8. China's Electricity Sector

Powering growth, keeping the lights on and prices down

Stephen Wilson, Yufeng Yang and Jane Kuang[1]

Introduction and historical context

Electricity is essential for both human and national development. China's leaders—many of them engineers—have long understood this. Indeed, improved and increased electricity supply were integral to at least two of the 'four modernisations' in Deng Xiaoping's landmark closing speech at the Third Plenary Session of the Eleventh Party Congress on 18 August 1977.

At the founding of the People's Republic in 1949, China had just 1.85 GW of installed electricity generation capacity and a population of more than 540 million (Jowett 1984). To put this in context, 1.85 GW is less than 2,000 MW—the capacity of a typical modern large coal-fired or nuclear power plant with two units. By 1982, China's installed power generation capacity had reached 50 GW for a population that passed the 1 billion mark in that census year (Jowlett 1984), about 800 million of whom lived in rural areas with limited or no access to electricity (Peng and Pan 2006, citing the in-depth chapter on China in IEA 2002).

By 1990, according to UN data, installed generation capacity had reached 138 GW, and according to the World Bank, more than 94 per cent of the population had access to electricity. In 2011, China's installed generation capacity passed the 1,000 GW mark, and has since overtaken the United States to become the largest power system in the world. By 2010, the World Bank reported near-universal electricity access of 99.7 per cent in China—equal to the rate across Organisation for Economic Cooperation and Development (OECD) countries.

1 This chapter is dedicated to the memory of Wang Leiping (1963–2015), a former energy specialist at the World Bank in Washington, DC. Stephen Wilson first met Leiping in 1997 while he was director of the Beijing Economic Research Institute for Water Resources and Electric Power (BERI), where he provided expert advice on the planning of much of China's generation and transmission system. This chapter reflects a number of things Leiping taught Stephen about China's power sector when they worked together at ERM Energy, and which have stood the test of time. The authors also acknowledge research support on the international comparators from Parth Goyal of Rio Tinto India. Any errors are the responsibility of the authors.

China's electricity sector faces the competing challenges of powering economic growth and development, and keeping the lights on and prices down. To explore how China's policymakers and companies respond to these challenges and to understand the likely future development of China's electricity sector, it is helpful to review how China made the journey from extremely limited electricity availability to universal access, driving a modern-day industrial revolution in the process.

A hydrothermal power system

While coal is the foundation fuel of China's power system today—and coal has been a vital energy source in China for hundreds of years—China's national vision for electricity has long included hydropower as a key source of supply, along with electricity for all and to power modern industry. Sun Yat-sen originally envisioned a large dam across the Yangtze River in 1919, and estimated its capacity as 22 GW. The 22.5 GW Three Gorges Dam is the world's largest power station and China's flagship hydropower project. Construction began in 1994 and the dam opened in 2008. The importance of hydropower was reflected in the name of the former Ministry of Water Resources and Electric Power, which was responsible for the electrification of the People's Republic of China (PRC) as a catalyst for industrialisation.

China has a hydrothermal power system: approximately 75 to 80 per cent coal-fired (thermal) and 15 to 20 per cent hydropower. While this chapter is about electricity, it is important to note that large-scale hydropower in China is not primarily about electricity generation. The dams are first and foremost about flood control—China has had devastating floods, killing large numbers of people and destroying livelihoods.

During the more than 2,000 years between the Han Dynasty (206 BC – 220 AD) and the Qing Dynasty (1644–1911), floods occurred on the Yangtze River nearly once every 10 years. During the past 300 years, severe floods breached the Jingjiang Dam 60 times, and disastrous floods struck twice in the past 100 years. Floods have been a persistent problem for residents and businesses along the Yangtze and for the Chinese Government (Chinese Embassy to the United States n.d.).

The dams are secondarily about irrigation and then about improved river navigation. Finally, electricity generation provides a revenue stream that enables the financing of the major capital works required to build the multipurpose dams on China's many rivers.

The purely hydrothermal structure of China's power sector has begun to change with the introduction of other forms of generation, including nuclear and gas-fired power plants and various forms of intermittent renewable energy, including solar and wind power. The first nuclear power plant was built at Daya Bay in Guangdong, near Hong Kong, in the 1990s. Yet even with the largest nuclear building program the world has yet seen planned or in progress, nuclear today comprises only a few per cent of national generation capacity. Similarly, natural gas-fired capacity—complementing coal in the thermal side of the system—is used mainly for electricity generation at peak times, due to the limited supply of gas from domestic sources and the relatively high cost of gas imported as liquefied natural gas (LNG) or via long-distance pipelines from Central Asia, South-East Asia and, in the future, from Russia. China's policies to provide financial encouragement for wind and solar power have stimulated one of the largest renewable energy programs in the world, but these sources also provide a small share of overall electricity generation.

Structure of this chapter

This chapter is organised as follows:

- The current situation and some of the challenges facing China's power sector are described, the evolution of China's electricity sector in the past 30 years and reforms undertaken to date are summarised, and the key policy issues facing the sector and how they have been managed so far are discussed.
- Selected international comparisons are drawn between China and other significant countries both in terms of the physical power systems and in terms of approaches to policy and regulation, with a particular focus on the experience of the United Kingdom and reference also to Australia.
- A framework for analysing ownership structures and regulatory approaches is defined.
- The chapter concludes with the policy choices available for China's power sector.

The current situation and some of the challenges facing China's power sector

The physical system

China, with 1.4 billion people, already has the largest power system in the world, with 1,260 GW of installed generation capacity (as of June 2014), having overtaken the United States, which has 1,040 GW for 325 million people. And yet, based on international electricity per capita indices (see Wensley et al. 2013) and conservative projections of gross domestic product (GDP) growth and energy efficiency improvements, China's system is still only half-developed, if that.

Zhou, X. (n.d.) noted that '[t]he construction of the Three Gorges Hydropower Project will further push forward the implementation of the nationwide interconnection program'. Not only is the Three Gorges power station large and, like all hydropower projects, fully flexible in its ability to ramp its output up and down almost instantaneously, it is also located in an advantageous central position in the emerging national grid (Figure 8.1).

Figure 8.1 The central location of the Three Gorges Dam

Source: image.baidu.com/.

Zhou, X. (n.d.) went on to write that '[t]he first 10–15 years of the 21st century will be a key period to form a nationwide interconnected grid. By the year[s] 2010–2020, a nationwide interconnected grid will be basically established, which will cover major regional and provincial power grids.' This transpired as expected: substantial progress has been made towards the vision of a single national grid, with alternating current (AC) interconnectors between a number of the regional grids, as well as long-distance ultra-high voltage (UHV) direct current (DC) lines, particularly from hydro projects in the south-west to large coastal demand centres, including Shanghai and Guangzhou.

