power shortages limited operating hours to midnight-6 am.

[9] Kahrl and Wang (2014) provide a detailed account of the "orderly electricity use" (有序用电) system developed to cope with power shortages.

plants, has fallen below the U.S. average.[10] Similar conditions apply to the grid, which has achieved a steady decline in transmission losses, which now approach the U.S. level of 5-6 percent.[11] The share of power consumed within generating facilities has also declined.

Table 3 about here

Reliability and Access

Although 2009 data show that "the number of outage hours would need to be reduced by more than half to reach current US average" levels (Kahrl et al 2011, p. 4036), more recent information from the World Bank's enterprise survey summarized in Table 4 demonstrates impressive levels of reliability. Chinese respondents report fewer outages, and quicker response to requests for new connections than informants in Brazil, India or the Russian Federation. The proportion of Chinese informants owning or sharing backup generators matches outcomes in Brazil and Russia and is far smaller than in India. Firms in Brazil, India and Russia are more than ten times as likely to identify electricity as a "major constraint" than are Chinese enterprises.

Reliability is highest in major cities. A visitor to western Sichuan province, reported daily power outages in May 2016 (personal communication).

Table 4 about here

China has reached a remarkable milestone by extending electricity to its entire rural populace. The electrification of isolated communities in Qinghai province completed this task in 2015 (Jia 2015a; China Electricity Yearbook 2015, p. 68). China has attained universal access at a far lower income level than in other large nations; in the U.S., the share of farm dwellings with electricity surpassed 50 percent only in 1946 and reached 95 percent only in 1956 (Historical Statistics 1975, series S, pp. 108-119).

Falling construction costs

Despite the considerable challenge of developing equipment and materials capable of withstanding the elevated temperatures and pressures associated with new generations of power generating equipment, the accumulation of experience in equipment manufacture and plant construction resulted in the downward trend in the unit cost of new thermal power plants

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[10] "In 2007 China's average heat rate for coal-fired power plants was. . . roughly 5% higher than the U.S. equivalent" indicating lower unit coal consumption (Williams and Kahrl 2008, p. 4). Average coal consumption in Chinese thermal generating plants declined thereafter (Table 3).

[11] See https://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3.

shown in Figure 2. North America and Western Europe experienced the opposite – rising costs of building new thermal plants (Samaras et al 2011, p. 18).

The magnitude of Chinese cost reductions is surprising: between 1996 and 2004, investment cost (*gongcheng zaojia*) per kilowatt of new thermal generating capacity declined by 38.4 percent while the overall investment cost index[12] rose by 12 percent – a gap of 50 percentage points! Comparing 1996 with 2012 shows an even larger gap of 77.3 percentage points between (declining, then stable) power plant costs and the steadily rising investment cost index. Unit cost for thermal power plants declined slowly after 2012, while the overall investment cost index continued to creep upward (China Electricity Report 2014, pp. 55-56; 2015, pp. 49-50; Abstract 2016, p. 57).

Figure 2 about here

The contrasting trends between unit cost of new thermal plants and the overall investment cost index indicates a remarkable combination of productivity gains and cost controls in building and equipping thermal power plants. This episode recalls a 1940s phenomenon in which unexpectedly rapid productivity gains accompanied steep wartime increases in U.S. production of cargo vessels known as "Liberty ships" (Thornton and Thompson 2001; Thompson 2001).

Technological catch-up and innovation

Successive international comparisons highlight the extent of technical progress in China's power sector. In 1990, the efficiency of coal-fired power generation in China, Korea and India lagged far behind results for the U.S. and Western Europe. By 2011, China and Korea had closed this gap, nearly matching the U.S. figure, while thermal efficiency in India's coal-fired plants showed little change from the 1990 level (Hussy et al 2014, p. 66).

As the scale of expansion in China's power sector created what quickly emerged as the world's biggest market for power plant equipment, major producers from Europe, North America and Japan rushed to seize this new opportunity. As in other sectors, Chinese officials adroitly deployed market size as a bargaining tool, steering international firms into joint ventures and technology licensing agreements that enabled domestic firms, most notably China's big three power equipment makers - Dongfang Electric, Harbin Electric and Shanghai Electric - to access advanced technology.

Although we cannot gauge the relative importance of various sources of knowledge and information, Chinese equipment-makers clearly benefited from expanded interaction with foreign partners, accelerating efforts to increase the scale of their equipment, while

[12] Investment cost index from http://data.stats.gov.cn/workspace/index?m=hgnd, accessed December 4, 2014; unit cost data from author's file "Thermal power construction costs.042316."

simultaneously introducing new generations of thermal technology – first “super-critical” and then “ultra-supercritical” - that employ elevated temperature and pressure in the combustion chamber to reduce fuel requirements and boost thermal efficiency.

Chinese policymakers place heavy emphasis on import substitution, especially in sectors like electricity that officials view as central components of national economic growth. With domestic firms supplanting overseas equipment suppliers, rapid upgrading – not just for thermal generation, but, as is evident from subsequent chapters, in multiple segments of the power sector, reflects advances on the part of equipment producers as well as among power generating and grid companies.

China’s success in “breaking into the top ranks of global power-equipment exporters,” together with growing overseas marketing of grid management services, and, most recently, of nuclear power expertise (see the chapter by Madhavan, Rawski and Tian), underlines the rapidity and extent of China’s catch-up in the electrical sector. While ”Chinese equipment makers face questions about quality control on their power turbines. . . . multinational companies that once cooperated with Chinese business groups now face them as competitors” (Areddy and Glader 2010). Similar comments apply to leading multinational suppliers of equipment for electric grids, hydroelectric facilities, wind turbines, solar assemblies and nuclear power plants.

Along with diminishing industry-wide technological and quality gaps, China’s power sector has begun to approach the global technology frontier in specific areas, of which long-distance transmission of ultra-high voltage AC current provides a leading example. The chapter by Yi-chong Xu attributes China’s advance in this area to an entrepreneurial campaign by leaders of State Grid Corporation, the world’s largest utility company. While some commentators question the economics of long distance AC power transmission and other State Grid innovations, Chinese grid facilities now use domestically manufactured equipment to move larger volumes of electricity over longer distances and at higher voltage than in Europe or North America.

Evidence of innovative effort is readily visible in Chinese factories and trade journals. A cutting-edge coal-fired generation plant in Shanghai reports unit coal consumption of 276 grams per KWh; combined with low effluent levels, the result is “far superior to the original design. . . creating the world’s best level” (Jia 2014a). The chapter by Madhavan, Rawski and Tian shows that Chinese researchers are investigating novel approaches to nuclear power generation. Shanghai Electric is experimenting with elongated rotors that could increase the efficiency of steam turbines (Interview, May 28, 2014). Alloy U-tubes tubes from Baoyin Special Steel Tube Co. used in nuclear plants’ steam generators reportedly deliver superior resistance to pitting while matching other characteristics of imported alternatives (Baiyin 2014).

Growing Environmental Concerns

Despite reductions in unit coal consumption (Table 3), expansion of power output and continued dominance of thermal generation place electricity generation among the leading contributors to urban air pollution. Data for 2013 show thermal power plants accounting for over one-third of China's total emissions of SO2, 17 percent of soot and dust, and over half of nitrous oxides (Li 2016). The combined impact of industrial emissions (with power plants contributing a considerable share) and exhaust from China's rapidly expanding fleet of motor vehicles has reversed two decades of gradual improvement (Rawski 2009) in urban air quality. Protracted episodes of haze and smog have aroused public indignation and turned urban air quality into a major political issue.

The official response has powerfully influenced the electricity sector:

- Rapid expansion of renewables, especially wind power, has raised the combined share of hydro (19.8 percent), wind (3.3), nuclear (2.9) and solar (1.2) in 2015 electricity output to 27.2 percent (Mathews 2016). Although the size of China's power industry limits the pace of structural change – the share of thermal facilities in overall generating capacity declined from 73.4 to 65.7 percent between 2010 and 2015 (China Electricity Council 2016), the impact of renewables and nuclear power is visible at the margin, where, as Mathews and Tan (2014) emphasize, the "leading edge" of both capacity and output growth is "demonstrably getting greener."

- Efforts to move dispatch toward prioritizing supply quota allocations for "clean" energy providers.

- Choice of technologies. Beijing has banned construction of new coal-fired generation plants in leading cities and, in some instances, required the conversion of coal-fired plants to natural gas. A nationwide campaign has sought to close small generating plants employing technologies now regarded as obsolete; modest results are visible in Table 2.

- Retrofitting. New policies require new coal-burning plants and incentivize older facilities to install modifications to increase combustion efficiency and/or remove harmful effluents from smokestack emissions, often with partial compensation in the form of supplements to on-grid tariffs.[13] Regulators have ramped up enforcement, imposing fines on violators (Jia 2014c).

[13] In December 2015, for example, NDRC joined with the Ministry of Environmental Protection and the National Energy Bureau to announce a program that awards price top-ups to coal-fired generation plants that meet "ultra-low" emission guidelines. See NDRC 2015; reference courtesy of Fredrich Kahrl.

- Subsidy elimination. Further policy initiatives have required provincial and local governments to eliminate power price discounts that had encouraged the expansion of energy-intensive industries like aluminum, steel, cement and heavy chemicals.[14]

- Penalty pricing. NDRC has added surcharges to electricity prices charged to energy-intensive industries, particularly when firms are judged to be employing obsolete technologies. In some cases, provincial governments are authorized to increase these levies.

- Long-distance transmission. Planners appear to be considering proposals that would increase the transmission of electricity from coal-rich provinces like Shanxi and Xinjiang to power-hungry coastal regions. This could be accomplished by building conventional coal-fired generation facilities or by converting solid coal into coal gas, which could serve as fuel for power generation. Such proposals seem problematic because they relocate rather than reduce effluents and also because the associated water requirements would strain the capacity of water-scarce mining regions. Use of air-cooled generation technology economizes on water, but reduces thermal efficiency, which raises coal consumption and unwanted emissions (Jia 2014b).

Globalization

Following an initial period in which the electric power sector's global involvement focused on equipment imports and absorption of overseas technology, China's electricity sector has emerged as a growing force in global markets for electrical equipment, project management and the construction and operation of generation facilities and electrical grids.

- Hydropower. Sinohydro Corporation is "the world's largest hydropower construction company with a 50% share of the international hydropower market" (http://www.internationalrivers.org/campaigns/sinohydro-corporation).

- State Grid Corporation, the world's largest utility company, has substantial overseas investments in power generation and grid construction and management (Xu 2016).

[14] Provincial and municipal power tariffs issued between 1980 and 2009 in Gansu and Lanzhou, for example, included concessional rates for electric furnace production of iron alloys and other enumerated industrial activities (Lanzhou 2011, pp. 265-282).

- China's Big 3 equipment makers are major sellers of thermal power equipment, with a combined 2013 global market share slightly trailing Alstom, the third-ranking firm (behind General Electric and Siemens) (Dash 2014).

- Slowing domestic demand growth has encouraged generation and construction firms to seek international contracts (Li 2015; Chen 2016).

- China's nuclear industry has recorded major progress in raising its global profile, with recent agreements and contracts in Argentina, Romania, Pakistan and the United Kingdom (see the chapter by Madhavan, Rawski and Tian).

Overseas activity is mostly, but not entirely in low- and middle-income countries: State Grid has invested in Australia, Portugal, Italy and Greece, while leading nuclear firms have joined a consortium undertake the United Kingdom's Hinkley nuclear project.

The motivation for overseas involvement combines standard trade drivers – Chinese firms offer an attractive price-quality combination – and special circumstances, including growing excess capacity and the obligation for big electricity firms, as centrally-directed State-controlled enterprises, to join the government's "Go Outward" and "One Belt One Road" campaigns.

This survey highlights China's electricity sector as the locus of dramatic achievement during the past several decades. Electricity producers and grid companies have increased supply, overcome massive power shortages, built a nationwide service network, improved reliability, absorbed new generations of technologies, and approached – in some cases, perhaps reached - global technology frontiers. These advances have transformed China's electrical industry from a weak laggard into a major force in global markets for equipment, construction, design and grid management services.

Despite these substantial and impressive accomplishments, discussions of China's electricity system bristle with strongly negative evaluations. Thus "China's electricity sector continues to demonstrate a number of fundamental shortcomings in its basic institutions and functions" which lead to "intractable implementation problem[s]" (Williams and Kahrl 2008, p. 12).

SHORTCOMINGS AND DEFICIENCIES IN CHINA'S ELECTRIC POWER SECTOR

What are these "fundamental shortcomings"? How do they lead to "intractable problems"? It is immediately evident that some difficulties reflect circumstances that extend far beyond the electric power industry: thus knowledgeable observers comment that "Many of the obstacles to electricity reform in China lie outside the electricity sector" (Kahrl et al 2011, p. 4033).

Overview

Although electricity markets in many countries display uncomfortable compromises between state control and market allocation, the imprint of the former plan system is particularly strong in China's power sector even after several decades of market-leaning reform. Documents and reports highlight details about physical quantities – of power production and consumption, coal use, equipment stocks, operating hours, and so on. Aside from information about investment spending, systematic compilations regarding prices, revenues, costs, and profits – the lifeblood of any market system – remain scarce. Rigid prices largely divorced from market pressures – another legacy of the plan era – may partly explain the tendency of official sources to omit information about values.

Preoccupation with investment reflects an emphasis on scale, a Stalinist legacy that permeates Chinese policy-making and is particularly prominent in the power sector. Even if expected financial returns are scant, investment projects that establish specific firms or industries as "key" or "backbone" elements in their local or sectoral environments may achieve handsome payoffs in the form of favorable policy treatment. The emergence of massive excess capacity beginning in 2014 did not induce a major pullback in investment spending that one would anticipate in a market system; instead, investment spending rolls on as firms "intensify investment to stake claims" ("跑马圈地"愈演愈烈投资 *paoma qiandi yuyanyulie touzi*) to capture market share in anticipation of the favorable policy treatment routinely awarded to scale (Wang and Yu 2016; Jiao 2016).

Vertical integration and self-reliance represent further plan legacies that figure prominently in today's electricity system. While specialization intended to develop firms' "core capabilities" is a central principle of the unbundling component of sectoral reforms in China and elsewhere, the desire to avoid dependence on outsiders, to limit negative consequences of unexpected price changes, and to create opportunities for resource extraction via opaque transactions among related parties motivates power generating companies to acquire coal mines, encourages grid companies and coal mines to invest in generating capacity, and inspires both generating and grid firms to acquire captive equipment producers.

Local and provincial governments, the subject of Margaret Pearson's chapter in this volume, pursue their own version of vertical integration through actions that reveal their preference for supplying their jurisdictions with locally-generated power and, especially under the shadow of possible electricity shortages, avoiding commitments to transfer electricity to other jurisdictions.

These tendencies have major consequences. Table 3 reveals the surprisingly small scale of power transfers across provincial boundaries and especially between China's seven multi-province electric power districts. Under the heading of "current problems facing the power industry's development," a 2001 report notes tartly that "the inter-provincial market is closed" (China Electricity Yearbook 2001, p. 16). Recent discussions confirm the persistence of obstacles to interregional power sales. A 2015 analysis suggested "allowing cross regional transactions and creating a nationwide power market" (Fan 2015). Numerous references to "barriers" (壁垒 *bilei*) hampering power sales across jurisdictions indicate that this issue remains unresolved (Lu 2017, Wang 2017).

Given the geographic gap between energy supply and demand, limited interregional power flow translates into larger shipments of coal and therefore greater concentration of air quality problems in coastal urban centers of electricity demand.

Within the sphere of official management, we encounter similarly uncomfortable arrangements, with central and local authorities jousting for control. Provincial and local taxes, fees and subsidies modify on-grid tariffs and retail prices set by NDRC, often with Beijing's assent, but sometimes in direct contradiction of central government preferences. Long lists of projects built without official authorization, invariably with the connivance of local leaders, testify to persistent incentive conflicts between different levels of China's complex administrative hierarchy (Cheng and Tsai 2009). In one particularly egregious episode, the Neimenggu provincial government concealed the construction of major power facilities, only to be caught out following a fatal construction accident; local authorities allowed work to continue "even after it was labeled illegal by central authorities" (Officials Penalized 2006; Oster 2006). Flouting of regulations may extend to the nuclear sector: 2016 draft regulations "clarify penalties for unauthorized construction or operation" of nuclear plants (NPP Siting 2016).

While the boundaries between plan and market and between central and local control remain unsettled, reform has injected intense focus on financial outcomes into every segment of the electric power system. China's system of dispatch illustrates how the resulting combination of profit seeking with ill-defined regulatory jurisdictions, conflicting governmental incentives[15] and sticky prices[16] ensures the emergence of substantial inefficiency.

Inefficient Dispatch

[15] Shenzhen officials complain of being required to purchase expensive electricity from external suppliers while low-cost local generation facilities are limited to fractional operation (Shenzhen Grid Reform 2015). Electricity Databook (2014, pp. 468-481) confirms low operating hours for Shenzhen plants.

[16] In the Hami district of Xinjiang, where the benchmark on-grid price is RMB 0.25 per KWh, large-scale industrial users pay RMB 0.35-0.4 per KWh, the same amount charged for deliveries to Henan, 2000 km away, even though local deliveries entail no long-distance transmission costs (Zhang Shuwei 2015).

Modern power grids deliver electricity from multiple producers to thousands of users. Since the demand for electricity reflects trends in overall economic activity as well as seasonal and time-of-day variations, the continual ebb and flow of power requirements calls for careful management of deliveries to the grid. This “dispatch” function assigns annual, monthly, daily, hourly, even minute-by-minute delivery quotas to individual power plants. Unless production falls short of demand, in which case dispatch involves nothing more than asking each plant to contribute the maximum possible output, effective grid operation requires the intervention of a system operator (in China, the grid company; elsewhere often an independent agency) that assigns hourly, daily etc. production quotas to specific generating facilities in order to match deliveries to shifting power demand.