Yet, in common with most other Chinese and foreign experts at the time, Zhou, X. (n.d.) also wrote, '[i]t is predicted that the nation's total installed capacity will reach 500GW in the year 2010 … [and] a total installed capacity of about 750GW by the year 2020'. The 2010 estimate turned out to be about half of the actual result, and the 2020 projection also looks like being only half or less of the likely outcome.

The sectoral structure of electricity consumption in China is approximately 70 per cent industrial, 20 per cent commercial and 10 per cent residential. In developed economies, the shares are approximately equal. Commercial and residential loads are more temperature sensitive and also vary more by season and throughout 24 hours in a day than does industrial load, which is relatively constant in aggregate.

With commercial and residential consumption expected to grow faster than industrial consumption in China in coming decades, proportionately greater demands will be placed on generation and transmission capacity, which consequently will become more valuable. The ability of the system to cope with seasonality and peak demands will become increasingly important.

Compounding these challenges, an increasing proportion of electricity coming from intermittent (wind and solar) and non-variable (nuclear) sources generates challenges for stability of the grid (Garnaut 2014: 11). Also with China moving to the new model of economic growth, it envisages a decline in the contribution of growth in the labour force and capital stock, leading to overall growth several percentage points lower than in the first decade of the century. The focus on increased productivity includes efforts to improve the efficiency with which energy is used, to reduce the amount of energy consumed in producing each unit of economic output.

Many of the structural changes embodied in the new model of economic growth have large and favorable implications for greenhouse gas emissions (Garnaut 2014: 7). Hence any reforms and regulatory mechanisms implemented will need to be appropriate for this reality.

Development of the regulatory system and reforms to date

Xu and Chen (2005) identify three phases in the development of the regulatory system of the power industry in China:

- phase I, 1949–85—power industry as state monopoly: the unification of government and business functions
- phase II, 1985–97—the unification of government and business functions with the gradual opening of the power generation market
- phase III, 1998–2002—separating the functions and responsibilities of the government from those of commercial enterprises, and establishing market mechanisms for the power industry in some pilot provinces and cities.

As Deng Xiaoping said, '[r]eform is China's second revolution'. Since the mid-1980s, the Chinese Government has carried out a series of power sector reforms. Xu and Chen (2005) comment on the success of these reforms:

> In China, the power industry has gone through a series of changes since 1985, including: the termination of the monopoly of 'exclusive investment in power generation', which existed for over 30 years during China's planned economy period; the gradual opening of the power generation market; and the introduction of new investment and operation entities to relieve the power shortage that had been hindering the development of the Chinese economy. Such changes led to the remarkably rapid development of China's power industry. For example, the demands for electricity have been largely met. (pp. 2458–2459)

The first major step in the reform process was corporatisation. Following the enactment of the Electric Power Law of the PRC in 1996:

> In 1997, the Chinese government took more radical steps to reform the power industry, particularly with respect to separating business operations and management from government oversight and guidance. The governmental functions of the former Ministry of Electric Power were divided between the State Power Corporation of China (which was newly established) and the State Economic and Trade Commission. (Xu and Chen 2005: 2459)

Towards the end of phase I, in 1980, during the early years of Deng's 'second revolution', the first China–Hong Kong power sector joint venture was proposed, which led to the 1,980 MW Daya Bay nuclear power plant in Guangdong with CLP Group and CGN Power.

The early stages of phase II saw five projects for a total of 3,950 MW by about 1991. All of these were greenfield projects, and most were joint ventures (JVs), including Shiajiao B by the Hopewell Corporation from Hong Kong, the first build-operate-transfer (BOT) power project in China. The latter part of phase II, from the early 1990s to the late 1990s, saw a stampede of foreign independent power producers (IPPs) into China, including Intergen (Shell and Bechtel), Mirant (Southern Company) from the United States, AES (also from the United States) and Meiya Power from Hong Kong. During the 'big rush', more than 100 memoranda of understanding (MoUs) were signed between foreign companies and Chinese partners for the development of power plants, and 29 large, mostly greenfield projects totalling more than 22 GW were developed. Milestones in this period included the first privatisation of an existing plant, when 55 per cent of a 2 × 200 MW plant in Liaoning Province was sold to a Hong Kong company; the first New York listing, by Huaneng, Naimeng Huadian renminbi-listing of Shanghai A-shares; the first competitively bid BOT project, Laibin 2 × 360 MW; and Zhejiang Southeast US dollar listing of Shanghai B-shares (Wilson and Wang 2002).

At this time, Guangdong was suffering power capacity shortages due to rapid growth in industrial demand, and self-generation—much of it by high-emission diesel generators and small, poorly controlled coal plants—was proliferating. Some of this was on-grid and some off-grid. As Figure 8.2 shows, 14 of 31 GW were not centrally dispatched at that time, including 10 GW of thermal plant and 4 GW of hydro plant.

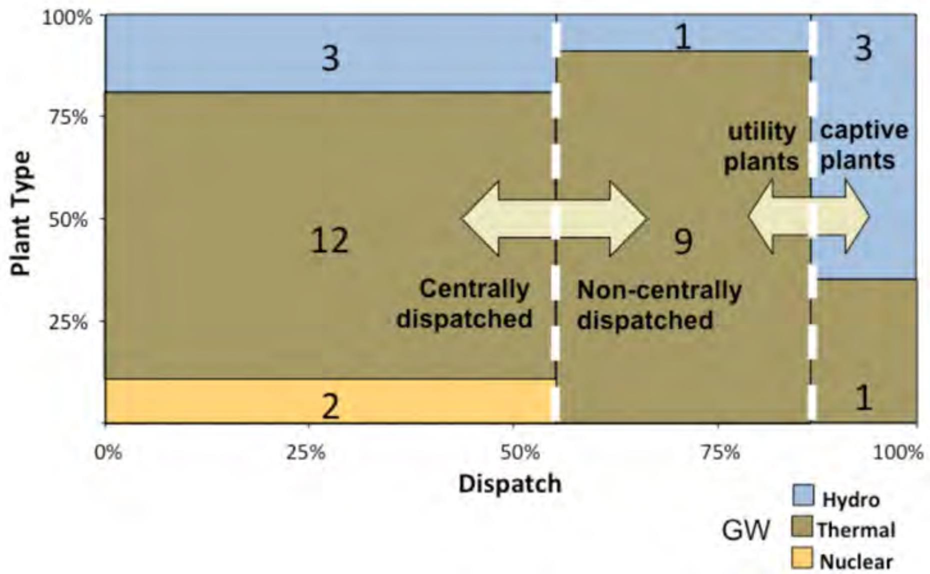

Figure 8.2 The Guangdong electricity sector in late 2002

Source: Wilson and Wang (2002).