In what order will the operator assign production quotas to various producers? The obvious answer: begin with the lowest-cost operator (where cost might include both environmental and financial metrics), then the next cheapest etc. This procedure is unusual in China. Instead, continuing a practice inherited from the former planned economy, multiple operators – typically coal-fired plants - are often assigned similar annual operating hours, even though some may have lower costs and/or lower unit coal consumption (and hence produce fewer effluents) than others (Interview, May 17, 2012). Thus the world-leading Shanghai Waigaoqiao plant mentioned above reported a load factor of only 78 percent, evidently because regulators sacrificed some of its “clean coal” potential to allow dirtier plants their “fair share” of sales (Jia 2014a). Elsewhere, *ad hoc* arrangements favor specific plants: at one Shaanxi firm, foreign investors obtained a special quota enabling them to sell 40-50 percent more power to the grid than nearby rivals (interview, June 11, 2013).

Organized trading of quotas, which would allow clean, low-cost producers to purchase quota from high-cost operators (thus reducing system costs while improving financial outcomes for all parties), although present, is not widespread. The result: unnecessarily high consumption of coal, excessive discharge of effluents, avoidable financial and maintenance costs (the latter resulting from capacity fluctuations in coal-fired plants that are designed to run near rated capacity). The current system also encourages overbuilding, because new plants can expect to receive a “fair share” of future demand (Kahrl et al 2011, p. 4034).

Chinese grid operators have recently begun to introduce “merit dispatch,” which prioritizes generators with low variable cost, thus dispatching hydro, nuclear, wind and solar energy ahead of power from coal-fired plants (Kahrl et al 2013, p. 362). This approach holds the promise of limiting environmental costs, but can be problematic because the intermittent power flow from non-nuclear sources of clean energy necessitates reliance on a flexible production component to fill temporary or seasonal gaps in the availability of water, wind or sun. Since limited resources and ill-advised policies have hindered the expansion of (relatively flexible) gas-fired power plants,[17] grid managers typically rely on coal-fired plants to fill supply gaps, a policy that, as noted above, raises both financial and environmental costs.

Despite these difficulties, efforts to quantify the inefficiencies arising from current dispatch arrangements deliver surprisingly small results. As the "equal hours" system would predict, plant-level data reveal low correlation between unit coal consumption and annual operating hours: a simple regression depicting 2010 operating hours as a linear function of coal use per delivered kilowatt-hour accounts for only 1.2 percent of observed variation in operating hours among 957 plants nationwide. Adding provincial fixed effects raises this figure to 8.7 percent; further inclusion of an interaction term linking coal use to interior location achieves a further increase, but only to 9.0 percent.[18] Similar analysis for Shandong province, among China's largest industrial producers, finds differential coal use accounting for only 7.3 percent of the variation in operating hours among 149 coal-fired plants.

Widespread underutilization of efficient plants prompts the following experiment with the 2010 data for Shanxi province: assign 6000 operating hours (a high figure) to the most efficient coal-fired plant; then assign 6000 hours to the next-best plant. Continue the process until the cumulative output of included plants matches the actual 2010 total. Then compare coal consumption under this hypothetical arrangement with the actual outcome. Although this procedure would result in the closure of 43 of 74 generating facilities, projected reduction in coal use is only 3 percent.

The reason: massive investment has boosted the share of large, modern plants in thermal plants (Table 2). In Shanxi, the combined 2010 output share of the plants (hypothetically) assigned zero operating hours was only 10.7 percent. This outcome confirms an earlier finding using 2008-2009 data for Guangxi province: "energy efficient dispatch delivers at most a modest (2-4%) coal savings" (Kahrl et al 2013, p. 365).

The surprising finding that glaring episodes of misallocation – inefficient dispatch is one, large-scale "spillage" of wind power is another – impose only marginal increases in system-wide costs prompts a different approach focused on the analysis of costs for the entire power system.

[17] Domestic production of natural gas remains modest; imports of Russian gas will provide no more than a modest increase in the share of gas-fired generation. Large shale gas deposits will be difficult to develop. High domestic gas prices and low profitability limit prospects for import-fueled development. Lu Bin (2016a) emphasizes the potential of gas-fired power expansion. He (2015ab) blames "existing pricing mechanisms and policies" for the slow advance of natural gas, reports low utilization of existing facilities, and proposes a price link between gas and electricity of the sort that has functioned poorly in responding to fluctuating coal prices.

[18] Plant-level data are from Electricity Databook 2010. Following advice from Michael Davidson, I eliminated observations for which reported coal consumption per KWh of delivered electricity was below 280 or above 600 grams. Statistical analysis courtesy of Professor Yang Song.

Excess Cost – A Sector-wide Perspective

Electricity, a large, high priority sector that affects China's entire economy, offers a unique opportunity to gauge the scale of inefficiency. This industry produces a single, homogeneous product. Five enterprise groups generate nearly half of total output, and two grid firms virtually monopolize distribution and delivery. The presence of a reasonable statistical base, along with extreme concentration, enhances the prospect that analyzing power sector data can provide fresh insight into China's economic performance and prospects.

Hsieh and Klenow (2009) estimate the productivity gains achievable by limiting cross-industry variations in efficiency to the level observed in U.S. manufacturing. We follow their approach by using information about U.S. prices and profitability to identify excess costs – the mirror image of inefficiency-related productivity shortfalls – in a single Chinese industry, the production and distribution of electricity. Since perfect efficiency is rarely attained, reference to observable benchmarks – outcomes in the U.S. electricity sector - avoids the exaggeration implicit in comparing actual outcomes with assumed perfection – a procedure that Demsetz (1969) ridicules as the "economics of nirvana."

Table 5 summarizes basic information about the Chinese and U.S. power systems in 2011, when the two systems generated similar volumes of electricity (Figure 1). The two sectors are roughly comparable in terms of generating capacity and geographic expanse, but show widely divergent patterns of employment and labor productivity.

Table 5 about here

Our procedure for ascertaining the rough dimensions of excess cost in China's power sector is simple and direct. A review of price and profitability shows that Chinese electricity prices are generally higher, and profits generally lower than in the U.S. power sector. The combination of higher prices and lower profits carries an unexpected implication: **the unit cost of generating, transmitting and delivering electricity is higher in China than in the United States.**

Excess costs measure the cost reductions needed to enable financial outcomes in China's electricity sector to match U.S. results over the decade 2005-2015 under a sequence of successively more demanding circumstances: with no price changes, with a 40 percent reduction in prices charged to industrial users, and with an across-the-board reduction of 33 percent in electricity prices.

The calculations that follow are far from precise. China's utility majors operate coal mines and equipment factories; sectoral totals include outcomes from these non-power businesses. The U.S. figures relate exclusively to investor-owned companies, and thus exclude public-sector operations; the U.S. totals also include results from non-power businesses. There is no adjustment for possible differences in Chinese and U.S. data definitions or accounting standards.

As a result, the margin of error surrounding our estimation of excess costs is large. This means that only large, decisive verdicts can be plausible.

Prices. Table 1 presents annual averages for Chinese electricity prices for all users and for "large industrial" purchasers (大工业 *dagongye*) covering 2003-2014. Chinese prices are converted to U.S. dollars at standard exchange rates for comparison with U.S. electricity prices for all users and for industrial customers. We derive an index of Chinese prices, taking the relevant U.S. price for each year as 100.

The economy-wide Chinese price average stood at roughly 70 percent of the comparable U.S. figure during 2003-2006, after which a combination of domestic price increases and increases in the international value of China's *renminbi* currency pushed Chinese prices to approximate parity with the U.S. average beginning in 2012.

Similar economy-wide average prices conceal major differences in the internal structure of Chinese and U.S. electricity charges. In comparison with U.S. rates, prices charged to Chinese households are far lower, and unit costs for Chinese industry are much higher. Table 1 shows that, once converted to U.S. dollar terms, electricity costs for Chinese large-scale industry (大工业 *dagongye*) have consistently matched or exceeded comparable U.S. prices, with the gap between (higher) Chinese and (lower) U.S. rates rising from under 10 percent during 2003-2007 to 50 percent or more beginning in 2011. Unit costs facing manufacturers outside the scope of large-scale industry are even higher: rates for "ordinary industry and commerce" (一般工商业 *yiban gongshangye*) were 28-30 percent above the charges for large-scale industrial users during 2013-15 (State Energy Administration 2015, p. 8; Price Competition 5, 2016).[19]

Currency exchange rates are not ideal for comparing prices and costs in economies with widely varying levels of per capita output and income. The central difficulty is the presence of activities like internal transportation and personal services that are rarely traded across national borders and therefore do not contribute to the determination of currency exchange rates. Purchasing power parity (PPP) exchange rates, calculated from price arrays that include non-traded as well as traded commodities and services, aim to overcome this weakness. Because non-traded commodities and services are often relatively inexpensive in low-income countries, multiple studies find that shifting from market to PPP exchange rates substantially raises the values of currencies of low-income countries relative to those of advanced economies.

[19] A comparison of "fully burdened" power costs for 2015, including all taxes and fees, found that "median electricity prices for industrial loads in the U.S. tend to be 34-49% lower than Chinese prices" (Comerford et al 2016, pp. 2-3).

China is no exception: Table 1 shows that PPP exchange rates for recent years value China's RMB currency at roughly RMB 3.5 per U.S. dollar, far above the market price of approximately RMB 6.3 per dollar. This study uses market exchange rates to compare prices, profits and costs of electricity generation, transmission and distribution in China and the United States. Shifting to PPP rates would sharply increase the U.S. dollar price of Chinese electricity – as shown by the italicized rows marked PPP in Table 1 – which would strengthen the unexpected conclusion that the cost of generating, transmitting and distributing each kilowatt-hour of electricity is substantially higher in China than in the United States.

Profitability. Compared with U.S. electric utilities, Chinese power firms benefit from low prices for labor, equipment and materials as well as low construction costs for new facilities and less stringent environmental requirements.[20] Chinese power operations use newer equipment that, on average, consumes less coal and may require less maintenance than is needed at older U.S. facilities.[21] At times, Chinese power plants have enjoyed access to domestic coal at prices below international market levels.

Industry-wide figures[22] summarized in Table 6 confound the expectation that high power prices and low costs should enable Chinese electricity firms to reap substantial profits. Table 6 provides two measures of returns showing annual industry-wide profits as percentages of annual sales revenue and of total assets during the decade 2005-2015.[23]

Table 6 about here

Profit margins – the ratio of profits to annual sales – are modestly higher for U.S. investor-owned electric utilities than for Chinese electricity firms. The average and median of annual profit margins on the U.S. side exceed comparable Chinese figures by 43 and 2 percent.

Profit margins are far more volatile on the Chinese side. During this 11-year period, profit margins for U.S. investor-owned utilities fluctuate within a narrow range between 9.97 and 12.21 percent. Annual profit margins in China's power sector fall within the range of 11.3-13.5

[20] Renmin University Professor ZHENG Xinye 郑新业 emphasized the latter item in an October 2016 seminar.

[21] Chinese specialists express surprise at the age and limited capacity of equipment that they encounter in U.S. power facilities. One informant commented that computers installed at a California dispatch facility "could not run the software that I write" for China's power system (June 3, 2013 interview).

[22] Industry-wide figures come from annual industrial statistics yearbooks that omit small plants and include firms that produce heat as well as electricity; both categories are small.

[23] As explained in the Appendix, reported sales are adjusted to eliminate double counting that would artificially reduce the profit-sales ratio for China's electricity sector.

percent in the initial and terminal years, but fall sharply in between, reaching a low of 2.83 percent in 2008.

Figures showing the annual pre-tax return on assets (ROA) display a similar contrast: ROA, the ratio of annual pre-tax profits to total assets, is substantially higher for U.S. investor-owned electric utilities (average 4.09, median 4.25 percent) than for Chinese firms (average 2.95, median 2.98 percent). As with profit margins, volatility is far higher on the Chinese side. Average and median ROA values for U.S. utilities during the decade 2005-15 exceed comparable results for China's electricity firms by 89 and 30 percent respectively.

These observations establish low profitability in China's electricity system as a long-term rather than a cyclical phenomenon. Low profits span intervals of rising (2005-2008) and declining (beginning in 2012) coal prices, variations that massively affect costs in China's coal-dominated power sector.[24] Low profits persist through periods of rapid (2005-07, 2009-11) and slow (from 2012) demand growth.

The figures in Table 6, while highlighting the U.S. power sector's superior financial results, may exaggerate the profitability of Chinese electricity firms. The difficulty involves possible underreporting of depreciation allowances, which reflect the annual costs assigned to long-lived assets (structures, machinery, vehicles, etc.). Standard sources give annual figures for "cumulative depreciation allowances" (积累折旧费 *jilei zhejiufei*); figures for "current year depreciation" (本年提取折旧费 *bennian tiqu zhejiufei*) appear for some, but not all years. Missing "current year" entries can be derived as the difference between cumulative depreciation totals for successive years.

Variation in the projected service lives of various assets adds unavoidable complexity. Although we cannot replicate the underlying calculations, industry-wide figures covering 2005-2015, summarized in Table 7, reveal obvious difficulties. China's power sector invests on a massive scale, resulting in substantial net annual additions to the stock of depreciable assets.[25] With no dramatic variation in the mix of assets or in the rules governing depreciation,[26] abrupt shifts in

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[24] Coal purchases account for approximately 70 percent of variable costs for thermal plants, which in turn supply roughly 70 percent of China's overall electricity output. Coal-fired generating plants absorbed 1.84 billion tons of coal in 2012 (Energy Statistics 2015, p. 109). Prices of thermal coal declined by RMB 150 during the course of 2013. A price decline averaging RMB 100 would have reduced 2013 production costs by RMB 184 billion, an amount equal to nearly two-thirds of the entire power industry's reported 2012 profits. See Wang 2014, Yearbook 2014, p. 264 and Table 6.

[25] "Net" additions to the asset stock refer to newly added assets less the sum of current depreciation expenses and the undepreciated value of facilities and equipment removed from service.

[26] Successive depreciation guidelines for the power sector show no major changes since 1985 (Depreciation 1985; Depreciation 1994; Depreciation 2015).

the scale of depreciation allowances or their relation to broad measures of assets or capital stock are highly improbable.

Table 7 about here

Sudden declines in annual depreciation allowances in 2008-2009, 2011-2012 and 2014-2015, as well as the near-stagnation of depreciation expenses in 2012-2013 and the sudden leap in 2014, seem unlikely to reflect actual operating conditions. These improbable sequences appear to confirm claims that China's large power-generating conglomerates (and other listed companies) periodically reduce depreciation allowances to embellish reported profits: a 2014 account quotes an industry specialist's view that China's big-5 power generating firms, which reported combined 2013 profits of RMB 74 billion, would have earned little or no profit had they employed the depreciation rates in place 10 years earlier (Wang 2014). Another study claims that depreciation reported by China's grid companies during 2007-2011 was at least five times the permissible amount (Power Prices 2014).

The following discussion focuses on officially reported data, ignoring possible overstatement of profits.

China: a high-cost electricity producer. Despite operating under a regime of high sales prices and low costs, China's power sector delivered consistently weak financial results during the decade beginning in 2005. Results in Table 6 shows that financial results for Chinese electric utilities generally lag behind similar measures for U.S. power companies. Domestic comparisons reinforce the impression of weak financial performance: ROA for the electricity sector lagged considerably behind the average for centrally-administered state-controlled firms operating under China's State-owned Assets Supervisory and Administration Commission (SASAC) throughout 2005-2012 (Table 6 and Lardy 2014, p. 56).

Low profitability combined with retail prices that, beginning in 2012, have matched or exceeded the U.S. average imply that, beginning in 2012 if not earlier, and despite multiple cost advantages, **the unit cost of generating, transmitting and delivering Chinese electricity, when converted to U.S. dollar terms, is higher than comparable costs for U.S. electric utilities.**

What is the scale of excess costs? China is the world's leading producer of electrical equipment, construction materials and many other manufactures needed to erect power plants, build grid systems, and generate and deliver electricity. The term "China price" reflects the reputation of Chinese industry for delivering serviceable products at low prices. Immense recent expansion of capacity means that the average age of equipment is far lower in China's power sector than in America's. This should translate into lower maintenance costs. Low wages provide Chinese firms with a further cost advantage (Table 5).

With the exception of coal, the chief variable cost item for China's power sector, for which domestic prices increasingly reflect international values, major cost elements endow China's electricity sector with a considerable cost advantage over U.S. utilities. Lean and efficient operations should translate this advantage into distinctly lower costs than the U.S. utility system can achieve. The discovery that production costs for Chinese electricity are higher than in the U.S. indicates the presence of substantial excess costs – expenses that could be eliminated if Chinese electric utilities could match levels of operational efficiency observed in the U.S.

These observations suggest a trio of benchmarks for appraising the magnitude of excess costs in China's power system during 2005-2015:

- Excess costs [A] measure the cost reductions required to enable China's electric power sector to match the observed financial performance of U.S. utilities **without changing the electricity prices charged to Chinese end-users.**

- Excess costs [B] measure the cost reductions required to enable China's electric power sector to match the observed financial performance of U.S. utilities **following an assumed 40 percent reduction in the price charged to industrial electricity users.**

- Excess costs [C] measure the cost reductions required to enable China's electric power sector to match the observed financial performance of U.S. utilities **following an assumed 33 percent across-the-board reduction in Chinese electricity prices.**

Each calculation determines the magnitude of cost reduction – in *renminbi* and as a percentage of reported sales costs (adjusted sales revenue minus profits, see Table 6) – needed for each year's Chinese financial outcomes to match average U.S. performance during 2005-2015.

These performance targets reflect observations in Table 6. The target for the profit-sales ratio is 11 percent – slightly below the 11.35 percent average and 11.47 median of annual results for U.S. utilities during 2005-15. The target ROA is 4.0 percent, which is 40 percent above the average Chinese ROA of 2.95 percent during 2005-2015 and slightly below the comparable U.S. average ROA of 4.09 percent (Table 6).

Table 8 compiles excess cost outcomes under the three sets of assumptions noted above.

Table 8 about here

Version [A] calls for sufficient cost reduction to match average U.S. financial metrics with no change to historic Chinese power prices. The results show that modest cost reductions averaging no more than 3.8 percent could have permitted actual results to match both the 11 percent profit-sales target and the 4 percent ROA benchmark during the decade ending in 2015.

Version [B], which requires cost reductions that elevate financial outcomes to the target levels in the face of a hypothetical 40 percent reduction in industrial power charges, is far more demanding. Results in Table 8 show that meeting either benchmark would require cost reductions of in the neighborhood of one-third.[27]

Version [C] investigates the magnitude of cost reductions needed to match recent financial outcomes for U.S. electric utilities under the assumption of a 33 percent across-the-board reduction in Chinese electricity prices. This approach avoids excessive focus on high prices imposed on industrial users, which arise from administrative choices rather than cost considerations.

Early reports following the recent wave of electricity reforms, discussed in greater detail below, include instances in which expansion of direct trading alone reduced prices by more than 30 percent in Guangdong, Anhui and Yunnan (Yao Jinnan 2016; May 2016 interviews); elsewhere, direct trading has delivered much smaller cost savings (e.g. Jiangsu Power Exchange 2016; LU Zheng 2016). Wide variation in the price consequences of direct trading and the paucity of information about the likely outcome of continuing changes in grid charges and in the organization of retail sales make it difficult to anticipate the eventual result. The assumed 33 percent price reduction embodied in Version [C], however, surely falls within the range of possible outcomes.

Results in Table 8 show that matching historic U.S. financial performance during 2005-2015 under an assumed 33 percent across-the-board price reduction in electricity prices would have required Chinese electricity firms to lower costs by approximately 35 percent.

The right-hand columns of Table 8 summarize the actual amount of cost reduction needed to attain an assumed ROA of 4 percent during the decade 2005-2015 under alternative assumptions. Average annual cost reductions range from RMB 73 billion for Version [A] (no price change) to much higher figures of RMB 770 billion for Version [B] (40 percent reduction in prices for industrial users). Imposing a 33 percent across-the-board price reduction (Version [C]) would require annual cost reductions averaging RMB 865 billion. Beginning in 2011, attaining a 4 percent ROA following either a 40 percent reduction in industrial power prices or a 33 percent sector-wide price cut would require annual cost reductions approaching or surpassing RMB 1 trillion.

The central role of industrial electricity use, which consistently accounts for 70 percent or more of overall Chinese power consumption (Table 8), offers a natural focus for appraising the magnitude of possible excess costs. Firms classified in the tariff category "large industry" (大工业 *dagongye*), which absorb the largest portion of industrial electricity sales, face tariffs that, when converted to U.S. dollars, exceed prices charged to U.S. industrial electricity users throughout the decade 2005-14; during 2011-

[27] The assumed 40 percent price reduction for industrial users reflects inconsistencies in the data underlying this essay. Data for 2014 indicate that the overall average of U.S. and Chinese power prices was virtually identical, that average prices for large-scale industrial users were 50 percent above the overall average (Table 1); that smaller industrial users paid 30 percent more for electricity than large users (State Energy Administration 2015), and that industrial users absorbed 70.7 percent of overall electricity supplies (Table 8). This combination is mathematically impossible. Sales of 70.7 percent of available electricity to industrial users at 50 percent above the overall average price would imply revenue from industrial sales amounting to 70.7 * 1.5 = 106.5 percent of the total – which cannot exceed 100 percent. Excess costs [B] limits the hypothetical reduction in industrial power charges to avoid this inconsistency, which is not limited to 2014.

2014, the price gap is 50 percent or higher (Table 1). An noted above, industrial users outside the scope of "large industry" pay even more.

U.S. electricity prices are neither artificially reduced to benefit industrial users nor artificially inflated to ensure outsized financial returns to electric utilities. With the benefit of multiple cost advantages, a well-managed Chinese electricity system should be capable of matching U.S. financial outcomes if the price charged to industrial users, who absorb the bulk of Chinese electricity (Table 8) were the same in China as in the U.S.

Excess cost estimates based on Version [B], which imposes a 40 percent reduction on electricity prices charged to Chinese industrial users, provide a plausible lower bound answer to the question "What is the magnitude of cost reductions needed to enable financial outcomes in China's electricity system to match the performance benchmark represented by the U.S. electricity system?"

Why is the excess cost figure associated with Version [B] a plausible **lower** bound?

- The assumed 40 percent reduction in prices charged to industrial users is considerably smaller than the actual gap between Chinese and U.S. industrial electricity prices in recent years. Table 1 shows that, on average, electricity prices paid by "large industry" in China exceeded average U.S. industrial electricity prices by 50 percent during 2009-2015. Higher prices charged to small and medium industrial users raise the industry-wide average: in 2014, the Chinese industry-wide average was perhaps 60 percent higher than average U.S. industrial power prices.[28]

- Bank lending rates are far higher in China, where the average rate on one-year loans during 2005-14 was 6.30 percent, than in the U.S., where, on average, the banks' prime lending rate was 4.68 percent during the same period.[29] Changing the financial performance benchmark underlying the calculations in Table 8 from matching U.S. utilities' average ROA (4.16 percent) to matching the U.S, utilities' ratio of ROA to cost of capital (4.09/4.68 or 0.87) would increase the magnitude of estimated excess costs because the Chinese ratio of ROA to capital cost, 2.95/6.30 = 0.47, is only 54 percent of the U.S. figure, whereas the Chinese ROA is 69 percent of the comparable U.S. figure (2.95/4.16 = 0.687).

- High prices charged to Chinese industrial electricity users conceal cost-shifting intended to underwrite low prices offered to households and to agricultural power users. This sort of cross-subsidy represents a politically-motivated financial transfer rather than any sort of cost overrun. These cross-subsidies, however, are far smaller than the amounts shown in the right-hand columns of Table 8.

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[28] Based on fragmentary data for 2016 showing that "large industry" absorbed 50.3 percent of Hubei power sales during the first two quarters (Hubei electricity 2016) and that "ordinary industry and commerce" (一般工商业 *yiban gongshangye*) absorbed 17.8 percent of total first-quarter sales in Jiangsu (Jiangsu electricity 2016). If sales to industry account for 70 percent of the total, with 50 percent going to "large industry" at a price 50 percent above the economy-wide average and 20 percent going to "ordinary industry and commerce" at a price 30 percent higher than the price for "large industry," the average power price for the two categories combined works out to 62.8 percent above the economy-wide average.

[29] Chinese lending rates for 2005-2014 courtesy of Nicholas R. Lardy; for 2015, calculated from Abstract 2016, p. 165. U.S. rates from http://www.federalreserve.gov/releases/H15/data.htm, accessed September 22, 2016.

- Tang (2014) estimates the combined subsidy for household (RMB 49.3 billion) and for agricultural (RMB 14.1 billion) electricity users at RMB 63.4 billion for 2010.

Chinese households used 698.9 billion KWh of power in 2013 (Yearbook 2015, Table 9-12), when the average power price was RMB 0.55748 per KWh for households and RMB 0.63549 for all Chinese users (State Administration of Energy 2015).

Taking the U.S., where residential electricity prices were 18.5 percent above the overall average in July 2015 and 18.4 percent higher than the average for July 2016, as a benchmark, we can crudely approximate the 2013 subsidy enjoyed by Chinese households as the difference between an assumed price of RMB 0.7498 (18% above the 2013 economy-wide average) and the actual household unit price, multiplied by 2013 household power consumption:

2013 subsidy ≈ 698.9 * [(0.63549 * 1.18) – 0.55748] = 698.9 * 0.1924 = RMB 134.5 billion

Assuming no change in the ratio between subsidies for household and for agricultural power use between 2010 and 2013, our crude projection of combined 2013 subsidies for these sectors is

RMB 134.5 billion * (63.4/49.3) = RMB 173 billion

Raising the assumed reduction in industrial power prices from 40 to 50 percent, a change that is entirely compatible with available information on electricity pricing, would increase the estimate of cost reduction required to attain a 4 percent ROA in 2013 by RMB 247.7 billion – far larger than the cross-subsidy amount for that year.

We conclude that the scale of cost reductions needed for China's electric power system to attain a profit/sales ratio of 11 percent or average ROA of 4.0 percent following an assumed 40 percent reduction in industrial power prices during 2005-2015 does indeed provide a plausible lower-bound measure of excess costs within China's electricity sector.

The scale of cost reductions required to match U.S. financial outcomes following a hypothetical 40 percent reduction in prices for industrial electricity shown in Table 8 ranges from 29.5 percent (to attain an 11 percent profit-sales ratio) to 3.95 percent (to reach an average ROA of 4.0 percent). We focus on the lower of these results, and propose **30 percent as a plausible lower bound estimate of excess costs in China's electricity industry.**

We make no claim of precision. Inconsistencies within the Chinese data underlying our calculations and also between Chinese and U.S. statistical compilations create the expectation of large error margins in our results.

As noted earlier, only big conclusions retain credence in the presence of large error margins. The findings summarized in Table 8 represent just such an outcome. Investigation of the simple relation Cost = Revenue – Profit shows that, notwithstanding the presence of multiple favorable circumstances, the unit cost of producing, transmitting and delivering electricity is substantially higher in China than in the U.S. While the exact measure of the cost gap, which we place at a minimum of 30 percent, may be disputed, the analysis presented here, which builds on quantitative materials distributed by Chinese industry and official sources, leaves no room to question the surprising conclusion that **unit costs of delivering electricity to end users are substantially higher in China than in the U.S.**

Where do excess costs cluster? What follows is an initial foray into the structure of Chinese electricity costs.

High rail freight and logistics expenses? Movement of goods in China is expensive. Coal, the largest single cargo in China's transport system, is no exception. The cost of shipping coal attracts vociferous complaints, which often repeat the claim that "According to statistics, the logistics cost of shipping coal over 1,000 km in China is 10-15 times the cost in the United States and 15-20 times that in Japan" (Coal Logistics 2015).

Following the cessation of Japanese coal mining in 2002, rail carriage of coal has all but disappeared, rendering the Japan comparison irrelevant. Rail freight costs for shipping coal are indeed higher in China than in the U.S. Conversion of cost figures at prevailing exchange rates shows that average rail freight per ton-km for Chinese coal shipments was 21-29 percent higher than comparable U.S. costs during 2003-2008; thereafter, the cost gap increased, in part because of the increased value of China's *renminbi* currency, so that by 2015, unit rail freight costs for Chinese coal exceeded comparable U.S. figures by 78 percent (Rawski 2015).

Commodity shipments attract numerous taxes and fees, many imposed by local authorities that resist Beijing's efforts at systematization and control. Again, coal is no exception: one survey reported 109 varieties of taxes and fees (Coal Costs 2015).

The potential for cost savings in the shipment of coal is considerable. China's power plants burned an average of 1.78 billion tons of coal annually during 2010-2015 (Energy Statistics 2015, p. 109), most delivered by rail. In 2012, when power plants consumed 1.84 billion tons (ibid.), average length of haul for railway shipments of coal was 645 km and average rail fees per ton-km were RMB 0.131 (Rawski 2015). Thus the cost of rail shipment was roughly 645 * 0.131 * 1.84 or RMB 155 billion. With fees reportedly occupying the same share of delivered coal costs as rail freight – 20 percent for each – and adding additional costs for short-haul trucking (8%) and port charges (5%) (Coal Logistics 2015), the 2012 data imply that costs of moving coal from the mines to China's power plants are in the neighborhood of RMB 155 billion * 49/20 or RMB 380 billion.

Chen Deming, China's Minister of Commerce, noted in 2012 that imposition of fees accounted for over half of logistics costs, and indicated that suitable reforms might halve the cost of moving goods (Yu 2012). Using 2012 figures, a 50 percent reduction in logistics costs would amount to RMB 190 billion. But even this large number, which amounts to 6.2 percent of 2012 (adjusted) sales costs for China's electricity sector (Table 6), would provide only a modest contribution to the cost reductions linked to Version [B] in Table 8.

Overbuilding? Beginning in the early 1980s, China experienced repeated episodes of severe power shortage. This stimulated a strong, and eventually successful effort to accelerate supply growth and eliminate the economic damage arising from electricity-related production stoppages. Given the long history of shortage, it is hardly surprising that supply growth overshot demand, leading to growing reports of falling utilization and idle generating facilities beginning in 2013.

The ongoing response to the recent demand slowdown, which has seen the annual growth of electricity consumption plunge from double-digits as recently as 2011 to less than 1 percent in 2015 before rebounding to 5.6 percent in 2016, demonstrates that excess investment is a long-term structural issue rather than a short-term adjustment problem. Building of new plants and requests for approval of additional projects continue even as utilization rates plunge dramatically (Table 3), estimates of excess generation capacity reach 38 percent (Lin, Liu and Ke 2016) and forecasts for future demand growth cluster in the low single digits: Lu Bin (2016d), for example, cites experts' expectations of "no quick rebound" in the pace of demand growth. Critics blame power firms and regional governments for pursuing "blind investments" (盲目投资 *mangmu touzi*) that aggregate into "Great Leap Forward-style" expansion of coal-fired generation facilities – referring to a period of recklessly wasteful investment during the late 1950s (Yuan Jiahai 2016; Li Beiling 2016).

Since construction costs do not enter into the calculation of annual profits, the direct impact of overbuilding on profits is limited to increased interest costs associated with the financing of new facilities. The indirect effect of excess capacity – growing difficulty in covering fixed costs following a general reduction in utilization rates – represents a greater threat to profitability, particularly for power generation firms, some of which have high ratios of debt to assets. Thus a 2016 report noted double-digit declines in operating cash flow for four of China's five largest power generation companies and commented that their businesses face "increasing pressure" and "increasingly urgent cash flow needs" (Working Capital 2016).

Pursuit of uneconomic technology? Field interviews raise the possibility of ill-advised outlays that produce only marginal efficiency gains. One plant manager reported that improvements costing RMB 260 million at two 300 MW thermal plants lowered coal consumption per KWh by about 20 grams; increasing utilization rates from 60 to 90 percent would reduce unit coal use by 11 grams and also lower power consumption within the plants – with zero investment expense.[30] Domestic critics complain that the productivity of State Grid Corporation's investment spending is falling and that efforts to develop long-distance high-voltage AC power transmission have encumbered China's grid system with high cost, underutilized facilities (Fu 2014; He 2015b; Jia 2015c). Others pillory efforts to pursue offshore wind farms as "floating white elephants" (Gao 2014). Loren Brandt and Luhang Wang find that Chinese wind turbine producers rush to produce high-capacity models while neglecting quality issues that plague the smaller models that dominate market sales.

Trapped power? As the share of power from intermittent sources (hydro, wind, solar) in total power generation increases, the likelihood of "spillage" or "curtailment"– electricity that never enters the grid and is therefore wasted – increases. Spillage can arise from technical conflicts or from economic choices – for example if grid companies resist pressure to pay high prices or to build expensive links to absorb "clean" power. China has the unfortunate distinction of the world's highest wind power curtailment rates – 17 percent in 2016 – more than double the highest reported elsewhere (Davidson 2016, Bai 2017). Unexpectedly low demand growth has encouraged Guangdong and other provinces to prioritize local thermal plants (and build new ones) while rejecting incoming power transfers from hydroelectric facilities in western provinces, leading to considerable spillage in the hydroelectric sector (Fu 2015). There are many reports of expanding curtailment: Xiao (2016) focuses on wind power, but others note similar phenomena affecting hydro, solar, and even nuclear generation (Zhu 2017).

Too many workers? 2011 data assembled in Table 5 show that, compared with its U.S. counterpart, China's electricity sector had slightly less installed capacity, generated 15 percent more power, and employed more than 6.5 times as many workers. Part of this gap arises from the need to provide services to a far larger number of (especially household) consumers. A portion may represent a sensible response to China's relatively low labor costs. Even so, rapid progress of equipment modernization and automation – for example, using drones to inspect electricity facilities (Yao Haitang 2016), makes it difficult to believe that, on average, efficient operation of each unit of Chinese generating, transmission and distribution capacity requires more than six times the number of workers associated with comparable (and typically older) U.S. equipment. The combination of increasing automation and declining growth of labor productivity, which rose by 70 percent during 2000-2005, by 54 percent during 2005-2010 and by 20.7 percent between 2011 and 2015, points to substantial opportunities to pare the costs –

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[30] June 2013 interview. In addition to reducing coal use, the improvements enabled these plants to meet specific environmental regulations.

not just wages, but equipment, vehicles, office space, and housing outlays - associated with overmanning.[31]

Of these potentially quantifiable cost items, only rail freight and logistics offers potential cost reductions that can even partially march the excess cost estimates associated with substantial price reductions (Table 8). Neither wages, which amounted to 3.1 percent of sales in the electric power sector during 2011 (Table 5) nor interest payments, which absorbed 0.12 percent of 2012 sales revenue for generating companies and even less for grid companies (Industrial Statistics 2013, i: 117, 226-227), are large enough to support even the small cost reductions needed to attain U.S.-style profit/sales or ROA outcomes under existing Chinese prices (Table 8, Version [A]), let alone the larger figures associated with Versions [B] or [C].

Plausible cost reductions associated with overmanning, excess investment, trapped power, pursuit of uneconomic technical advances and logistics could not deliver the savings required to approach either the profit-sales or ROA metric if electricity charges to industrial users were lowered by 40 percent to approximate the U.S. level (Version [B]).