Not long after, as China's electricity demand growth rate started to accelerate, Zhejiang Province would suffer severe capacity shortages and rolling blackouts during the peak summer season. One of the present authors was asked to assist Zhejiang Energy to forecast the 2003 summer peak demand. Distinguishing seasonal fluctuations from the suddenly accelerating underlying demand was a difficult task. Ironically, a year or two earlier, foreign investors such as National Power had looked at a power plant investment in Zhejiang, and decided against it, having doubted the demand outlook (Gordon 2005).

Such lack of foreign confidence in China's continued economic growth and development, and need for electricity—which appears rather quaint from the comfortable perspective of 2015—was perhaps a factor in China's lack of confidence in seeking foreign investors as the answer to the country's power needs. By the early 2000s, a number of foreign IPPs were watching and waiting and some were already withdrawing from the Chinese market. This followed the 1996–97 reforms heralding the beginning of phase III, and disappointments on the part of a number of Western IPPs arising from misunderstandings about the terms and status of their power purchase agreements (PPAs) with their local counterparts and the system operators in the power grids hosting their power plants. The backdrop to this was a regional investment climate clouded by the aftermath of the Asian Financial Crisis, and such high-profile figures as the last governor of Hong Kong, Chris Patten (1998), openly questioning 'Asian values' in print and through a television documentary series.

Before his departure from Hong Kong in mid-1997, Patten had asked whether there might be scope for competition in Hong Kong's electricity sector to replace the Scheme of Control agreements with the government that were used to regulate Hong Kong's two vertically integrated investor-owned power utilities. The resulting study, presented to the Legislative Council under Chief Executive Tung Chee-hwa's post-handover government concluded that genuine competition would not be feasible in Hong Kong's power sector without the existence of a competitive market in Guangdong (Wilson et al. 1999). Hong Kong was not to be a laboratory for Chinese power sector reform.

By the end of phase III of its reform process, China had less and less need for any of the three things that foreign IPPs could bring: capital, technology and management skills. China was well on the way to becoming an exporter not an importer of capital. With the exception of certain gas-turbine technology (not particularly relevant in a country with limited availability of high-cost gas) and some nuclear technology, China already had world-class, highly competitive power plant manufacturers. And imported Western managers, in most cases with very limited Chinese language and cultural skills, could hardly be considered competitive candidates to run power plants in China.

Figure 8.3 presents the ownership structure of the generation sector in China in late 2002, just before the break-up of the State Power Corporation (SPC) monopoly, showing the role of the SPC, other Chinese state-owned enterprises (SOEs), privately controlled Chinese companies and foreign private companies.

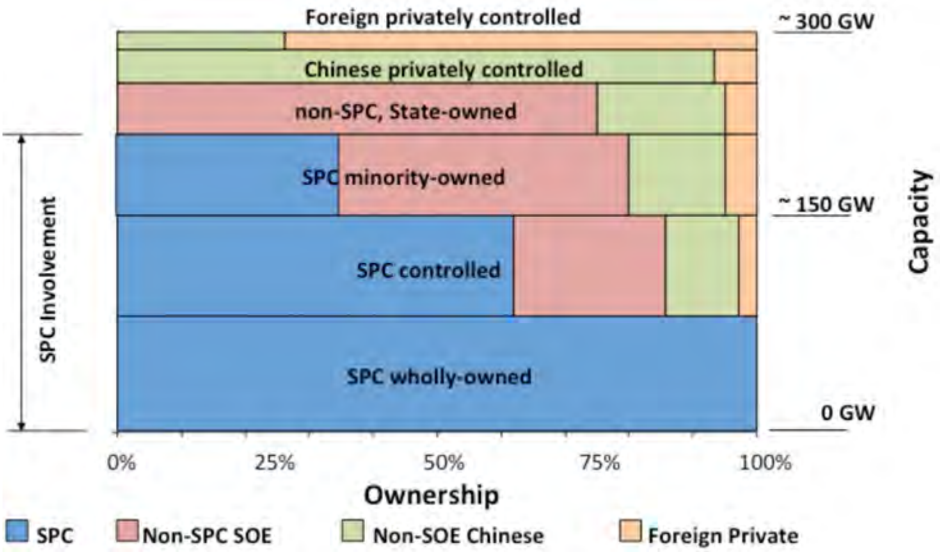

Figure 8.3 Structure of generation capacity ownership in China in late 2002

Source: Wilson and Wang (2002).

A key question at the time was would the privatisation trend continue, with the role for foreign private companies and Chinese non-SOEs extending from the margins at the top right of the diagram towards the bottom left? Or would the trend be reversed?

An industry structure for a future competitive market

The beginning of 2003 marks what we might call phase IV of China's power sector reforms: putting in place the architecture for future competition. A major restructuring of the SPC, separating generation from transmission, had put in place an industry structure to enable wholesale competition:

> China dismantled the State Power Corporation on December 29, 2002 and set up 11 new companies in a move to end the corporation's monopoly of the power industry. The former State Power Corporation owned 46% of the country's electricity generation assets and 90% of the electricity supply assets.

> The new companies include two power grid operators, namely the State Power Grid and China South Power Grid. Each of the five electricity generation companies own[s] less than 20% of China's market. They will compete with each other for signing contracts with the power grid operators. (Xu and Chen 2005: 2462)

The 'big-five gencos' (generation companies) are as follows:

- **China Huaneng Group** is the largest and oldest power generation company in China, established in 1985. By the end of 2014, Huaneng had 130 plants, more than 110 GW of generation capacity and more than 60 Mt of annual coal production.

China Datang Corporation, Huadian Group, China Guodian Corporation and China Power Investment Corporation (CPI Corp) were all incorporated in 2002 from the former SPC as part of the restructuring.

- **China Datang** has China's largest coal-fired power plant (Inner Mongolia Tuoketuo), the world's largest wind farm (Inner Mongolia Chifeng) and the second-largest hydropower project (Longtan Hydro). By the end of 2014, Datang had 68 plants and more than 120 GW of power generation capacity.
- **Huadian Group** has 70 plants with 123 GW of capacity.
- **China Guodian** has 94 plants with a total capacity of 123 GW.
- **CPI** has the highest proportion of clean energy of the Chinese generation companies, which accounts for 30 per cent of its generation capacity. It has participated in nine nuclear power projects in China and has also developed downstream industries including alumina refineries. CPI has 65 plants with a combined 90 GW of capacity.

A number of the big-five gencos have integrated up the value chain by acquiring coalmines to secure and manage the fuel supply to their power plants.