<u>System costs?</u> Our inability to attribute China's surprisingly high electricity costs to specific, quantifiable causes directs attention to possible excess costs arising from the institutional matrix within which this sector operates. Three areas stand out:

- *Managerial complexity.* "General fragmentation of authority" in China's administrative system means that "policy-making is. . . characterized by an **enormous amount of discussion and bargaining**. . . (Lieberthal 1995, 173, with emphasis added). While this description refers to governmental processes, the multiplicity of official and corporate actors involved in decisions about siting, building and operating power plants, about the construction and operation of grid facilities, about the dispatch, allocation and pricing of power flows, and about the remediation of effluents associated with electricity production ensure the expenditure of "enormous" resources in everyday decision-making surrounding China's power sector.

  Since "discussion and bargaining" are the function of managers, rather than ordinary workers, it is not surprising to find in Table 9 that managers at 16 large Chinese power-related firms account for 17.76 percent of 2014 employment at these companies, 11 percentage points above the U.S. figure of 6.77 percent for electricity generation and transmission.

[31] Labor productivity is measured as the quotient of overall power generation and sector-wide employment. See author's file Electricity cost data 032616, Tab Output per worker.

Table 9 about here

Applying the proportion of managers in 16 firms to the entire Chinese power sector – note that these firms employ 80 percent of China's electricity work force - and taking the U.S. proportion of managers as a benchmark, we conclude that the unusual complexity of business arrangements may require the employment of 0.11 * 2600.1 = 286,000 **additional** managers, a figure equivalent to nearly three-quarters of the entire U.S. electricity industry work force! This calculation vividly illustrates the potential magnitude of system costs in one segment of China's economy.

- *Institutional conflicts.* Many examples can illustrate the frequency and pervasiveness of costly outcomes arising from conflicting interests within China's power system.
    - Critics excoriate the "Great Leap Forward-style" rush to build new thermal power plants even as utilization of existing coal-fired facilities plunges (Li 2016; State Energy Administration 2016). Even as proposed expansion of coal-fired power plants encounters "strict and even punitive policy constraints," a report that coal-fired co-generation, combining generation of heat and power, faces "more lenient" approval and construction requirements (Lu Bin 2016c) may offer a new outlet for the investment hunger of local governments even though 70 percent of cogeneration plants run by the Big 5 generating companies lost money in 2013 (Yu 2015).

    - Numerous reports describe the construction and operation of power facilities in the absence of official approval. One account cites government estimates that "One fifth of the power plants in China are illegal" (Oster 2006).

    - Local protectionism motivates efforts to build duplicative (but locally-controlled) power plants to channel demand to locally controlled generation facilities, or to prevent "imported" power from underselling local producers. This may explain Michael Davidson's (2016) observation that newly commissioned, technologically sophisticated, clean, low-cost generating plants may run far below optimum capacity – as reported in He (2015b), while higher-cost facilities continue to receive substantial operating hours.

    - Prior to recent reform initiatives, China's major grid companies were notorious for concealing detailed cost information. An official of the former State Electricity Regulatory Commission explained that key cost items related to grid management are "intentionally hidden from outside view" (May 17, 2012 interview).

- *Resource extraction.* China's electricity system is dominated by massive state-owned firms whose politically potent leaders, labyrinthine organization, and multiple layers of subsidiaries offer considerable shelter from external scrutiny. These firms' involvement in large numbers of construction projects, no-bid contracts, and related party transactions creates ample opportunities for leaders at all levels to obtain private benefits at the expense of corporate financial outcomes.[32] One regulatory official sees these firms as "cradles for corruption" (Huang and Yu 2015). While the recent anti-corruption campaign seeks to diminish actual or potential political opposition as well as financial malpractice, continuing focus on the energy sector, including major electricity firms, leaves no doubt that various forms of resource extraction are deeply embedded in the structure of China's power sector. The resulting excess costs, while not subject to even the crudest estimation, could be very large.

RETROSPECT AND PROSPECT

The experience of China's electric power sector during the past several decades is, first and foremost, a story of remarkable success. Formerly dominated by small, antiquated, fuel-gobbling generating plants and bypassing vast rural areas while scrambling to satisfy urban demand, China's power system now comprises a nationwide network of modern generation facilities linked to regional grid networks. Important metrics such as unit coal consumption, self-consumption of power by generating facilities, and transmission losses resemble the values observed in advanced nations. Theft of power and payment arrears, phenomena that destabilize electricity operations in many low- and middle-income nations, are notably absent: State Grid Corp. reportedly collected over 99.9 percent of electricity charges in 2011, in part because "improved risk control" including legal actions that recovered RMB 2.62 million in unpaid bills during that year (State Grid 2012, p. 164).[33]

This impressive transformation coexists with a regime of surprisingly high costs and prices. China's unexpected combination of high electricity prices, low prices for materials, equipment and labor used to generate, transmit and deliver power, and low profits signals the presence of

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[32] Gezhouba Dam Group (葛洲坝集团), ranked 48 and 36 in 2012 and 2014 among China's 100+ central SOEs for "rule of law," illustrates these difficulties. During 2012-2014, the firm worked to "establish contract management" and "standardized management." During 2015, "the company reviewed a total of 62,091 contracts valued at RMB431 billion" – evidently a new development. Although "building a legal system is not easy," integrity among subsidiary enterprises "improved." See Duan Guiheng (2016).

[33] Lu Bin (2016e) cites an exception – residents stealing steam from a troubled Jiangsu plant.

large-scale inefficiency. A lean and efficient power system should have the capacity to deliver electricity to China's firms and households at substantially reduced costs.

Our finding that attaining financial outcomes similar to those achieved by U.S. electric utilities while lowering industrial electricity charges toward the prevailing U.S. level would require cost reductions in the neighborhood of 30 percent represents a lower-bound estimate of the potential for cost reduction within China's electricity system. Alternative calculations using purchasing-power parity (PPP) exchange rates rather than market rates to convert Chinese electricity prices to U.S. dollars, a plausible approach in cross-national comparisons involving economies at different levels of development, would raise our estimate of potential cost reduction.

Since readily quantifiable sources of excess costs, including rail freight charges for coal – the main source of energy for China's power sector – cannot provide more than a fraction of the savings needed to match U.S. utilities' financial outcomes if industrial power prices were shifted toward the U.S. level, we conclude that elevated costs are deeply embedded within the structure of China's power system. Major reductions will not be a matter of lopping off obvious cost overruns, but seem likely to require far-ranging reform of current business and regulatory practices.

This diagnosis exactly matches recent Chinese policy initiatives. Following a decade-long hiatus, far-ranging electricity reform reappeared on Beijing's policy horizon in 2015. The new reform push employs transparency as a lever to extend market pressures and thus reduce power costs. Beginning with Shenzhen, regulators have conducted audits of formerly concealed grid costs. In place of opaque negotiations between the grid companies and government agencies, we see the gradual emergence of a system conforming to international regulatory standards described in Irene Wu's chapter: regulators determine authorized grid charges by adding a specified profit markup to a roster of approved costs (Shenzhen Grid Reform 2015); published accounts suggest that regulators typically allow profit margins in the neighborhood of 8 percent above approved costs.[34] Standardization of grid charges smooths the path for a second innovation: rapid expansion of direct sales agreements between generating companies and large industrial users.

Although the financial impact of initial grid pricing reforms is small when compared to 2015 grid revenues of RMB 3653 billion (China Industrial Statistics 2016, i: 99), consequences have mounted as the reform unfolds. The Shenzhen reforms anticipated reductions in grid fees amounting to RMB 700 million during 2015-2017 (Shenzhen Grid Price 2015). Subsequent reforms covering five provinces anticipate reduced grid revenues of RMB 5.6 billion during 2016-2018 (Yao Jinnan 2016). According to State Grid's president, pricing reforms trimmed his firm's revenues by RMB 56 billion during the first half of 2017 (Huang and Song 2017).

[34] Cheng (2016) cites a range of 8-10 percent for solar projects; Zhang Zirui (2016a) interviews an industry specialist who uses 7.38 percent in analyzing prospects for offshore wind projects; Pipeline (2016) cites 8 percent as the prospective rate of return for natural gas pipelines.

The potential impact of direct sales is far greater. In Yunnan, direct sales surpassed 45 percent of industrial power consumption in early 2016, with average prices declining by RMB 0.18 per kilowatt-hour (Yao Jinnan 2016). A nationwide reduction of this magnitude in 2015, when industry absorbed 70.9 percent of China's 5,550 billion kwh of power use, would have lowered electricity charges by RMB 708.3 billion, a substantial fraction of even the largest excess cost estimates derived in Table 8. Direct sales amounted to 19 percent of overall power consumption in 2016 (Fan and Li 2017) – amounting to 27 percent of industrial power use. Policy announcements projected that direct sales would reach 30 percent of industrial use in 2016, with full liberalization of industrial and of commercial sales anticipated for 2018 and 2020 respectively (Jia 2016).

The impact of expanded entry into retail electricity sales, the third leg of the current reform agenda, remains unclear. However with the number of power sales firms rising from "over 300" to 6,387 between March 2016 and February 2017, and with entry open to newcomers, including private firms, from outside the power sector, implementation of this initiative opens the door to further reduction of electricity charges (Lu Bin 2016b; Power Sales 2017).

Reforms that reduce costs to electricity users represent identical revenue reductions for the companies that generate and deliver electricity. Opposition by representatives of the generating and grid companies (Jia 2015b; Lu Binggen 2016) cannot withstand the pressure arising from China's current combination of high power prices, massive overbuilding of power plants, declining operating hours and financial exigencies among power users, many suffering from the consequences of their own past investment excesses. The inevitable result: increased pressure on firms that enter the latest round of reform initiatives with a history of weak financial results (Table 6) will magnify an already formidable array of challenges.

Slowing demand growth is the central reality confronting China's entire electricity supply chain: coal mining, generation and grid companies, equipment manufacturers, design institutes and construction firms. Nationwide growth of electricity consumption, which raced ahead for decades at or near double-digit rates, has slowed. Following near-stagnation in 2015, China's National Energy Agency projects annual demand growth during 2016-2020 in the range of 3.6-4.8 percent (Electricity Plan 2016). Reflecting the impact of this growth slowdown, an executive of Shanghai Electric, a leading supplier of power plant equipment, commented in 2014 that demand for thermal power equipment had dropped by 50 percent during the previous five years, and, with government officials blacklisting coal, could see a similar decline during the following five years (Mu and Shu 2014).

Interaction between the unexpected slowdown of demand expansion and massive capacity growth (Figure 1) has produced a steep drop-off in utilization rates (Table 3). Average operating hours for China's vast fleet of coal-fired generating plants, which typically face breakeven points (at which revenues suffice to cover loan repayments as well as operating costs) of 5,000-5,500 annual hours, plunged to 4,165 hours in 2016, the lowest since 1964, with further reductions anticipated (May 17, 2012 interview; China Electricity Council 2016; Li 2016; Table 3).

At the same time, generating firms, which are major sources of airborne effluents, face escalating cost pressures arising from the government's increasingly forceful response to widespread public concern over urban air pollution. Officials have ordered power plants to retrofit effluent-reducing devices; offsetting increments to on-grid prices offer only partial compensation for the resulting cost increases; promised subsidy payments are often in arrears (Yu Chunping 2015; Zhang Zirui 2016b). In some instances, particularly in the largest cities, authorities have banned new coal-fired plants – ignoring industry assurances regarding the benefits of "clean coal" (Jia 2014ab) and forced existing plants to shut down or convert from coal to natural gas.

Three additional developments may escalate financial pressure:

- Growth of power from intermittent sources is driving up costs for both grid operators and for the (typically coal-based) back-up operations that supply power when wind and sun are not available (Xie 2016); Kahrl and Wang (2014, p. 7) present 2011 provincial data showing a steep rise in wind curtailment once wind power exceeds 4-5 percent of provincial electricity output.

- Proposed use of demand management aimed at reducing peak power requirements, for example through the extension of time-of-day power pricing, could further reduce operating hours.

- Plans to raise deposit rates paid by China's banks, if fully implemented, could lead to higher lending rates, and thus impose cost increases, especially on the heavily indebted generating sector.

These circumstances have spawned mounting financial uncertainty, especially for the five big generating companies, which entered the recent round of reforms with debt-asset ratios approaching 90 percent – among the highest for China's centrally-managed state enterprises (China Electricity Yearbook 2012, p. 144). Reduced cash flow among the five large generating companies (Working Capital 2016) may push cost cutting ahead of capacity expansion among the priorities of electricity executives, especially in the generation sector.

Looking Forward

The central finding of this study, summarized in Table 8, is that advances in technology and service provision conceal massive opportunities to lower costs. While downward price pressure affects all segments of the industry, cost reduction of the order suggested by the figures in Table 8 can only occur in the production and distribution of electricity from coal-fired generating facilities. Fixed costs predominate at both hydroelectric and nuclear plants; chances of finding substantial opportunities for reducing operational costs appear slight, particularly in the nuclear sector, where post-Fukushima escalation of safety measures has imposed layers of unexpected expenses. Wind and solar, with a combined output share of 4.5 percent in 2015, have small operating costs and are in any case too small to deliver cost reductions that would meaningfully affect industry-wide totals.

The intensification of market forces inherent in ongoing electricity reforms will direct demand toward low-cost sources of electricity. Successful pursuit of cost reduction has the potential to lower the absolute and relative cost of coal-fired power. Institutional arrangements and policy structures that routinely tilt toward long-dominant coal interests (Zhang Shuwei 2016), illustrated by the November 2016 announcement of long-term contract arrangements that will provide electricity producers with thermal coal at a 25 percent discount to the current market price, reinforce this prospect (Zheng 2016).

Substantial reductions in nuclear plant operating hours (e.g. Nuclear Facilities 2016) show how the interaction among excess capacity, latent cost reduction potential and market deepening may spark a reversal of recent declines in the volume and share of coal-fired power generation – the exact opposite of Beijing's declared policy objectives and of the international community's expectations following the 2016 Paris accord. Massive expansion of thermal power generation envisioned in the November 2016 announcement of 13th Five-Year Plan (2016-2020) targets for electricity, along with the likelihood of additional growth inherent in the repeated proviso that Beijing would "strive to limit" 2020 thermal capacity to the targeted figure, highlights the formidable resilience of China's coal interests.

Can the current revival of reform momentum overcome a tangled web of circumstances that has allowed institutional legacies, inchoate policies, ineffectual regulation and large-scale misappropriation of resources to transform this technically progressive sector's bright prospects into a latent financial nightmare? And can ongoing reform efforts limit or reduce the environmental costs associated with Chinese electricity production?

Although the obstacles to thoroughgoing reform appear formidable, so too are the capabilities available to China's electric power system. Individual segments have avoided the accumulation of excess costs that plagues the system as a whole: power output per unit of installed capacity exceeds performance in the U.S. (Table 5) and the trajectory of new plant costs demonstrates an exceptional capacity for cost control (Figure 2). China leads the world in erecting wind and solar generation facilities, and boasts a large and rapidly growing fleet of nuclear power plants.

The threatened transformation of a crucial economic sector into a long-term fiscal burden and environmental incubus may elicit a determined effort to mobilize the resources responsible for the power sector's many achievements to create institutional systems surrounding the production and distribution of Chinese electricity that can match the system's technical excellence.

APPENDIX

CALCULATION OF PROFIT-SALES RATIO

Annual yearbooks of Chinese industrial statistics provide information on sales revenue (S), assets (A) and profits (π) of the electricity industry. We use this information to calculate the ratio of profits to sales as well as the return on assets.

The yearbook figures on sales revenue, however, do not match comparable information regarding U.S. investor-owned utilities. Chinese grid companies purchase electricity from power plants, then resell the electricity to end-users. This means that amounts paid to generating companies are counted twice in compiling data on industry-wide sales: once when the generating companies sell electricity to the grid, and a second time when the grid resells this power (less transmission losses) to end users.

Under U.S. institutional arrangements, when separate companies generate and transmit electricity, end-users are billed separately for electric power and for transmission and delivery services, so that summing the sales of various companies counts generating company revenues only once.

Using reported data to compare the profit/sales ratio for Chinese and U.S. electric utilities will thus exaggerate the relative profitability of U.S. firms because total sales of generating firms will appear once in the denominator of the formula $100^* \pi/S$ for the U.S. industry but twice in a similar calculation on the Chinese side.

To avoid this distortion, Table A-1 derives **adjusted** sales figures for Chinese electric utilities that eliminate this double counting. The adjusted sales figures, denoted by S’, are comparable with reported sales for U.S. investor-owned electric utilities.

The adjustment is shown in Table A-1.

Adjusted revenue S’, measured in billion RMB, is derived from

reported sales S – measured in billion RMB

reported power production Q – measured in billion KWh

the percentage of gross electricity output consumed within generation facilities c

and the average wholesale or on-grid price received by the generating companies P – RMB per MWh.

The derivation is:

$$S' = S - [(.001P) * (.01Q*(1-c))]$$

We thus obtain a revised sales total by subtracting the grid’s payment to generating companies for incoming power flows from reported industry-wide sales.

.001*P is the wholesale electricity price expressed in RMB per KWh (1 MWh = 1000 KWh)

.01*Q*(1-c) is the total of electricity supplied to the grid. Q measures gross power output, including electricity consumed within generating plants.

For example, If c=5%, then (100-c) is 95%, .01*95 = 0.95, which is the share of power output that reaches the grid; more generally, .01*Q*(1-c) is the actual power flow to the grid.

ROA FOR U.S. ELECTRICITY FIRMS, 2005-2015

Profit figures for China's electricity sector appear in Table 6; these are pre-tax figures.

Table A-2 tabulates our estimate of the pre-tax return on assets (ROA) for investor-owned U.S. utilities.