- **Shenhua Group**, meanwhile, has integrated down the value chain by developing power plants in addition to its complex of 70 operational coalmines, including some of the largest open-cut and underground mines in the world, 1,765 km of railway lines, 185 Mt of coal port and wharf capacity, 30 coal vessels and coal-to-liquids plants. Through its 21 wholly owned and holding subsidiaries, the group has 68 GW of power plant, of which 61 GW is coal-fired.
- **China National Nuclear Corporation** (CNNC) and **China General Nuclear Corporation** (CGN; formerly China Guangdong Nuclear Power Corporation or CGNPC) are the main companies investing in nuclear power plants in China. More recently, the **State Nuclear Power Technology Corporation**

> (**SNPTC**) has had a key role as the partner with Toshiba-Westinghouse in the construction and development of third-generation advanced-passive (AP) reactor technology in China. In early 2015, it was announced that SNPTC and CPI will merge to form the State Power Investment Group, which will have assets equivalent in size to the sum of CNNC and CGN assets.

On 30 December 2002, the government also set up the State Electricity Regulatory Commission (SERC), to supervise market competition and issue licences to operators in the power industry (Xu and Chen 2005). SERC was responsible for administration and regulation of the electricity and power industry, including regulating the development of electricity markets and advising the National Development and Reform Commission (NDRC) on setting tariffs, while the NDRC actually sets the tariffs, transmission, distribution, safety and technical standards, issues business licences, establishes environmental laws and supervises development of the industry. In March 2008, the National Energy Administration (NEA) was established under the NDRC, and on 26 March 2013, Xinhua reported that SERC was to be dissolved and its functions incorporated within the NEA. Its main responsibilities would include drafting and implementing energy development strategies, plans and policies; advising on energy system reform; and regulating the sector (Xinhua 2013).

Bordie et al. (2014) observed that the rail sector, which plays a key role in transporting coal—by far the major fuel used in power generation—is the last of China's large network or infrastructure industries previously organised as government ministries to be reformed. Network and infrastructure sectors in China that were reformed previously include airlines, telecommunications, power and water, oil and gas, and highways.

In the case of the power sector, China's reforms have not yet proceeded to the extent of the reforms in the United Kingdom, Australia and parts of the United States. In China, state ownership retains a dominant role, although through a number of 'competing' corporate entities rather than the semi-monopolistic former SPC. The structure of the industry, its ownership and the role of competitive forces and regulation remain largely the same as those put in place in 2002, as described by Xu and Chen (2005). There are good reasons for this, which we return to later in this chapter.

Meanwhile, China has greatly expanded the capacity, efficiency and reliability of its power supply. With the emerging challenges of increasing power costs, security, power demand growth and environmental issues related to both the consumption of electricity generation and the production of coal in particular, the government has actively developed programs to increase energy efficiency and minimise emissions.

The 'golden decade' from 2003–04 to 2012–13 saw unprecedented rates of electricity demand growth, generation capacity additions, coalmine developments, production and consumption, and associated rail, port and transmission infrastructure development. By 2010, China had a 1,000 GW power system, when a 500 GW system had been anticipated a decade earlier. Its coal industry had grown from 1 billion tonnes to more than 3 billion tonnes, when a 2 billion tonne coal and coal-rail system had been considered a challenge a decade earlier. This development path has raised questions about environmental impacts, amid the constant challenges of economic competitiveness and energy security.

Yet these questions are relevant to all energy sources and power generation technologies, although not in similar degree. China has the world's largest hydropower plant and hydropower sector, which are not without environmental issues—some with international dimensions in the region. China was on the way to having the world's largest and most rapid nuclear power plant construction program when the East Japan earthquake, tsunami and subsequent decisions led to the destruction of the Fukushima nuclear power plant in Japan. The program has been slowed, but is still likely to become the world's largest sometime in the 2020s. China also has the world's largest installed capacity of wind and solar power.

Parallel reforms and regulation in related industries

In addition to its role as electricity price regulator through the NEA, the NDRC plays a key role in regulating prices in other industries, a number of which are closely related to electricity, including the coal market and the rail freight sector. Since the major power sector reforms of 2002, China's coal market has undergone substantial reform, prices are now essentially determined by market competition between large SOEs, provincial SOEs, private companies and small local township and village enterprises, as well as by imported coal. As a result, coal prices have become much more volatile, rising to very high levels when the market was tight several years ago, and to well below the cost of production for many producers in the currently oversupplied market.

When coal prices were high, power generators' margins were severely squeezed or negative. The NDRC revised wholesale power tariffs accordingly, but electricity prices have remained 'ratcheted' at about that level, after coal prices declined.

Rail freight transport, which accounts for a significant part of the value chain for coal delivered to power plants, particularly in coastal and southern China, is in the early stages of reform (Bordie et al. 2014). The current healthy margins for power generators provide an opportunity to ratchet up rail freight tariffs to reduce the financial challenges facing the rail sector.

The gas sector has undergone some reform of pricing, but the high-pressure transmission pipeline network is not yet fully open to third-party access. The relatively limited availability and high delivered cost of natural gas in China, and the policy priorities for its use in sectors other than electricity generation, mean that gas sector reform is not likely to be as high a priority for the power sector in China as it has been in other countries.

Looking to the future, the key to economic reform is to properly handle the relationship between government and the market. As China is transforming itself from a highly power-centralised planned economy to a market-led economy, this implies a gradual process of government devolving decision-making back to enterprises. This has been the key topic in electricity sector reform in China.

In 2002, the State Council issued a 'Proposal for Power Sector Structural Reform', which marked the beginning of the last round of power sector reform. The key achievement of this round of reform is that it has led to competition in the power generating industry. According to the proposal, there is a separation of power generation and power transmission. The State Electricity Company (SEC) has been divided into power generation and transmission businesses. The objective set out in the proposal is also to 'gradually realise the separation of transmission and distribution service[s] of State Grid and also introduce competition in power retailing'. However, State Grid has entrenched its monopoly in dispatch management, transmission and market transactions. This has greatly hindered the interaction between power users and power producers. Reform of the State Grid is therefore the most important step in the next round of electricity market reform.

Separation of transmission ownership from system operation (generation dispatch) is likely to be key to the success of these reforms. Woolf (1996) has made the case for a genuinely independent system operator (ISO).

On 18 March 2012, the State Council stressed again that the key to deepening power sector reform is to carry out trials for separation of transmission and distribution, and to ensure that distributed energy power generation can access the grid without 'bias', which will ensure continuous reform of the power sector.

Selected international comparator countries

Before discussing alternative industry and regulatory frameworks and the choices available to China, it is helpful to review the electricity sector in other countries and their experience of reform.

- **The United States** has a number of weakly interconnected or unconnected regional grids, ageing infrastructure, and is a laboratory of regulatory arrangements in a federal system.
- **Japan** has one of the world's largest power systems, but its grid is fragmented among the vertically integrated regional Japanese power utilities, each with its own franchise monopoly, protected by grid frequency incompatibility—some operate at 50 Hz, others at 60 Hz. The vertical franchise monopolies are now under pressure from the government to reform after the Fukushima shock to the system.
- **India** has a coal-dominated hydrothermal system. Unlike China, in India, the electrification rate is very low.
- **Russia** has abundant gas reserves and generally poor resource utilisation and conversion efficiency. China is a neighbour and customer of Russian energy.
- **Germany** is generally considered to be a model of industrial efficiency. Its power system is one of the largest in Europe and is central to the European grid, on which it relies to balance its large proportion of intermittent wind and solar renewable energy.
- **Canada** has an eclectic system, with ownership and regulatory framework varying across Provinces, with parts integrated into adjacent United States systems.
- **France** has a nuclear-dominated power system complemented by gas, with extensive interconnections with neighbouring countries. Government-controlled Electricité de France dominates the market in an example of the state-owned corporate model within a wider competitive market according to EU rules.
- **Brazil** has a hydro-reliant system vulnerable to drought.
- **The United Kingdom** was the pioneer in privatising electricity markets and attempting to introduce competition to reduce the need for regulation. In more recent years, numerous centrally planned mandates, particularly on renewable energy and nuclear power, have in practice squeezed the role of competition in the power market.
- **Australia** has the longest interconnected electricity market and was an early follower of the United Kingdom in electricity reform, with the state of Victoria moving first and far on privatisation.

China plus these 10 comparator countries account for two-thirds of the global installed power generation capacity (including self-generation) and span a wide range of industry and regulatory models. Most of the 1.25 billion people currently without electricity are outside the 11 comparator countries (825 million), except for India (400 million). Table 8.1 shows the data. Table 8.2 provides a summary of the industry structure, ownership, forms of regulation and extent of competition for the 10 comparator countries.

Table 8.1 Electricity sector of China and 10 comparator countries

Country	Land area	Pop'n 2010	Access 2010	Capacity 2010	GDP	Ownership
	(m sq km)	(million)	(%)	(GW)	(US$ b)	(type)
China	9.60	1,360	99.7	999	5.9	Mixed
United States	9.63	312	100	1,041	15.0	Variety[a]
Japan	0.38	127	100	287	5.5	Private
Russia	17.1	144	100	223	1.5	State
India	3.29	1,206	75	207	1.7	Mixed
Germany	0.36	83	100	163	3.4	Mixed
Canada	9.98	34	100	132	1.6	Mixed
France	0.55	63	100	125	2.6	State
Brazil	8.51	195	98.9	112	2.1	Mixed
United Kingdom	0.24	62	100	94	2.4	Private[b]
Australia	7.74	22	100	60	1.1	Mixed
Subtotal	67.38	3,609	91.5	3,443	43.0	
RoW	67.04	3,307	74.0	1,672	22.2	
World	134.42	6,916	83.1	5,115	65.2	

[a] From private to state to cooperative.
[b] Includes foreign state entities.
Sources: Land area, UN FAO; population, UNDP (data.un.org); capacity, UNDP; electricity access, World Bank database.

Table 8.2 Electricity industry structures and forms of ownership, regulation and competition

Country	China	Japan	Russia
Industry model	Corporatised	Corporatised	Corporatised
Ownership of generation	State	Mix of private and state governments	Mixed private and government
Ownership of transmission	State	As above	State
Ownership of distribution	State	As above	State
Key legislation	State and federal	Federal	Federal
Form of regulation	Price regulation	Competitive market oversight	Price regulation
Regulator/s	NDRC, State Electricity Regulatory Commission	METI, ESCJ, NRA	Ministry of Energy, Federal Tariff Service, FAS
Extent of competition	Competition to build new power plants, but not for dispatch	Limited to very large customers	None

Country	Brazil	India	Germany
Industry model	Corporatised	Corporatised	Regulated market
Ownership of generation	Mixed private and government	Mixed private and government	Mix of private and state governments
Ownership of transmission	Federal and state	Federal govt	As above
Ownership of distribution	Mixed	Mixed	As above
Key legislation	Federal	State and federal	State and federal
Form of regulation	Competitive market oversight	Price regulation	Competitive market oversight
Regulator/s	MME, ANEEL, CNPE and CMSE	MoP, CERC	Federal Network Agency, Federal Cartel Office, state regulatory authorities
Extent of competition	Limited: periodic auctions held for new generation capacity	No competitive market. Capacity shortages and substantial self-generation	Wholesale and retail markets, under EU law

Country	France	United States	Canada
Industry model	Regulated market	Varies by state	Varies by province
Ownership of generation	Mix of private and state governments	Mix: investor-owned, state govt, coops	Mixed: investor-owned, state govt
Ownership of transmission	Federal	As above	As above
Ownership of distribution	State and federal	As above	As above
Key legislation	Federal	State and federal	Provincial and federal
Form of regulation	Competitive market oversight	Price regulation and market oversight: varies by state/region	Varies by province
Regulator/s	CRE, FCA	FERC, NERC, plus regulators in each state, members of NARUC	NEB plus regulators in each province
Extent of competition	As required by EU law	Varies from state to state from full competition to no choice	Varies between provinces, includes competitive markets, some US-integrated

Country	United Kingdom	Australia
Industry model	Market model	Market model in NEM states
Ownership of generation	Mix of private and state governments	Mix of private and state governments
Ownership of transmission	Federal	As above
Ownership of distribution	Private	As above
Key legislation	Electricity Act (1989)	National Electricity Law, plus various state laws
Form of regulation	Competitive market oversight	Competitive market oversight
Regulator/s	OFGEM, GEMA, CMA, ONR	AEMO, AER, ACCC, AEMC, plus state regulatory oversight
Extent of competition	Wholesale and retail markets	Wholesale and retail markets

China's profile in the global power industry

China today has the largest power system in the world. As Figure 8.4 shows, while China has close to universal electricity access, China's power system development measured in kilowatts of generation capacity per capita and economic development measured in GDP per capita are still far below the levels of the seven developed countries in the sample.

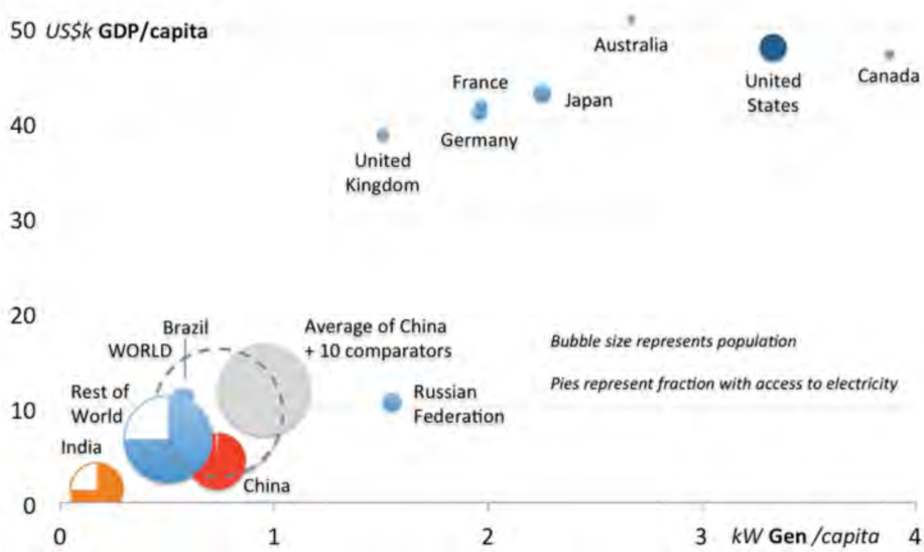

Figure 8.4 Global comparison of power systems (2010 data)

Source: Authors' analysis using data from UNDP and World Bank.