John Hanson of Riverstone Advisers LLC compiled annual **after-tax ROA** data for 25 U.S. electric utilities covering the years 2005-2014. I eliminated one firm for which the data series was incomplete and calculated industry-wide ROA for each year in two versions: the unweighted average of 24 firm-level ROAs, and a weighted average using 2014 sales figures as weights. After-tax ROA data for 2015 are from csimarkets.com. The 2015 figure for one firm, CMS, is the average of figures for Q1 and Q4.

The right-hand columns of Table A-2 derive actual 2014 income tax rates for each firm. The unweighted and sales-weighted average tax rates for that year are 29 and 28 percent respectively.

I apply the 2014 sales-weighted average tax rate of 28 percent to the entire period 2005-2014 to obtain a series of estimated **pre-tax ROA** for the U.S. electric utility sector. Results appear in Tables A-1 and Table 6.

The list of firms, annual ROA and 2014 sales appear in Table A-2.

REFERENCES

Abstract. 2014. 中国统计摘要 2014 [China Statistical Abstract 2014]. Beijing: Zhongguo tongji chubanshe.

Abstract. 2016. 中国统计摘要 2016 [China Statistical Abstract 2016]. Beijing: Zhongguo tongji chubanshe.

Areddy, James T. and Paul Glader. 2010. "India Deal Puts China in GE's League." *Wall Street Journal.* October 28. http://www.wsj.com/articles/SB10001424052702304173704575579261842597870 , accessed April 3, 2016.

BP 2015. *BP Statistical Review of World Energy 2015.*

Bai Yanfeng 白彦锋. 2017. "弃风"怪圈如何破 [How to break the cycle of 'abandoned wind']. 中国能源报 [China Energy Report] June 28, p. 18.

Baiyin 2014. "Industrialization of 690 Alloy U-tube for Nuclear Power Plant Steam Generator." Presentation by Baiyin Special Steel Tube Co., Ltd. Conference presentation, Pudong, China. May 29.

Bie Fan 别凡 . 2014. "煤价续跌 煤电价格联动被重提" [Falling coal prices highlight the link with power prices]. 中国能源报 [China Energy Report] June 23, p. 10.

Chen Zheng 陈峥. 2016. "中国能建动员部署加快业务转型."[Chinese Energy Builders Mobilize to Accelerate Transformation of their Business]. 中国能源报[China Energy Report]. April 18, p. 25.

Chen Zongfa 陈宗法. 2015. 新电改后电价还会涨吗 [Can power prices still rise after the new electricity reforms?]. Accessed November 3, 2016 from http://finance.sina.com.cn/zl/energy/20150331/122321853235.shtml.

Cheng Sisi 成思思. 2016. 标杆电价开启光热大市场 [Benchmark price opens a big market for solar power]. 中国能源报 [China Energy Report] September 5, p. 1.

Cheng, Tun-jen and Chung-min Tsai. 2009. "Powering rent seeking in the Electricity Industry." In *Rent Seeking in China,* ed. Tak-Wing Ngo and Yongping Wu. London and New York: Routledge.

China Electricity Council. 2016. 中电联发布《2016 年度全国电力供需形势分析预测报告[China Electricity Council issues 'Forecast report for 2016 national electricity supply-demand situation']. Accessed March 3, 2016 from http://www.cec.org.cn/yaowenkuaidi/2016-02-03/148763.html

China Electricity Report. Annual, 2013-2016. 中国电力行业年度发展报告[Annual Development Report of China's Electricity Industry]. Beijing: Zhongguo shichang chubanshe.

China Electricity Yearbook. Annual. 中国电力年鉴 [China Electricity Yearbook]. Beijing: Zhongguo dianli chubanshe.

Coal Costs. 2015. 我国煤炭为何成本高？"我国煤炭为何成本高?" [Why is China's cost of coal so high?" Accessed March 27, 2916 from http://www.chinabidding.com/infoDetail/224959193-News.html

Coal Logistics. 2015. "煤炭物流成本分析报告" [Analytic report on logistics costs for coal]. Accessed March 27, 2015 from http://www.chinawuliu.com.cn/xsyj/201503/24/299730.shtml.

Comerford, Tim, Dennis Meseroll, Tracey Hyatt Bosman and Gao Yong. 2016. "A Comparison of U.S. & China Electricity Costs." Biggins Lacy Shapiro & Company / Tractus Asia Limited.

Dash, Parismita. 2014. "A Comparative Analysis of BHEL & Shanghai Electric Co. in reference to Power Industry of India and China." Accessed April 23, 2016 from http://13jgbs-pdash.blogspot.com/.

Davidson, Michael. 2016. "Electricity Systems Integration Challenges: A Local Perspective." Unpublished.

Demsetz, Harold. 1969. Information and Efficiency: Another Viewpoint." *The Journal of Law & Economics* Vol. 12, No. 1), pp. 1-22.

Depreciation. 1985. 国营企业固定资产折旧试行条例一九八五年四月二十六日 [Draft Provisions on Fixed Asset Depreciation by State-operated Enterprises, April 26, 1985]. Accessed March 22, 2016 from http://www.nxcz.gov.cn:7002/%5Cdocuments%5Clib1%5C200004030247.HTM.

Depreciation. 1994. "电力工业企业固定资产年折旧率表（自一九九四年七月一日起施行）. [Table of Annual Depreciation Rates for Fixed Assets of Electric Power Enterprises (effective July 1, 1994)]. Accessed March 22, 2016 from http://www.sbgl.cn/news/news8/2010-06-05/2020.html

Depreciation. 2015. "2015 固定资产折旧年限最新规" [New 2015 Regulation on Annual Depreciation Limits for Fixed Assets]. Accessed March 22, 2016 from http://jskjxh.com/infoview.asp?id=601

Duan Guiheng. 段贵恒. 2016. 建设法治央企 打造法治能建 [Building rule of law in central SOEs]. 中国能源报 [China Energy Report]. August 8, p. 25.

Electricity Databook. 2010. 2010 年电力工业统计资料汇编 [Electricity Industry Data Compendium 2010]. Online edition accessed through CNKI zhishi wangluo fuwu pingtai.

Electricity Databook. 2014. 2014 年电力工业统计资料汇编 [Electricity Industry Data Compendium 2014]. N.p.: Guojia dianligongsi zhanlue guihuabu.

Electricity Databook. 2015. 2015 年电力工业统计资料汇编 [Electricity Industry Data Compendium 2015]. N.p.: Zhongguo dianliqiye lianhehui guihuafazhanbu. 2016.

Electricity Operations. 2014. "2014 年 1-12 月份电力运行简况" [Outline of Electricity Operations, January-December 2014]. Accessed 011616 from http://www.sxcoal.com/dl/4034681/articlenew.html (see file "NEA 2014 Electricity Report…").

Electricity Outcome. 2016. 国家能源局关于 2015 年度全国电力价格情况汇总 [National Energy Agency summary regarding 2015 nationwide electricity pricing]. November 2. Accessed May 30, 2017 from http://shoudian.bjx.com.cn/news/20161102/785537.shtml .

Electricity Plan. 2016. 国家能源局正式发布《电力发展"十三五"规划（2016-2020 年》[National Energy Agency formally issues "Electricity Development Guidelines for the 13th Five-Year Plan Period (2016-2020)"]. Accessed November 12, 2016 from http://www.escn.com.cn/news/show-362013.html.

Energy Report. 1997. 中国年鞥元 1997 年白皮书 [China's Energy: 1997 White Paper]. Beijing: Zhongguo wujia chubanshe.

Energy Statistics. 1997-1999. 中国能源统计年鉴 1997-1999 [China Energy Statistical Yearbook 1997-1999]. Beijing: Zhongguo tongji chubanshe.

Energy Statistics. 2006. 中国能源统计年鉴 2006 [China Energy Statistics Yearbook 2006]. Beijing: Zhongguo tongji chubanshe.

Energy Statistics. 2011. 中国能源统计年鉴 2011 [China Energy Statistics Yearbook 2011]. Beijing: Zhongguo tongji chubanshe.

Energy Statistics. 2015. 中国能源统计年鉴 2015 [China Energy Statistics Yearbook 2015]. Beijing: Zhongguo tongji chubanshe.

Fan Pengfei 凡鹏飞 and Li Rong 李嵘. 2017. 电力市场化改革开启加速模式 [Power marketization reform enters acceleration mode]. 中国能源报 [China Energy Report]. April 17, p. 4.

Fan Ruohong. 2015. "State Council Aims to Cut Power Prices for Big Manufacturers." Accessed December 18, 2015 from http://english.caixin.com/2015-12-15/100888436.html?utm_source=The+Sinocism+China+Newsletter&utm_campaign=cfe50428e6-Sinocism12_15_1512_15_2015&utm_medium=email&utm_term=0_171f237867-cfe50428e6-29602929&mc_cid=cfe50428e6&mc_eid=05464ef5ec

Fifty Years. 2000. 中国工业交通能源 50 年统计资料汇编 1949-1999 [Statistical Compendium: 50 Years of China's Industry, Transport and Energy]. Beijing: Zhongguo tongji chubanshe.

Fu Yuewen 傅玥雯. 2014. 10 项典型电网工程投资成效报告发布. [Report Released on 10 Typical Power Grid Construction Projects]. 中国能源报 [China Energy Report]. June 9, p. 2.

Fu Yuewen 傅玥雯. 2015. 今年汛期，再议弃水 [Again, Proposals to Abandon Hydropower During This Year's Flood Season]. 中国能源报 [China Energy Report]. August 10, p. 16.

Gao Wei 高为. 2014. 海上风电不是"水中白象 [Offshore Wind Power Generators are not 'Floating White Elephants']. 中国能源报 [China Energy Report]. May 5, p. 4.

Haley, Usha C.V. and George T. Haley. 2013. *Subsidies to Chinese Industry.* New York: Oxford University Press.

Han Xiaoping. 韩晓平. 2016. 十三五能源规划不能再搞竭泽而渔 2.0 [Energy Guidelines for the 13th Five-Year Plan cannot drain the swamp again to catch fish]. Posted July 12 at http://www.china5e.com/energy/news-951417-1.html ; accessed October 10, 2016.

He Yongjian 何勇健. 2015a. 价格改革:如何当好能源革命的先行军 [The Path Forward for Energy Price Reform]. 中国能源报 [China Energy Report]. July 20, p. 3.

He Yongjian 何勇健. 2015b. "十三五"电力规划应强调系统优化. [13th Five-year Plan Should Emphasize Electric Power System Optimization]. 中国能源报 [China Energy Report]. August 3, p. 3.

Historical Statistics. 1975. *Historical Statistics of the United States, Colonial Times to 1970.* Washington DC: Bureau of the Census. 1975.

Hsieh, Chang-tai and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China and India." *The Quarterly Journal of Economics* (2009) 124 (4): 1403-1448.

Huang, Kaishi and Shiqing Song. 2017. "China's Power Pricing Reform Burns 56-Billion Yuan Hole in State Grid's Eranings." June 29. Accessed June 29, 2017 from http://www.caixinglobal.com/2017-06-29/101107481.html.

Huang Kaishi and Yu Ning. 2014. "Debates on Ways to Reform Power Industry Heat Up." http://english.caixin.com/2014-11-10/100749059.html.

Hubei Electricity. 2016. 一季度湖北省用电量增长 5.32% 增幅超全国约 3 个百分点 [Hubei 2016 Q1 electricity usage up 5.32%, 3 points above the national figure]. Accessed September 20, 2016 from http://www.hubei.gov.cn/zwgk/hbyw/hbywqb/201604/t20160412_817764.shtml.

Huo Youguang. 2013. "电价"迷宫"：一地 300 多种销售电价" [Electricity Price Labyrinth: One Locality, 300+ Prices." *Daiyi caijingbao* May 14. Accessed November 4, 2014 from http://wap.sciencenet.cn/blogview.aspx?id=689824.

Hussy, Charlotte, Erik Klaassen, Joris Koornneef and Fabian Wigand. 2014. "International Comparison of Fossil Power Efficiency and CO2 Intensity – Update 2014. Utrecht: Ecofys.

Industrial Economy. Annual, 2006-2012. 中国工业经济统计年鉴 [Yearbook of China Industrial Economy Statistics]. Beijing: Zhongguo tongji chubanshe.

Industrial Statistics. Annual, 2013-2016. 中国工业统计年鉴 2013. [China Industrial Statistics Yearbook 2013]. 2 vols. Beijing: Zhongguo tongji chubanshe.

Jia Kehua 贾科华. 2014a. "冯伟忠：煤电完全可以建在城市" [Feng Weizhong says absolutely OK to build coal-fired power plants in our cities]. 中国能源报 [China Energy Report]. May 5, p. 15.

Jia Kehua 贾科华. 2014b. "煤电酝酿革命性技改" [Coal-fired Power Brewing a Revolutionary Technical Transformation]. 中国能源报 [China Energy Report]. June 9, p. 15.

Jia Kehua 贾科华. 2014c. "脱硫问题突出 14 家煤电受罚" [14 power plants fined to crack the SO2 problem]. 中国能源报 [China Energy Report], June 23, p. 15.

Jia Kehua 贾科华. 2015a. "青海无电人口年底通电" [Qinghai's Populace will Achieve Full Access to Electricity by Yearend]. 中国能源报 [China Energy Report]，March 28, p. 2.

Jia Kehua 贾科华. 2015b. 电改时机对电企不利 [Some State Grid projects have low utilization]. 中国能源报[China Energy Report]. August 8, p. 2.

Jia Kehua 贾科华. 2015c. 部分电网工程利用率偏低 [Timing of Electricity Reform Will Damage the Power Generating Companies]. 中国能源报[China Energy Report]. July 20, p. 4.

Jia Kehua. 贾科华. 2016. 电力市场建设路线图现雏形 [Electricity market roadmap taking shape]. 中国能源报[China Energy Report]. March 28, p. 2.

Jiang Lei 江镭. 2014. 内陆核电建设具备内生动力. [Inland Nuclear Power Construction Brings Endogenous Dynamics]. 中国能源报[China Energy Report]. November 17, p. 18.

Jiangsu Electricity. 2016. 江苏一般工商业及其他用电类别价格每千瓦时降低 0. 73 分 [Jiangsu power cost falls 0.73 cents per KWh for ordinary industry and commerce and for users classified as 'other']. Accessed September 20, 2016 from http://www.js.xinhuanet.com/2016-06/21/c_1119076806.htm.

Jiangsu Power Exchange. 2016. 江苏拟年内开展电力竞价交易 [Jiangsu to open an electricity exchange with competitive bidding this year]. 中国能源报[China Energy Report] August 22, p. 10.

Jiao Yue 矫月. 2016. 电力业产能过剩堪比煤炭：分配发电量仅够维持电厂不饿死 [Power sector excess capacity comparable to coal; dispatch allocations preserve plants from starvation]. 证券日报 [Securities Daily]. April 1. Accessed September 1 from http://www.china5e.com/news/news-938341-1.html.

Kahrl, Fredrich and Xuan Wang. 2014. *Integrating Renewables into Power Systems in China: A Technical Primer – Power System Operations.* Beijing: Regulatory Assistance Project.

Kahrl, Fredrich, Jim Williams, Ding Jianhua and Hu Junfeng. 2011. "Challenges to China's transition to a low carbon electricity system." *Energy Policy,* 39, pp. 4032-4041.

Kahrl, Fredrich, James H. Williams and Junfeng Hu. 2013. "The political economy of electricity dispatch reform in China." *Energy Policy* 53, pp. 361-369.

Labor Yearbook. 2012. 中国劳动工资统计年鉴 2012. 中国劳动工资统计年鉴 2012 [China Labor and Wage Statistics Yearbook 2012]. Beijing: Laodong renshi chubanshe.

Lanzhou. 2011. 兰州供电公司志 1986-2009 [Annals of the Lanzhou Power Supply Company, 1986-2009]. Lanzhou: Gansu renmin chubanshe.

Lardy, Nicholas R. 2014. *Markets over Mao: the Rise of Private Business in China.* Washington, DC: Peterson Institute for International Economics.

Li Beiling. 李北陵 2016. "控制火电盲目增长应成共识" [Controlling Blind Expansion of Thermal Power Should be a Consensus]. 中国能源报 [China Energy Report]. January 4, p. 5.

Li Fenglin. 李凤琳 2015. "电企加快布局"一带一路"建设. " [Power companies accelerate arrangements for construction under 'One Belt, One Road']. 中国能源报 [China Energy Report]. July 13, p. 15.

Lieberthal, Kenneth. 1995. *Governing China: from revolution through reform*. New York: W.W. Norton.

Lin Jiang 林江, Liu Xu 刘栩, and Ke Yizhi 柯意志. 2016. 从备用容量视角看中国电力过剩 [China's electricity surplus from the perspective of spare capacity]. 中国能源报 [China Energy Report]. July 25, p. 4.

Lu Bin. 卢彬 2016a. 气电代替煤电优势明显 [Obvious advantages of replacing coal with gas-fired electric power]. 中国能源报 [China Energy Report]. March 7, p. 10.

Lu Bin. 卢彬 2016b. 多元主体进军售电领域 [Multiple agents enter electricity sales]. 中国能源报 [China Energy Report]. March 21, p. 10.

Lu Bin. 卢彬 2016c. "热电联产迎来新机遇."[Co-generation of Heat and Power Ushers in New Opportunities]. 中国能源报 [China Energy Report]. April 11, p. 10.

Lu Bin. 卢彬 2016d. "盈利空间缩水 经营压力陡增 [Profit margins shrink amidst sharp increases in operating pressure]. 中国能源报 [China Energy Report]. September 5, p. 10.

Lu Bin. 卢彬 2016e. 煤电"寒冬"迎供暖考验 [Can Coal-fired power plants meet the challenge of providing heat during a cold winter]. 中国能源报 [China Energy Report]. October 17, p. 10.