Let us take a closer look at systems which have relevance to China's efforts to build a more competitive electricity market. We have selected the United Kingdom and Australia with its National Electricity Market (NEM), with a particular emphasis on the state of Victoria, as the examples. The United Kingdom was the pioneer in introducing privatisation and competition to large, national-scale electricity systems. Victoria was an early follower, while the other states in Australia have a variety of ownership structures, which, like China, include continued government ownership of generation, transmission and distribution assets.

The United Kingdom's history of electricity ownership and structure

Historically, the electricity sector in most countries was perceived to be a public good or was seen primarily as an essential service. Electricity transmission and distribution networks tended to be viewed as having strong natural monopoly characteristics. It does not make economic sense to duplicate network infrastructure because of their public goods character. This thinking was not limited to the networks transmitting and distributing the electricity, but extended to the power plants generating the electricity. The economies of scale available from large, centralised power plants tended to reinforce the view of the entire system as one large, natural monopoly.

This thinking is evident in the long history of the UK electricity industry. By World War II, the United Kingdom had more than 600 electric power companies, both 'local authority undertakings' (electricity distribution businesses belonging to local governments) and private companies—constituting quite a decentralised system. After the war, the political climate tended to favour nationalisation and centralisation. This had not always been the prevailing thought.

In 1831, Michael Faraday discovered electric induction, and then magneto-electric induction. He produced the first electric generator in his laboratory in London, and laid the basis for the transformer and the electric motor. By 1879, Thomas Edison in the United States had perfected a practical electric light bulb. The first legislative milestone in the UK electricity industry was *The Electric Lighting Act 1882*, which allowed the setting up of supply systems by individuals, companies or local authorities. Numerous amendments and new acts followed, including the 1909 Act regulating planning consent for building power stations; the 1919 Act, passed during the reconstruction of the nation's industries after World War I, which rejected the recommendations of two committees to effectively nationalise the industry and to unify generation, transmission and distribution; the 1922 Act; the 1926 Act creating the Central

Electricity Board and the National Grid operating at 132 kV and 50 Hz AC; *The Electricity Supply (Meters) Act 1936*; and *The Hydro-Electric Development (Scotland) Act 1943*.

The Electricity Act 1947 established the British Electricity Authority (BEA), responsible for bulk electricity generation and transmission, and nationalised and merged the more than 600 small electricity companies into 12 'area electricity boards'. *The Electricity Reorganisation (Scotland) Act 1954* moved responsibility for Scottish electricity supply to the Scottish Office, replacing the BEA with the Central Electricity Authority (CEA). *The Electricity Act 1957* dissolved the CEA and replaced it with the Central Electricity Generating Board (CEGB) and the advisory and supervisory Electricity Council.

Various other amendments and acts on electricity (and gas) were passed in 1961, 1963, 1968, 1972 and 1979. All of these—a large body of incrementally evolving legislation, representing the journey from small, entrepreneurial, private and local authority electricity supply businesses—were repealed by *The Electricity Act 1989*, which was a revolutionary piece of legislation that swept away the nationalised structure and (re-)privatised the industry.[2]

> The [government] White Paper 'Privatising Electricity' published in February 1988 proposed splitting the CEGB into a transmission system operator, eventually called The National Grid Company (which was transferred to the joint ownership of the 12 Area Boards, who were retitled 'Regional Electricity Companies') and two generators called Big G, which eventually became National Power (40GW) and Little G, which eventually became PowerGen (16GW). The rationale for this split was the hope that National Power would be big enough to absorb the uncertainties of the operating performance of Britain's idiosyncratic nuclear reactors, and also bear the capital cost and operational risks of the 1200MW Sizewell B pressurised water reactor being built, together with three more units which the government hoped would be built. (Henney 1994, summarised in Henney 2011)

A major lesson in the United Kingdom was that the nuclear sector could not thrive under competitive market conditions without some form of government support. This was a big factor in the way the generation sector ended up being structured at the time of privatisation. Henney continues:

2 A list of major events in the history of the United Kingdom's electricity supply is available from: en.wikipedia.org/wiki/Timeline_of_the_UK_electricity_supply_industry.

> But while the government could manipulate the valuation and finances of the existing nuclear plants, it could not obscure the future construction cost risks, nor the high cost of electricity from Sizewell B. The financial advisers concluded that the nuclear plants could not be sold and eventually the government was forced to put them in Nuclear Electric, which would remain in public ownership. By now there was no time to split up National Power and PowerGen, and the industry started its existence with a most unsatisfactory generation structure of a dominant price setting duopoly, which was … to cause many problems and costs. (Henney 1994, summarised in Henney 2011)

National Power and PowerGen were both privatised in a 60 per cent float in March 1991, and the balance in 1995. Nuclear Electric, formed in 1990 as a government-owned corporation to remove the 11 GW of nuclear assets from National Power's portfolio, was privatised as British Energy in 1995, without Magnox Electric, which became part of BNFL in 1998. Electricité de France (EdF), a corporation largely owned by the French Government, acquired British Energy in 2009. North Scotland Hydro-Electric board became Scottish Hydro-Electric, and was privatised in 1991. The South of Scotland Electricity Board's non-nuclear plants became Scottish Power and the nuclear plants were put into Scottish Nuclear. The 1989 Act created 12 regional electricity companies (RECs) from the area electricity boards, which were each then sold in 1990 in a public float.

Lessons from the history of electricity in the United Kingdom

The above summary of the history of legislation in the electricity industry in the United Kingdom paints a picture of constant evolution and organisational change. The changes from 1882 to 1989 reflect the evolution of society and technology and the tide of prevailing political philosophy during that century.

State ownership, which has been adopted in the United Kingdom and many other countries, is one remedy to the natural monopoly problem, but other models are possible, including regulated private ownership. By the late 1980s, leading economists and engineers had recognised that electricity generation and retail supply need not necessarily be considered natural monopolies.

Modern information technology and control systems (which were still in their infancy in 1989) today enable electricity to be competitively generated, centrally scheduled and dispatched according to a set of market rules, subject to technical engineering constraints in power stations and throughout the network.

Henney's (2011) view of the initial outcomes of UK electricity privatisation listed a number of 'clear political gains' as well as economic gains from cost reductions, along with identification of serious flaws. In his words, privatisation:

> [A]ppeared to free [electricity] generation from government imposed fuel policies; reduced the political power of the electric industry and its political dependents, British [power] plant manufacturers and British Coal; increased the industry's accountability because the government had not been particularly competent at controlling what it owned; freed the industry from public sector constraints; and allowed government to focus on tasks which only it could fulfil. There were significant cost gains from stopping the construction of three [nuclear] PWRs [pressurised water reactors] and four 900MW coal plants that had been planned. Manpower reduced by 40% by April 1993 compared with 1990, and equipment buying was more careful and more cost conscious. But there were serious flaws with privatisation, notably the creation of a duopoly of price setting generators, and customers got a poor initial deal—most customers' prices increased to pay for the generous financing of the industry, which resulted in major gains for shareholders. (Henney 2011)

Competition policy and electricity reform in Australia

The first moves to define and establish a national grid in Australia followed the Special Premiers Conference in 1991, where:

> Discussions … focussed on measures to increase national efficiency and international competitiveness and to move towards a single national economy. The focus was on micro-economic reform in the areas of regulatory reform; road and rail transport; electricity generation, transmission and distribution; and reform of Government Trading Enterprises. (COAG 1991)

This followed the then prime minister Bob Hawke's 12 March ministerial statement, 'Building a competitive Australia', which noted that:

> The Trade Practices Act is our principal legislative weapon to ensure consumers get the best deal from competition. But there are many areas of the Australian economy today that are immune from that Act: some Commonwealth enterprises, *State public sector businesses*, and significant areas of the private sector, including the professions. (Hawke 1991, emphasis added)

A subsequent meeting of the premiers and chief ministers in November endorsed the need for a national competition policy and an independent review of the *Trade Practices Act 1974*. On 26 February, shortly after taking office as prime minister, Paul Keating tabled the major ministerial statement 'One nation' (Keating 1992), foreshadowing the prominence that the Commonwealth would give to competition policy as one of seven elements of its economic and social strategy for the 1990s. On 4 October, Keating appointed Professor Fred Hilmer to head the National Competition Policy Review, which delivered its report on 25 August 1993.

The evolution and operation of Australia's national competition policy are well summarised by Kain et al. (2001) and provide the national context for the reform of state public sector businesses in Victoria, including the then State Electricity Commission of Victoria (SECV).

Victoria's experience of UK-inspired reforms

As it turned out, the State Government of Victoria led by example the introduction of Australia's competitive NEM, and retail customer choice of supplier by rapidly restructuring and privatising the state's electricity sector. This program was driven by the premier Jeff Kennett and treasurer Alan Stockdale, who set out to privatise assets as a means of retiring the state government debt of $32 billion. During its time in office, Kennett's government raised more than $30 billion by selling businesses in energy, transport and other areas.

In the words of Kennett's pre-election energy policy of 1992, they would 'implement structural changes in the energy industry necessary to promote economic prosperity and job opportunities for more Victorians'. The reforms therefore represented a combination of pragmatism (reducing government debt) and political philosophy—specifically, the view that private businesses, motivated by profit and constrained by competitive forces, with regulatory supervision where required, would use capital and operate more efficiently than government-owned monopoly corporations. The Kennett government split the privatised businesses into competing units whenever possible, to facilitate commercial rivalry.

The UK reforms under *The Electricity Act 1989* provided the inspiration and general template, and a number of advisors who had worked on the UK electricity privatisation also worked on the Victorian electricity privatisation.

In the late 1980s and early 1990s, reports by the Industry Commission, the Tasman Institute, the Business Council and the Review Committee of the Victorian Parliament had critically reviewed the performance of the SECV. The industry had pursued efficiency improvements through outsourcing, transfer pricing, downsizing and internal power pool arrangements, albeit within the constraints of an integrated monopolistic industry structure (Fearon and Moran 1999).

In October 1994, Victoria's electricity industry was again restructured, largely into the final form for privatisation. Transmission was disaggregated into the Victoria Power Exchange (VPX), a non-commercial body responsible for system operation and control, transmission planning and market operations; and Power Networks Victoria (PNV), responsible for transmission assets, maintenance and operations. Five businesses responsible for distribution networks and retail energy supply to customer accounts were created. Generation Victoria was separated into four individual baseload power stations (including Loy Yang B, then under construction), one portfolio of hydro-plant and one of intermediate and peaking gas plant. During 1995–97, all of these businesses, except the gas portfolio, were privatised. Proceeds amounted to $24 billion—some $13 billion in excess of the SECV's book value of assets recorded in 1993.

Australia's NEM today

The NEM itself began operations in 1998, with three states—Victoria, New South Wales and South Australia—followed by Queensland. Tasmania joined in 2005, with the commissioning of Basslink.

> Australia's NEM is the world's [longest] interconnected system. It stretches for more than 4000 kilometres from Port Douglas in the north of Queensland, to Port Lincoln in South Australia and via the Basslink undersea cable between Victoria and Tasmania … The NEM was designed to include six distinct regions, represented by the five states, with the addition of the Snowy Mountains Hydro-Electricity Scheme as the sixth region (the Australian Capital Territory is incorporated into NSW). Each of these regions operates their own market for the supply and demand of electricity. However, every region is connected through at least one interconnector that allows for electricity to be imported or exported between regions. (NERA Economic Consulting 2007: 3)

Figure 8.5 shows the generation and transmission topology of the physical system in which the NEM operates. NERA Economic Consulting (2007: Figure 2.1) shows interconnection capacity between the states. Figure 8.6 shows the geographic coverage of the NEM in the context of Australia and the other smaller systems that are not part of the NEM.

Figure 8.5 Generation and transmission map of the NEM

Source: AEMO (2015).