Lu Bin. 卢彬 2017. 区域电力市场建设步履缓慢 [Slow advance in establishing cross-regional electricity market]. 中国能源报 [China Energy Report]. May 8, p. 111.

Lu Binggen 卢炳根. 2016. 直购电尚需加快择点试行 [Accelerate Selection of Experiment Points for Direct Power Sales]. 中国能源报 [China Energy Report] April 11, p. 5. '

Lu Zheng. 路郑. 2014. 装备国产化用户国货情结成关键. [User Attitude Toward Domestic Products is Key to Equipment Localization]. 中国能源报 [China Energy Report]. July 21, p. 19.

Lu Zheng. 路郑. 2016. 江苏电力交易持续释放改革红利 [Jiangsu electeicity exchanges releases sustained reform bonus]. 中国能源报 [China Energy Report]. September 12, p. 21.

Manshū kaihatsu. 1964-65. 满洲开发 40 年史 *Manshū kaihatsu yonjū nenshi* [Forty-year History of Development in Manchuria]. 3 vols. Tokyo: Manshū kaihatsu yonjū nenshi kankōkai.

Mathews, John A. 2016. "China's Continuing Renewable Energy Revolution – latest trends in electric power generation." *The Asia-Pacific Journal*, Vol. 14, Issue 17, No. 6, September.

Mathews, John A. and Hao Tan. 2014. "China's renewable energy revolution: what is driving it?" *The Asia-Pacific Journal*, Vol. 12, Issue 43, No. 3, November 3.

Mu Sinan 牟思南 and Shu Li 黍离. 2014. 上海电气：好辰光还要自己把握 [Shanghai Electric: Holding its own in good times]. 中国能源报 [China Energy Report]. June 9, p. 19.

NDRC. 2015. 国家发展改革委 环境保护部 国家能源局关于实行燃煤电厂超低排放电价支持政策有关问题的通知 [NDRC, Ministry of Environmental Protection, National Energy Administration Circular of the People 's Government of the People' s Republic of China on the Issue of Ultra Low Emission Electricity Tariff Support Policies for Coal - fired Power Plants]. December 2. Accessed from http://www.sdpc.gov.cn/gzdt/201512/t20151209_761941.html November 4, 2016.

NPP Siting. 2016. 两部门拟规定核电厂选址事项应征求公众意见 [Two Departments Draft Regulations Require Seeking the Public’s Opinion on Siting for Nuclear Power Plants]. Posted and accessed September 20, 2016 at http://www.china5e.com/news/news-960847-1.html.

Nuclear Facilities. 2016. “China to build more nuclear power facilities in next five years.” *China Daily*. November 10. Accessed November 12, 2016 from http://www.chinadaily.com.cn/business/2016-11/09/content_27322467.htm.

“Officials penalized for accidents at unauthorized power station.” 2006. Accessed November 6, 2016 from http://news.xinhuanet.com/english/2006-08/17/content_4970889.htm.

Oster, Shai. 2006. “Illegal Power Plants, Coal Mines In China Pose Challenge for Beijing.” http://www.wsj.com/articles/SB116718773722060212, accessed April 5, 2016.

Pipeline. 2016. 管输天然气定价将出新规 [New Pricing Regulations for Natural Gas Pipelines]. 中国能源报 [China Energy Report]. August 22, p. 2.

Power Equipment Review. 2017. **我国电力工业设备管理多项指标居世界领先地位** [Management of Equipment China’s Electric Power Sector leads the world in multiple dimensions]. April 1. Accessed April 4, 2017 from http://www.china5e.com/news/news-983305-1.html.

Power Prices. 2014. “揭示上网电价矛盾真相 控诉上网电价政策违法” [Reveal the truth about contradictory on-grid power prices: true complaints of illegalities in power pricing policy]. Accessed December 11, 2014 from http://bbs.bjx.com.cn/thread-1202785-1-1.html .

Power Sector Preview 2016. 中电联发布《2016 年度全国电力供需形势分析预测报告》[China Electricity Council Issues Report estimating 2016 electricity supply and demand]. February 3. Accessed March 13, 2016 from http://www.cec.org.cn/yaowenkuaidi/2016-02-03/148763.html .

Power Sales. 2017. 全名单丨全国已成立 6389 家售电公司（截止 2017-2-10）[List of enterprise names: 6389 power sales firms established as of 2-10-2017]. Accessed June 29, 2017 from http://www.wxhaowen.com/article_b915ce59436a4fb79c295c0a88ea11b1.shtml.

Price Competition 1. 2016. “全国电价大比拼系列 1：发电“自损指数” [National price competition series 1: power generation ‘self-loss index’]. http://shoudian.bjx.com.cn/news/20161123/791039.shtml , accessed June 1, 2017.

Price Competition 2. 2016. 全国电价大比拼系列 2：发电“上网卖个好价钱” [National price competition series 2: power generation ‘online to sell at a good price’]. http://shoudian.bjx.com.cn/news/20161124/791369.shtml, accessed June 1, 2017.

Price Competition 4 2016. 全国电价大比拼系列 4：电网盈利的法宝［National price competition series 4: the magic of power grid profit]. http://shoudian.bjx.com.cn/news/20161129/792404.shtml, accessed June 1, 2017.

Price Competition 5. 2016. 全国电价大比拼系列 5：哪旮电最贵？哪旮居民最幸福？[National price competition series 5: Which grid charge is most expensive? Which residents are happiest?]. shoudian.bjx.com.cn/news/20161201/793150.shtml, accessed June 1, 2017.

Price Yearbook. 2011. 中国物价年鉴 *2011.* [China Price Yearbook 2011]. Beijing: Zhongguo wujia chubanshe.

Price Yearbook. 2014. 中国物价年鉴 *2014.* [China Price Yearbook 2014]. Beijing: Zhongguo wujia chubanshe.

Rawski, Thomas G. 2009. “Urban Air Quality in China: Historical and Comparative Perspectives.” In *Resurgent China: Issues for the Future.* Ed. Nazrul Islam. Houndmills and New York: Palgrave-Macmillan, pp. 353-370.

Rawski, Thomas G. 2015. “China’s Railways – another instance of large-scale excess costs?” Unpublished.

Samaras, Constantine, Jeffrey A. Drezner, Henry H. Willis, and Evan Bloom. 2011. “Characterizing the U.S. Industrial Base for Coal-Powered Electricity.” Santa Monica: RAND Corporation.

Shenzhen Grid Price. 2015. 深圳输配电价公布 成本测算中核减 1/4 资产 [Shenzhen Cost Estimates for Electricity Transmission and Distribution Remove one-fourth of Assets]. Accessed April 2, 2016 from http://www.nandudu.com/article/14810.

Shenzhen Grid Reform. 2015. “一分钱后的博弈，算清电网糊涂帐从深圳开始” [Game on following a one cent reduction – Shenzhen begins to decipher muddled grid accounts]. Accessed April 2, 2016 from http://www.wusuobuneng.com/archives/16489 .

Shepherd, Christian and Lucy Hornby. 2016. “Beijing Wind Energy Law Tested.” *Financial Times*, April 1, p. 3.

State Energy Administration 2015. 2013-2014 年度全国电力企业价格情况监管通报.［Nationwide supervisory report on electricity companies’ price conditions during 2013-2014]. Accessed December 21, 2015 from http://zfxxgk.nea.gov.cn/auto92/201509/t20150902_1959.htm

State Energy Administration. 2016. “2015 年全国 6000 千瓦及以上电厂发电设备平均利用小时情况”[2015 Average Operating Hours for Generation Equipment of 6000 kw and up]. Accessed March 13, 2016 from http://www.cec.org.cn/yaowenkuaidi/2016-01-29/148607.html

State Grid. 2012. 国家电网公司年鉴 2012*.* [State Grid Corporation of China 2012 Yearbook]. Beijing: Zhongguo dianli chubanshe.

Tang Yaojia 唐要家. 2014, "电价管制刚性的政治经济学逻辑"[Political Economy Logic of Rigid Electricity Pricing] 中国地质大学学报（社会科学版）14.4 (July 2014), p. 3

Thompson, P. "How Much did the Liberty Shipbuilders Learn," *Journal of Political Economy* 109.1 (2001): 103-137.

Thornton, R.A. and P. Thompson, "Learning from Experience and Learning from Others: An Exploration of Learning and Spillovers in Wartime Shipbuilding." *American Economic Review* 91.5 (2001): 1350-1368.

U.S. Bureau of Labor Statistics. 2011. May 2011 National Industry-Specific Occupational Employment and Wage Estimates: NAICS 221100 - Electric Power Generation, Transmission and Distribution (accessed 27 February 2015)

U.S. Bureau of Labor Statistics. 2014. Occupational Employment Statistics, May 2014:.http://www.bls.gov/oes/tables.htm

U.S. EIA. 2012. *Electric Power Annual 2012.*

U.S. EIA. 2014. *Electric Power Annual 2014.*

U.S. EIA. 2015a. *Electric Power Annual 2015.*

U.S. EIA. 2015b. U.S. Energy Information Administration. "Electricity. Detailed State Data. 1990-2013 Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860)." Accessed April 18, 2016 from https://www.eia.gov/electricity/data/state/ .

U.S. EIA. Monthly. *Monthly Energy Review.*

Wang Bingning 王冰凝. 2014. 电企盈利虚假繁荣 [Power Company Profits Show False Prosperity]. 华夏时报[Huaxia Times] January 24. http://www.chinatimes.cc/article/40810.html.

Wang Lu 王璐 and Yu Yao 于瑶. 2016. 产能过剩创纪录电企陷亏损 为抢市场仍大量投资 [Despite record excess capacity and company losses, power firms pursue big investment to capture the market]. 经济参考报 [Economic information news]. Posted August 22 and accessed September 11, 2016 at http://blog.china5e.com/jiangxiaojuzi/archives/10488.

Wang Peng 王鹏. 2017. 打破省间壁垒, 政企合力加快推动区域电力市场 [Let government and enterprise join to break the barriers between provinces and accelerate the promotion of cross-regional electricity markets]. 中国能源报 [China Energy Report]. June 19, p. 4.

Williams, James H. and Fredrich Kahrl. 2008. "Electricity reform and sustainable development in China." *Environmental Research Letters* 3 (2008) 044009.

Working Capital. 2016. 发电企业密集发债 补充流动资金 [Power Generation Firms issue debt to replenish liquidity]. 中国能源报 [China Energy Report]. September 19, p. 10.

Xiao Qiang 肖蔷. 2016. 国家建立风电投资监测预警机制 [Government establoishes monitoring and warning systems for wind power]. 中国能源报[China Energy Report]. July 25, p. 1.

Xie Guohui. 谢国辉. 2016. 大规模风电并网成本上升不容忽视 [Do not ignore large-scale cost increases from integrating wind power into the grid]. 中国能源报[China Energy Report]. March 7, p. 22.

Xu, Yi-chong. 2002. *Powering China: reforming the electric power industry in China.* Aldershot, Hants: Ashgate.

Xu, Yi-chong. 2004. *Electricity reform in China, India and Russia: the World Bank template and the politics of power.* Cheltenham and Northhampton. Edward Elgar.

Xu, Yi-chong. 2016. *Sinews of Power: The Politics of the State Grid Corporation of China.* Oxford and New York: Oxford University Press.

Yao Haitang 姚海棠. 2016. "不断破解无人机"成长"的密码 [Continue to Crack the Code for Expanded Use of Drones]. 中国能源报 [China Energy Report], April 18, p. 24.

Yao Jinnan. 姚金楠 2016. "发改委：配电价改革试点初见成效" [NDRC: Preliminary View of Results from Pilot Reforms to Pricing of Electricity Transmission and Distribution]. 中国能源报 [China Energy Report]. April 4, p. 2.

Yearbook. Annual. 中国统计年鉴 [China Statistical Yearbook]. Beijing: Zhongguo tongji chubanshe.

Yu Chunping 余春平. 2015."正视煤电科学发展面临的挑战 [Recognize the Challenges Facing the Science of Coal-fired Electricity]. 中国能源报 [China Energy Report]. January 12, p. 15.

Yu Menglin 于孟林. 2012. 煤炭物流高成本有望缓解 [High Cost of Shipping Coal May Ease]. 中国能源报 [China Energy Report], April 2, p. 17.

Yu Ning 于宁. 2014. "电改十二年为何理不清输配电价？"[Why This Disarray in Electricity Transmission and Distribution Price after 12 Years of Reform?]. Accessed January 25, 2016 from http://www.tgpcanada.org/news.aspx?vid=962.

Yuan Jiahai 袁家海 . 2016. 中国燃煤发电项目经济性研究 [Economic analysis of China's coal-fired thermal power generation projects]. Beijing: Greenpeace.

Zhang Shuwei 张树伟. 2015. 能源管理"量价分离"亟需改变 [Separation of Quantity and Price in energy management requires reform]. 中国能源报 [China Energy Report]. January 5, p. 4.

Zhang Shuwei 张树伟. 2016. “十三五”如何改善弃风限电? [How can we deal with abandoned wind power under the 13th Five-Year Plan?] 中国能源报 [China Energy Report]. October 10, p. 1.

Zhang Weirong 张维荣 . 2016. 中国火电产业发展概论 [Introduction to the development of China’s thermal power industry]. Beijing: China Electric Power Press.

Zhang Zirui 张子瑞. 2016a. 缺乏适宜国产机组掣肘海上风电 [Lack of suitable domestic equipment constrains offshore wind power]. 中国能源报 [China Energy Report]. March 7, p. 12.

Zhang Zirui 张子瑞. 2016b. “十三五”风电如何破茧重生 [How can wind power break out of the cocoon under the 13th Five Year Plan]. 中国能源报 [China Energy Report]. June 19, p. 18.

Zheng Xin. 2016. “Coal mines, utilities ink long-term price deal.” *China Daily*. November 10. Accessed November 12, 2016 from http://www.chinadaily.com.cn/business/2016-11/10/content_27329554.htm.

Zhu Xuehui 朱学蕊. 2016. “内陆核电：静候发令 蓄势待跑” [Inland nuclear power: when the order is issued, be ready to run]. 中国能源报 [China Energy Report]. September 5, p. 18.

Zhu Xuehui 朱学蕊. 2017. 核电“消纳症”仍待解 [Nuclear power absorption issue still awaits resolution]. 中国能源报 [China Energy Report]. February 13, p. 12.

Table 1

China and U.S. Electricity Price Comparison: Economy-wide and for Industrial Users, 2003-2014

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Unit prices and costs RMB per MWH													
Retail price economy-wide average	434.69	455.09	484.98	499.04	508.51	532.1	530.72	571.22	583.16	625.2	635.49	647.05	643.33
price for large-scale industry	426	457	485	516	523	536	555.32	617.72	718.61	770.41	652.47	655.86	643.97
Average On-grid Price	308.46	312.5	318.79	330.53	336.28	360.34	381.99	384.56	396.5	441.20	442.79	438.94	388.25
T&D Cost: RMB per MWH*	126.23	142.59	166.19	168.51	172.23	171.76	148.73	186.66	186.66	184.00	192.7	208.11	216.48
Percent of retail price	29.0	31.3	34.3	33.8	33.9	32.3	28.0	32.7	32.0	29.4	30.3	32.2	32.2
Exchange rate RMB/$ - MARKET	8.277	8.2768	8.1917	7.9718	7.604	6.9451	6.831	6.7695	6.4588	6.3125	6.1932	6.1581	6.228
PPP	*2.695*	*2.804*	*2.822*	*2.844*	*2.988*	*3.159*	*3.132*	*3.309*	*3.506*	*3.524*	*3.545*	*3.517*	*3.466*
China retail price ($ per MWH)													
Economy-wide	52.52	54.98	59.20	62.60	66.87	76.62	77.69	84.38	90.29	99.04	102.61	105.07	105.07
large-scale industry	51.47	55.21	59.21	64.73	68.78	77.18	81.29	91.25	111.26	122.05	105.35	106.50	106.50
PPP Economy-wide	*161.29*	*162.30*	*171.86*	*175.47*	*170.18*	*168.44*	*169.45*	*172.63*	*166.33*	*177.41*	*179.26*	*183.98*	*185.61*
PPP large-scale industry	*158.07*	*162.98*	*171.86*	*181.43*	*175.03*	*169.67*	*177.31*	*186.68*	*204.97*	*218.62*	*184.05*	*186.48*	*185.80*
US retail price ($ per MWH)													
Economy-wide	74.4	76.1	81.4	89	91.3	97.4	98.2	98.3	99	98.4	100.7	104.4	104.1
Industrial users	51.1	52.5	57.3	61.6	63.9	69.6	68.3	68.2	66.7	66.7	68.9	71	69.1
China average price, US=100													
Economy-wide	70.6	72.3	72.7	70.3	73.2	78.7	79.1	85.8	91.2	100.7	101.9	100.6	100.9
Industrial users**	100.7	105.2	103.3	105.1	107.6	110.9	119.0	133.8	166.8	183.0	152.9	150.0	154.1
PPP Economy-wide	*216.8*	*213.3*	*211.1*	*197.2*	*186.4*	*172.9*	*172.6*	*175.6*	*168.0*	*180.3*	*178.0*	*176.2*	*178.3*
PPP large-scale industry	*309.3*	*310.4*	*299.9*	*294.5*	*273.9*	*243.8*	*259.6*	*273.7*	*307.3*	*327.8*	*267.1*	*262.7*	*268.9*
Coal price indexes (2005=100)													
China mine-mouth price	82.5	85.6	100.0	105.0	109.0	116.5	110.2	118.8	125.9	123.7	121.4	108.0	92.2
Asian market price	59.1	117.1	100.0	91.3	136.8	239.4	127.4	170.5	203.3	170.6	147.0	126.0	102.7

*T&D Cost refers to unit cost for transmission and delivery of electricity.

** ratio of Chinese price for large industrial users to U.S. average for industrial users

Sources: U.S. data from U.S. EIA 2012 and 2014, Table 2.7 and 2015a, Table 2.4. Chinese price data for 2003-11 from Tang 2014, for 2013-2014 from State Energy Administration 2015.
for 2012: Chinese retail price and T&D cost from Chen 2015. Average on-grid price calculated as a residual. 2011/2012 price change for large-scale industry is assumed to be the same in percentage terms as the change in overall average retail prices.
for 2015: Chinese prices and T&D cost from Price Competition 2 2016, Price Competition 4 2016 and Price Competition 5 2016.

Exchange rates: Abstract 2014, p. 143; Abstract 2016, p. 167.

Coal prices: for Asian markets, from BP 2015, p. 30; 2015 figure based on price decline from US$77.89 to $63.52 between Dec. 2014 and Dec. 2015
See https://ww.quandl.com/data/BP/COAL_PRICES-Coal-Prices , accessed June 19, 2017.
For China, see Yearbook 2007, p. 333 (for 2003-2006); Price Yearbook 2011, p. 548 (for 2007-2010); Price Yearbook 2014, p. 573 (for 2010-2013); information for 2014-2015 from www.stats.gov.cn, accessed March 23, 2016.

Source for China PPP conversions: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm, accessed February 6, 2017.

Table 2
China Electricity - Rising Scale of Plant and Equipment, 2000-2014

A. Thermal Power Generation Facilities (MW)

Category	Thermal Generation Facilities 2000 Number of Units	Generating Capacity GW	Share (%)	Thermal Generation Facilities 2013 Number of Units	Generating Capacity GW*	Share (%)	Thermal Generation Facilities 2015 Number of Units	Generating Capacity GW	Share (%)
Total	5235	282.9	100.0	7223	851.6	100.0	7526	970.3	100.0
600 MW and above	22	13.2	4.7	529	349.2	41.0	609	416.4	42.9
300-599	291	96.8	34.2	919	298.1	35.0	1051	346.0	35.7
200-299	232	47.4	16.8	246	51.8	6.1	254	54.9	5.7
100-199	376	43.6	15.4	468	65.2	7.7	467	64.0	6.6
Under 100	4314	81.9	29.0	5068	87.4	10.3	5145	89.0	9.2

B. Length of Power Transmission Lines 35 kv and higher (1000 km)

	Transmission Lines 2000 Length (1000 km)	Share of Total %	Transmission Lines 2013 Length (1000 km)	Share of Total %	Transmission Lines 2015 Length (1000 km)	Share of Total %
Total	726.2	100.0	1554.0	100.0	1696.8	100.0
Under 220 kv	562.6	77.5	1010.0	65.0	1087.7	64.1
220 kv and up	163.6	22.5	544.0	35.0	609.1	35.9
of which: 1000 kv			1.9	0.1	3.1	0.2
±800			6.9	0.4	10.6	0.6
750			12.7	0.8	15.7	0.9
±600			1.4	0.1	1.3	0.1
500	26.8	3.7	146.2	9.4	169.8	10.0
330	8.7	1.2	24.1	1.6	26.8	1.6
220	128.1	17.6	339.1	21.8	380.1	22.4

* Total shown is sum of components; source showed a total of 848.9 GW

Sources: for 2000: China Electricity Yearbook 2001, pp. 668, 676.
for 2013: China Electricity Report 2014, pp. 53, 55.
for 2014: China Electricity Report 2015, pp. 61, 63.
for 2015: China Electricity Report 2016, pp. 67, 69.

Table 3

Technical Indicators for China's Electricity Sector, National Averages, 1965-2016

Year	Generating Plants: Annual Operating Hours, All Plants	Generating Plants: Annual Operating Hours, Thermal Plants	Internal Power use All plants %	Transmission & Distribution Loss %	Standard Coal Consumption grams per kWh: Generated	Standard Coal Consumption grams per kWh: Delivered	Aggregate Power Use Share Shipped Across: Provinces (percent)	Aggregate Power Use Share Shipped Across: Districts (percent)
1965	4920	n.a.	6.98	7.31	477	518	n.a.	n.a.
1975	5197	n.a.	6.23	10.21	450	489	n.a.	n.a.
1985	5308	n.a.	6.42	8.18	398	431	n.a.	n.a.
1995	5216	n.a.	6.78	8.77	379	412	n.a.	n.a.
2005	5425	5865	5.87	7.21	343	370	13.6	3.3
2006	5198	5612	5.93	7.04	342	367	n.a.	2.9
2007	5020	5344	5.83	6.97	332	356	11.8	3.0
2008	4648	4885	5.90	6.79	322	345	12.9	3.1
2009	4546	4865	5.76	6.72	320	340	14.3	3.3
2010	4650	5031	5.43	6.53	312	333	14.0	3.5
2011	4730	5294	5.39	6.52	308	329	13.3	3.6
2012	4579	4965	5.10	6.74	305	325	14.4	4.1
2013	4521	5012	5.05	6.69	302	321	14.8	4.6
2014	4318	4739	4.83	6.64	300	319	15.6	5.4
2015	3969	4329	5.90	6.41	297	315	15.3	5.6
2016	3785	4165	n.a.	6.47	n.a.	312	15.3	5.7

Sources:

Except as noted, data for 1965-2014 are from
http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2015-11-30/146012.html , accessed December 19, 2015.

Thermal plant operating hours for 2005-2012 from Zhang Weirong (2016, p. 48); for 2013-2015 from Han 2016.

Data in the two right-hand columns calculated from information in Electricity Yearbook 2006, p. 39 and 2010, p. 34; China Electricity Report 2015, pp. 74, 93; Electricity Databook 2011, p. 64; 2012, p. 58; 2014, p. 50 and 2015, pp. 41, 48, 50.

Data for 2015-2016 in the six left-hand columns are from Power Equipment Review 2017; Price Competition 1 2016; Power Sector Preview 2016; Electricity Databook 2015, p. 6; and Electricity Outcome 2016.

n.a. indicates values for which the author has found no data.

Table 4

Power System Reliability and Access Compared: China, Brazil, India, Russian Federation, 2012-2014

Category	China 2012	Brazil 2009	India 2014	Russia 2012
Number of outages in a typical month	0.1	1.6	13.8	0.3
Days to obtain an electricial connection	6.9	27.7	21.9	120.4
Percent of firms				
Owning or sharing a generator	8.0	7.9	46.5	8.9
Identifying electricity supply as a major constraint	1.8	46.0	21.3	23.1
Rural electrification rate, 2013 (percent)	100.0	97.0	74.0	100.0

Sources: World Bank Enterprise Survey Data https://www.enterprisesurveys.org/data/exploreTopics/Infrastructure#all-countries--7
accessed March 31, 2016

Rural electrification: http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/
Russia access: http://data.worldbank.org/indicator/EG.ELC.ACCS.ZS

Table 5
China and U.S. Electricity Comparison for 2011

	Unit	U.S.	China Power Sector Value	China Power Sector Index with U.S. = 1
Electricity Output	Bill. Kwh	4,100	4,713	1.15
Power Generating Capacity	GW	1164.0	1062.5	0.91
Workers	1000s	395.7	2,589.0	6.54
Electricity output per man-year	MWH	10361	1820	0.18
Electricity output per GW of capacity	Bill. Kwh	3.5	4.4	1.26
Installed capacity per 1,000 workers	GW	2.94	0.41	0.14
Annual Average Wage	US$	66,830	*8,763*	0.13
	RMB		56,600	
Annual Wage Bill	Bill. US$	26.4	*22.6*	0.86
	Bill. RMB		145.8	
Sales Revenue	Bill. US$	371.0	*455.5*	1.23
	Bill. RMB		2941.8	
Wages as percent of sales	percent	7.1	5.0	0.70

note: figures in *italics* converted at the average exchange rate for 2011 (Abstract 2016, p. 167):
US$1 = RMB 6.4588

Sources:
output and installed capacity: see sources for Figure 1
labor and wages: Labor Yearbook 2012, Table 3.02b; U.S. Bureau of Labor Statistics 2011
sales revenue: Chinese data (adjusted to avoid double counting) from Table A-1;
U.S. data from U.S. EIA (2012), Table 1.1.

Table 6

Profitability of Chinese and U.S. Electric Utilities Compared, 2005-2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average	Median
China Electric Power Sector (Billion RMB)													
Sales revenue - as reported [S]	1774.6	2151.8	2636.8	2975.0	3331.7	4044.9	4716.5	5127.4	5593.9	5931.5	5493.1		
Sales revenue - net of double counting [S']	1024.3	1260.8	1597.6	1799.4	1994.4	2514.9	2948.4	3039.1	3310.4	3510.8	3396.1		
Assets [A]	3937.5	4645.7	5348.5	6223.8	6908.7	7672.5	8382.1	9207.3	10246.8	10376.2	11934.4		
Profit [π]	115.8	168.9	198.2	50.9	120.6	196.8	192.7	274.6	394.4	418.6	457.4		
Sales cost (= S' - π)	908.6	1091.8	1399.4	1748.6	1873.8	2318.1	2755.8	2764.5	2916.0	3092.2	2938.6		
China sector profit margin (%) = 100*π/S'	**11.30**	**13.40**	**12.41**	**2.83**	**6.05**	**7.83**	**6.53**	**9.03**	**11.91**	**11.92**	**13.47**	**9.70**	**11.30**
Pre-tax return on assets (ROA, %) = 100*π/A	**2.94**	**3.64**	**3.71**	**0.82**	**1.75**	**2.57**	**2.30**	**2.98**	**3.85**	**4.03**	**3.83**	**2.95**	**2.98**
Major investor-owned U.S. electric utilities ($ Mill.)													
Electric Utility Operating Revenues	234,909	246,736	240,864	266,124	249,303	260,119	255,573	249,166	257,718	271,832	260,121		
Electric Utility Operating Costs	207,830	218,445	213,076	236,572	219,544	234,173	228,873	220,722	227,483	240,643	228,366		
Electric Utility net operating income	27,079	28,291	27,788	29,552	29,759	25,946	26,700	28,444	30,235	31,189	31,755		
U.S. electric utility profit margin (%)	**11.53**	**11.47**	**11.54**	**11.10**	**11.94**	**9.97**	**10.45**	**11.42**	**11.73**	**11.47**	**12.21**	**11.35**	**11.47**
U.S. pre-tax return on assets (ROA, %)*	**3.60**	**4.43**	**5.09**	**5.00**	**4.25**	**4.53**	**4.56**	**3.05**	**3.38**	**3.73**	**3.37**	**4.09**	**4.25**
Ratio: U.S. to Chinese electric utility profit margins	**1.02**	**0.86**	**0.93**	**3.93**	**1.97**	**1.27**	**1.60**	**1.26**	**0.98**	**0.96**	**0.91**	**1.43**	**1.02**
Ratio: U.S. to Chinese electric utility pretax ROA	**1.22**	**1.22**	**1.37**	**6.12**	**2.43**	**1.77**	**1.98**	**1.02**	**0.88**	**0.93**	**0.88**	**1.89**	**1.30**

Sources: Chinese data on sales revenue, assets and profits for 2005-2011 from Industrial Economy, various issues; for 2012 and 2013, from Industrial Statistics 2013 and 2014.
2014 data from China Electricity Report 2015, p. 136 (assets), p. 137 (profits)
2014 sales revenue S calculated from 2013 figure using annual change in retail price (Table 1) and 4.14% rise in nationwide power consumption (China Electricity Report 2015, p. 93).
2015 data for sales revenue （主营业务收入), assets and profits (营业利润）from Industrial Statistics 2015 i: 68, 99, and 129.

Adjusted sales [S'] to eliminate double counting from Appendix Table A-1.

U.S. data: ROA from Appendix Table A-2; other data from U.S. EIA 2015a, Table 8.3.

Note: the Chinese data exclude "below norm" firms with annual sales less than RMB 5 million (RMB 20 million beginning in 2011)
and, for some years, include firms that produce heat; both components are small.

Table 7

Depreciation Allowances for China Electric Power Sector, 2005-2014
(billion RMB and percent)

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Accumulated depreciation	1116.5	1324.2	1558.2	1927.9	2114.6	2517.2	2944.7	3324.0	3704.5	4284.3	4729.9
Current year depreciation											
Annual amount											
Reported	192.9	230.5	271.3								
Derived		207.7	234.0	369.7	186.7	402.6	427.5	379.3	380.5	579.8	445.6
Percent change from previous year											
Depreciation											
Reported		19.5	17.7								
Derived			12.7	58.0	-49.5	115.7	6.2	-11.3	0.3	52.4	-23.1
Comparison: annual percent change in											
Power generating capacity	14.9	22.3	14.7	11.1	10.3	14.0	6.6	7.9	8.8	9.0	10.6

Sources:
Depreciation data for 2005-2011 from annual issues of Industrial Economy; for 2012-14, from Industrial Statistics 2013, 2014 and 2015, i: 79 in each case.
for 2015 from Industrial Statistics 2016, i: 69.
Annual change in capacity computed from sources underlying Figure 1; for 2015, from Electricity Databook 2015, p. 3.

Table 8

China Electricity Excess Cost Analysis, 2005-2014

Year	Industry Share in Electricity Use %	Percentage Cost Reduction Needed to Achieve: 11 percent Profit/Sales Ratio — Version [A] Current Retail Prices	Version [B] 40% price reduction for industry	Version [C] 33% price reduction for all users	4.0 percent Return on Assets — Version [A] Current Retail Prices	Version [B] 40% price reduction for industry	Version [C] 33% price reduction for all users	Cost Reduction to Attain 4.0% ROA (RMB billion) — Version [A] with Current Retail Prices	Version [B] 40% price reduction for industry	Version [C] 33% price reduction for all users
2005	74.3	-0.3	29.5	32.8	4.6	38.1	41.8	41.7	346.0	379.8
2006	74.4	-2.8	27.8	31.1	1.5	35.9	39.7	16.9	392.1	432.9
2007	74.3	-1.6	28.6	31.9	1.1	35.0	38.8	15.7	490.2	542.9
2008	73.5	8.4	35.3	38.6	11.3	41.6	45.3	198.1	727.1	791.9
2009	72.5	5.3	32.8	36.5	8.3	39.2	43.4	155.8	734.3	813.9
2010	73.8	3.4	32.0	35.3	4.7	36.8	40.5	110.1	852.7	940.0
2011	72.7	4.8	32.5	36.2	5.2	36.3	40.5	142.6	1000.5	1115.6
2012	72.7	2.2	30.6	34.4	3.4	35.4	39.7	93.7	978.0	1096.6
2013	72.4	-1.0	28.2	32.3	0.5	33.4	38.0	15.5	973.6	1107.9
2014	70.7	-1.1	27.5	32.2	-0.1	32.0	37.4	-3.6	983.8	1148.6
2015	71.6	-2.9	26.6	31.1	0.7	33.8	38.8	19.9	992.1	1140.6
Average	73.0	1.3	30.1	33.9	3.8	36.1	40.4	73.3	770.0	864.6
Median	72.7	-0.3	29.5	32.8	3.4	35.9	39.7	41.7	852.7	940.0

Sources:

Calculated from data on adjusted sales S', profits π, and sales costs (= S'-π) from Table 6. For industry's share in electricity use, see Energy Yearbook 2011, pp. 82-83 (for 2005-2010); China Electricity Report 2013, p. 79 (for 2011-2012); ibid. 2014, pp. 87-88 (for 2013) Electricity Operations 2014 (for 2014); China Electricity Council 2015 (for 2015).

Table 9

China and U.S. Electricity Sectors: Employment and Proportion of Managers, 2014

	Employment (1000s)	Of which: managers (percent)	number (1000s)
China: Electric Power Sector	**2600.1**		
Total for 16 large firms	**2084.2**	**17.76**	**370.1**
Five Big Generation Firms	**589.8**	**17.95**	**105.9**
Huaneng	139.9	12.26	17.2
Datang	103.8	16.39	17.0
Huadian	104.6	22.76	23.8
Guodian	128.3	18.25	23.4
CPI	113.2	21.65	24.5
Two Major Grid Firms	**1067.3**	**15.61**	**166.6**
State Grid	785.0	17.95	140.9
Southern Grid	282.3	9.11	25.7
Regional Electricity Firms	**43.7**	**20.80**	**9.1**
Guangdong Power	13.7	27.49	3.8
Neimengu Power	17.6	11.37	2.0
Shaanxi Power	12.4	26.80	3.3
Construction Firms	**343.4**	**24.62**	**84.5**
China Electric Construction	188.5	25.30	47.7
China Energy Construction	143.5	22.74	32.6
Beijing Energy Investment	11.4	36.96	4.2
Others	**40.0**	**9.79**	**3.9**
China National Nuclear	8.9	14.24	1.3
China General Nuclear	29.8	7.69	2.3
Shenhua Energy	1.3	27.49	0.4
U.S: Electricity Generation & Transmissio	**389.8**	**6.77**	**26.39**

Sources:

China: sector-wide data: 2014 employment calculated from 2013 figure assuming the same percent change for electric power as reported for combined employment in electricity-heat-water-gas on NBS web site, consulted March 27, 2016.

Firm-level data from China Electricity Report 2015, p. 273.

U.S. data: U.S. Bureau of Labor Statistics 2014

Table A-1

Chinese Electricity Industry Sales Revenue Adjusted to Avoid Double Counting, 2005-2015

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Reported Sales Revenue S (RMB Billion)	1774.6	2151.8	2636.8	2975.0	3331.7	4044.9	4716.5	5127.4	5593.9	5931.5	5493.1
Power output Q (Bill. KWh)	2,500.3	2,865.7	3,281.6	3,466.9	3,714.7	4,207.2	4,713.0	4,987.6	5,431.6	5,794.5	5739.9
Self consumption share c (%)	5.87	5.93	5.83	5.90	5.76	5.43	5.39	5.10	5.05	4.83	5.9
Power supplied to Grid (Bill. KWh) = .01*Q*(100-c)	2353.5	2695.8	3090.2	3262.3	3500.9	3978.5	4459.1	4733.2	5157.1	5514.7	5401.2
On-grid price P (RMB per MWh)	318.79	330.53	336.28	360.34	381.99	384.56	396.5	441.20	442.79	438.94	388.3
Double counting D (RMB Bill.) D =.001*Q*(100-c)*P	750.3	891.0	1039.2	1175.6	1337.3	1530.0	1768.0	2088.3	2283.5	2420.6	2097.0
Adjusted Sales Revenue S' without double counting S' = S - D (RMB Billion)	1024.3	1260.8	1597.6	1799.4	1994.4	2514.9	2948.4	3039.1	3310.4	3510.8	3396.1
Reported industry-wide profit π (RMB Bill)	115.8	168.9	198.2	50.9	120.6	196.8	192.7	274.6	394.4	418.6	457.4
Assets A (RMB billion)	3937.5	4645.7	5348.5	6223.8	6908.7	7672.5	8382.1	9207.3	10246.8	10376.2	11934.4
Profitability											
Profit/Adjusted sales revenue (%) =100*π/S'	11.30	13.40	12.41	2.83	6.05	7.83	6.53	9.03	11.91	11.92	13.47
ROA (%) = 100*π/A	2.94	3.64	3.71	0.82	1.75	2.57	2.30	2.98	3.85	4.03	3.83

Sources: P is the average on-grid price from Table 1; for S, A and π, see Table 6.
Q: Yearbook 2016, Table 13-13; for 2015, Electricity Databook 2015, p. 2.
c: Author's file "Basic Indicators" with data from http://www.cec.org.cn/guihuayutongji/tongjxinxi/niandushuju/2015-11-30/146012.html; for 2015, Price Competition 1 (2016).

Table A-2

Average Return on Assets (ROA) for U.S. Investor-owned Electric Utilities, 2005-2014

Amounts in $1000s

Symbol	**Name**	2014 Sales $ Billion	2014 revenue share	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	2014 income before tax	2014 income tax	2014 tax rate
AEE	Ameren	6.05	0.02074191	3.40	2.90	3.07	2.79	2.64	0.59	2.20	-4.25	1.34	2.70	2.69	970000	377000	0.39
AEP	American Electric Power	17.02	0.05835162	2.30	2.70	2.78	3.24	2.91	2.46	3.79	2.36	2.67	2.82	3.33	2490000	942000	0.38
CMS	CMS Energy	7.18	0.02461602	-0.53	-0.50	-1.45	2.03	1.52	2.20	2.59	2.28	2.62	2.61	2.45	729000	250000	0.34
CNP	CenterPoint Energy	9.23	0.03164427	1.43	2.49	2.25	2.38	1.89	2.22	6.49	1.87	1.39	2.71	0.00	885000	274000	0.31
D	Dominion Resources	12.44	0.04264948	2.11	2.71	5.74	4.52	3.04	6.58	3.18	0.65	3.50	2.51	3.27	1780000	452000	0.25
DTE	DTE Energy	12.3	0.0421695	2.41	1.84	4.09	2.26	2.18	2.57	2.79	2.33	2.53	3.36	2.51	1280000	364000	0.28
DUK	Duke Energy	23.93	0.08204196	3.30	3.02	2.53	2.65	1.95	2.27	2.81	2.00	2.33	1.60	2.34	4130000	1670000	0.40
ED	Consolidated Edison	12.92	0.04429512	3.03	2.86	3.38	3.91	2.61	2.86	2.81	2.84	2.59	2.58	2.61	1660000	568000	0.34
EIX	Edison International	13.41	0.04597504	3.34	3.32	2.98	2.96	1.97	3.01	0.05	-0.20	2.23	3.58	2.22	1980000	443000	0.22
ES	Eversource Energy	7.74	0.02653593	-2.05	3.99	2.15	2.08	2.35	2.72	2.62	2.39	2.80	2.85	2.91	1300000	468300	0.36
ETR	Entergy	12.49	0.0428209	3.04	3.66	3.51	3.53	3.37	3.33	3.44	2.07	1.69	2.14	0.00	1550000	589600	0.38
EXC	Exelon	27.43	0.09404142	2.16	3.65	6.10	5.89	5.60	5.05	4.65	1.74	2.17	1.95	2.41	2490000	666000	0.27
FE	FirstEnergy	15.05	0.05159764	2.74	3.98	4.12	4.08	2.97	2.15	2.16	1.57	0.78	0.59	1.11	171000	-42000	-0.25
LNT	Alliant Energy	3.35	0.01148519	-0.10	4.26	5.96	3.99	1.50	3.34	3.39	3.28	3.44	3.39	3.10	440000	44300	0.10
NEE	NextEra Energy	17.02	0.05835162	2.94	3.72	3.46	3.86	3.46	3.86	3.49	3.14	2.85	3.43	3.35	3650000	1180000	0.32
PCG	PG&E	17.09	0.05859161	2.67	2.88	2.82	3.49	2.94	2.50	1.79	1.62	1.53	2.51	1.40	1800000	345000	0.19
PEG	Public Service Enterprise	10.89	0.03733544	2.24	2.53	4.70	4.14	5.52	5.34	5.03	4.14	3.87	4.48	4.47	2460000	938000	0.38
PNW	Pinnacle West Capital	3.49	0.01196517	1.66	2.87	2.72	2.13	0.58	2.87	2.66	2.88	3.02	2.86	3.04	644400	220700	0.34
PPL	PPL	11.5	0.03942677	3.80	4.39	6.58	4.50	1.87	3.41	3.96	3.54	2.51	3.66	1.74	2130000	690000	0.32
SCG	SCANA	4.95	0.01697065	3.45	3.21	3.20	3.26	3.03	3.00	2.92	2.98	3.16	3.36	2.80	786000	248000	0.32
SO	Southern	18.47	0.06332282	4.14	3.80	3.91	3.84	3.40	3.81	3.97	3.95	2.68	3.01	3.11	3010000	977000	0.32
SRE	Sempra Energy	11.04	0.0378497	3.47	4.83	3.81	4.08	4.11	2.55	4.22	2.48	2.74	3.02	3.53	1520000	300000	0.20
WEC	WEC Energy Group	5	0.01714207	3.08	2.93	2.94	2.95	3.02	3.54	3.91	3.88	3.98	3.97	2.18	950000	361700	0.38
XEL	Xcel Energy	11.69	0.04007817	2.45	2.63	2.56	2.68	2.71	2.87	2.96	2.99	2.92	2.88	2.52	1550000	523820	0.34
SUM of 2014 Revenues		291.68	1														
Annual average ROA (%)																	
After-tax: unweighted				2.35	3.11	3.50	3.38	2.80	3.13	3.25	2.19	2.56	2.86	2.46			0.29
After tax: 2014 sales weights				2.59	3.19	3.67	3.60	3.06	3.26	3.28	2.19	2.43	2.69	2.43			0.28
Pre-tax ROA assuming 28% tax rate				**3.60**	**4.43**	**5.09**	**5.00**	**4.25**	**4.53**	**4.56**	**3.05**	**3.38**	**3.73**	**3.37**			

Summary	Unweighted	Sales Wts
After-tax ROA for 24 firms, 2005-2015		
Average ROA	2.87	2.94
Median ROA	2.86	3.06
Coefficient of variation	0.15	0.17

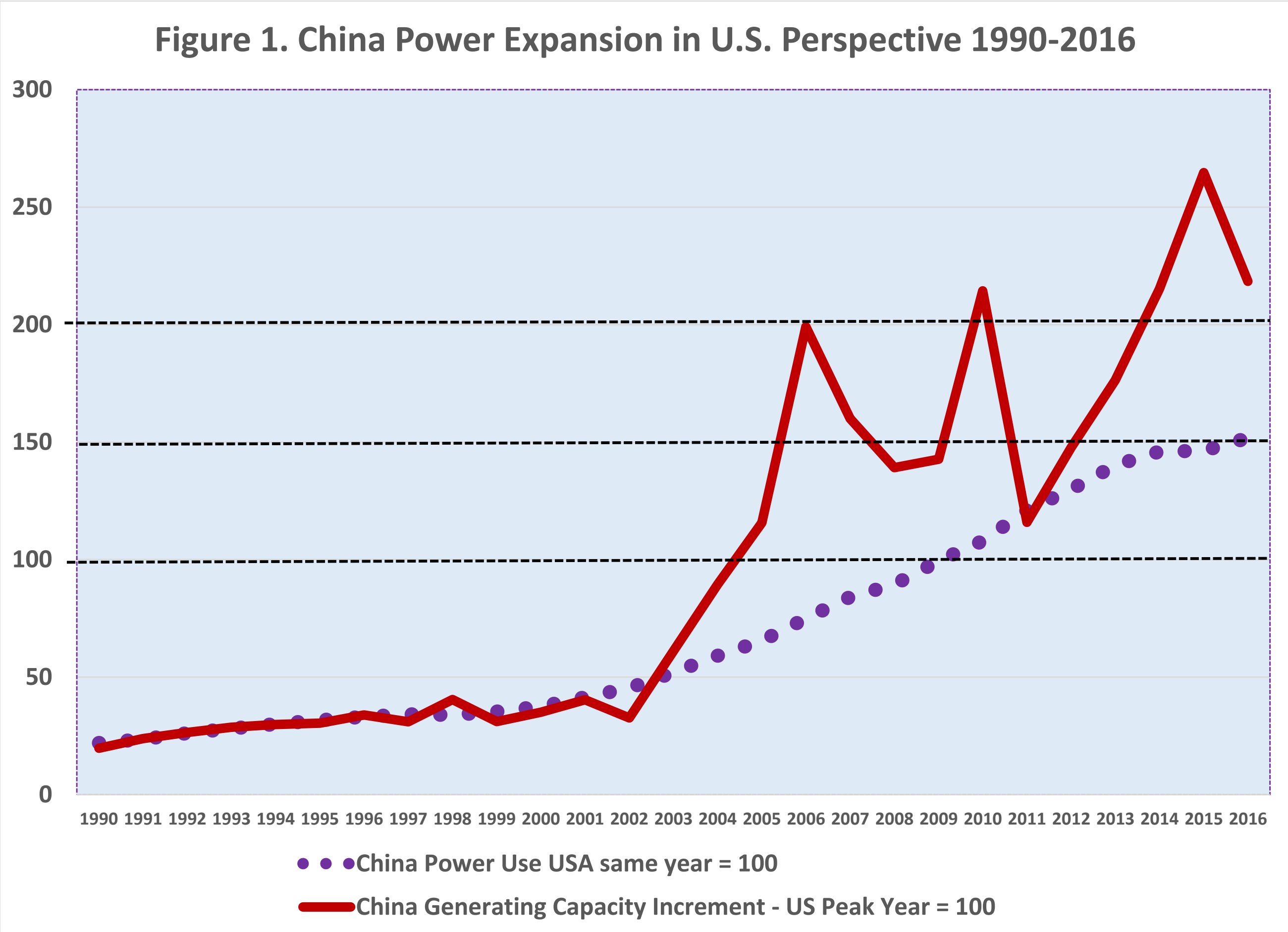


Figure 1. China Power Expansion in U.S. Perspective 1990-2016
300
250
200
150
100
50
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
China Power Use USA same year = 100
China Generating Capacity Increment - US Peak Year = 100

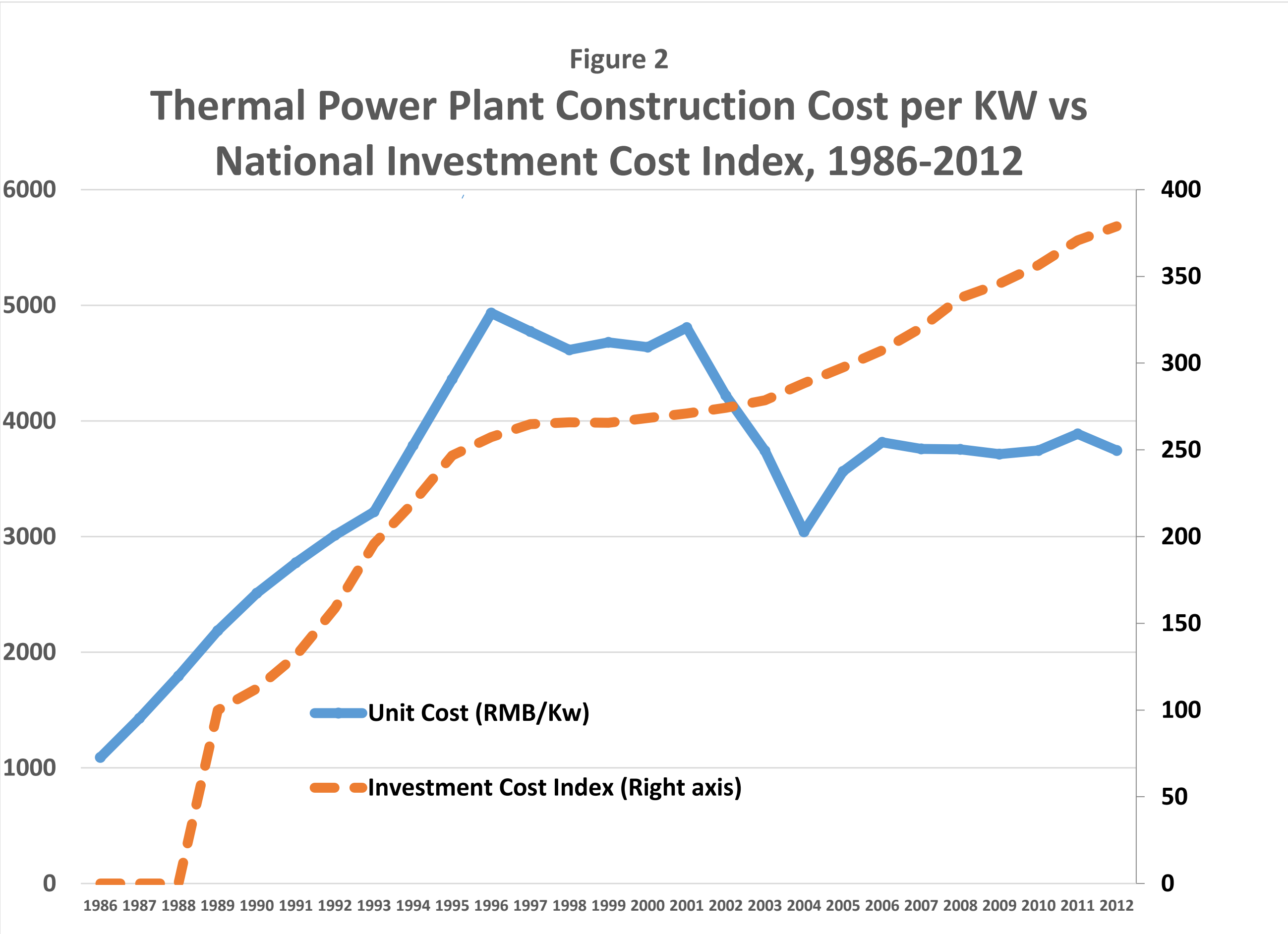
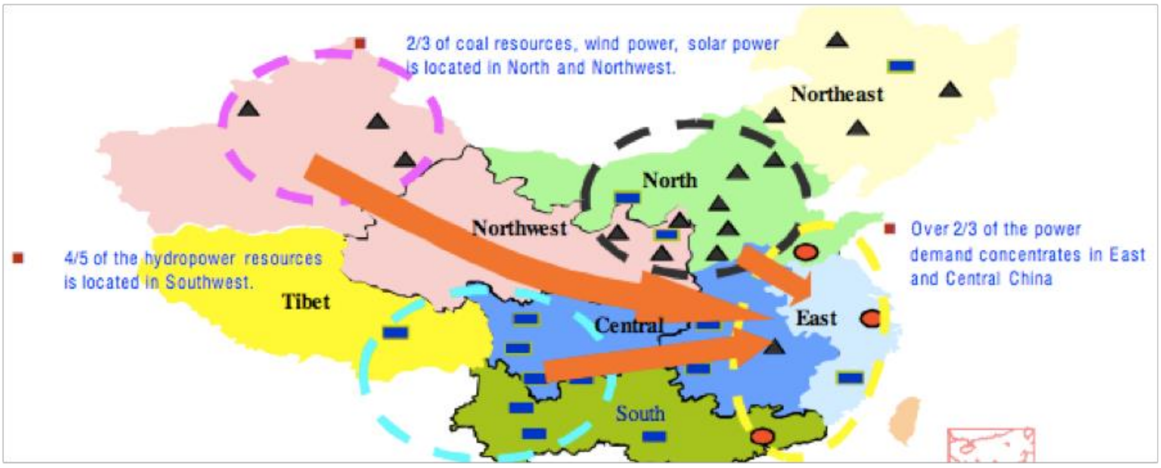


Figure 2
Thermal Power Plant Construction Cost per KW vs National Investment Cost Index, 1986-2012
6000
5000
4000
3000
2000
1000
0
400
350
300
250
200
150
100
50
0
Unit Cost (RMB/Kw)
Investment Cost Index (Right axis)
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

Map 1. China Energy Geography



Map 2. China's Major Grid Systems

Source:
https://www.google.com/imgres?imgurl=http://www.etransition.org/images/stategridmap.png&imgrefurl=http://www.etransition.org/images/programssmartgrid.html&h=358&w=900&tbnid=wvwedD74z1wsLM:&docid=OGJWuLRExO8fcM&ei=7Br8VrVvzJiZAa3JrsAE&tbm=isch&ved=0ahUKEwi1la-OhenLAhVMTCYKHa2kC0gQMwgdKAAwAA#h=358&w=900, accessed March 30, 2016