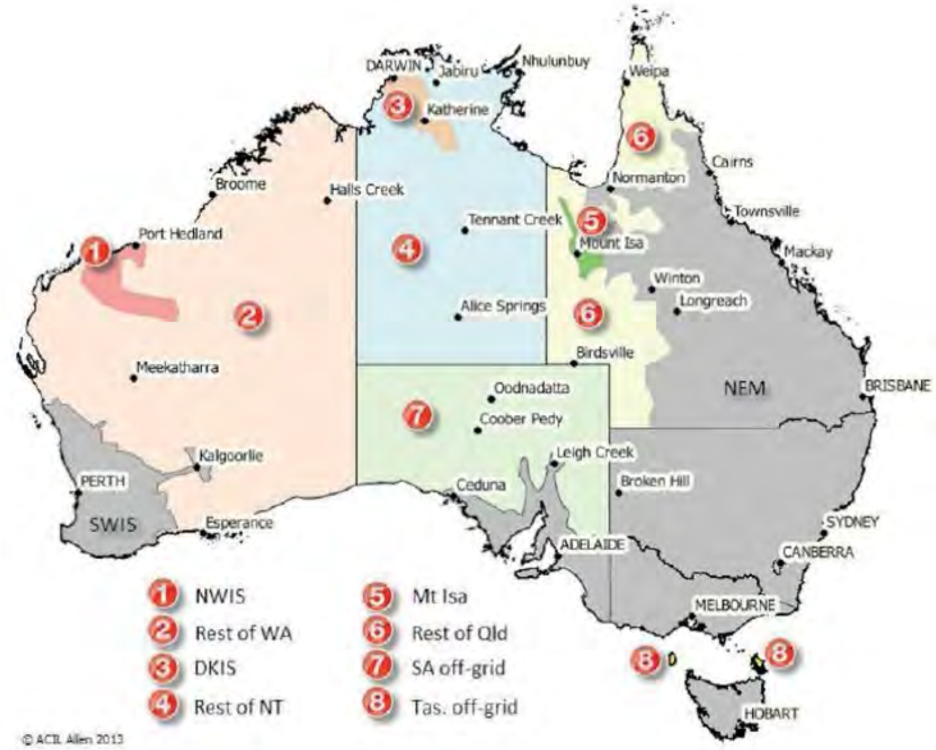

Figure 8.6 Australia's NEM and other electricity markets

Notes: Region 1, NWIS, is the North-West Interconnected System. Region 9 includes off-grid areas of New South Wales, Victoria, the Australian Capital Territory and external territories. These areas are too small and geographically scattered to present on this map. 'Rest of WA' excludes the South-West Interconnected System (SWIS) connected areas of Western Australia. 'Rest of Qld' excludes NEM-connected areas of Queensland.
Source: Hyslop et al. (2014).

South Australia followed Victoria's lead in privatising its generation, transmission and distribution assets, but the other states have largely retained electricity assets in state ownership as government corporations.

After the Victorian privatisation, it turned out that a number of foreign companies had significantly overbid in the tenders for the generation assets, based on the expectation that wholesale prices would be approximately double the level they turned out to be. This later led to a number of bankruptcies and debt writedowns.

Policy goals and a framework for analysing ownership structures and regulatory approaches

Drivers of electricity reform vary from one jurisdiction to another. While policy goals also vary, they almost universally include the goal to ensure consumers and businesses have a safe, reliable and efficiently priced supply of electricity that does not adversely affect the natural environment. While specific to electricity, this is consistent with the universal framework of the more general 'energy policy trilemma', as described by Wensley et al. (2013).

Cost-efficiency is required for efficient pricing. Installed capacity—in generation, transmission and distribution—is an important part of the cost of electricity supply. Therefore, the market and regulatory arrangements need to avoid overinvestment (or premature investment) in capacity, which raises costs above their efficient level, and at the same time avoid underinvestment (or late investment) in capacity, which compromises the reliability of supply.

Issues with competitive electricity market models

The introduction of competition to electricity markets requires careful consideration and design. Competition between generators over common transmission networks and competition between retailers over common distribution networks do not arise spontaneously, but need to be created by design, through a set of market rules by which all market participants are bound, and an appropriate initial industry structure. This requires substantial expert input from engineers, economists and legal experts.

Transmission and distribution networks have significant natural monopoly characteristics, and need to be regulated accordingly, with the policy objectives in mind.

It is essential to consider the initial conditions in the market. Whether the market has excess capacity, demand balanced with capacity including sufficient reserve margin for the desired level of reliability or insufficient capacity will have an enormous bearing on market outcomes.

When competition was introduced to the UK and Victorian power markets in the 1990s, there was more than sufficient generation and transmission capacity, and despite this, the generation planning and design departments in the former state-owned monopoly companies (CEGB in the United Kingdom and SECV in Victoria) were planning major plant additions. The introduction of market discipline prevented the construction of overcapacity, and competitive forces squeezed economic inefficiencies out of the operation of the existing fleet.

If, however, competition was introduced to a market with insufficient capacity, wholesale prices could rise dramatically, which may or may not be acceptable to policymakers. High prices would send a strong signal to build more plants, but could lead to bankruptcies if retailers were not able to pass the costs on to end consumers, or to political instability if end prices became very high. This would be a particular risk, and potentially damaging to the credibility of policymakers, particularly if the introduction of competition had been promoted to citizens and electricity consumers as a way to drive down prices.

At the same time as competition can drive down prices, it tends to increase price uncertainty. Depending on the characteristics and design of the market, it can also increase price volatility. The value of lost load (VoLL) is the economic or financial opportunity cost of electricity supply interruption. VoLL varies by customer type, but for most customers is tens or hundreds of times the delivered economic cost of the electricity itself. Therefore, it can easily be a thousand times or thousands of times the value of savings to customers from increased economic efficiency. Therefore, a single interruption to electricity supply of several hours' duration can wipe out the gains from lower prices accumulated over an entire year.

Designers of competitive markets need to consider how reliability, including sufficient generation reserve margin (as well as sufficient transmission capacity), will be assured in the absence of central planning. Capacity reliability margins require investments of the appropriate quantity, location (for both generation and transmission), timing, type (whether generation and/or transmission as well as fuel and plant choices) and environmental impact including emissions.

Companies investing in competitive markets take into account the return they expect to achieve, and make decisions according to their assessment of whether this is commensurate with the level of risk. If assets have the potential to become stranded in the future, the level of investment risk increases.

In some circumstances, privatisation can relieve capital constraints, particularly where government-owned entities have been subject to public sector borrowing requirements. Government borrowing limits have led to underinvestment, for example, in rural distribution networks in New South Wales in the 1990s, where projects to reduce line losses that would have paid back the investment rapidly could not be undertaken.

Financial risk tends to be higher in competitive markets than in non-competitive markets, due to price and volume risk. This is in addition to the fact that the cost of capital for private companies is higher than for government corporations.

Organisational models and a broad analytical framework

The general classification typology introduced by Bordie et al. (2014) to describe models for the organisation of the rail sector can be adapted and applied to the electricity sector. It adopts a two-axis categorisation, providing a matrix framework for the various models of ownership, organisational structures and regulation of the electricity industry around the world (Figure 8.7).

On one axis, we consider the *ownership* of the power sector, distinguishing state-owned from privately owned companies, and acknowledging that in some countries there is a mix of the two, whether from one region of the country to another, for different parts of the system (for example, generation, transmission, distribution and retail energy supply) or through partial floats of shares in companies.

On the other axis, we consider the *structure* of the industry in terms of the degree of vertical integration or separation, and the extent of *regulation*. We note that models can exist with either no formal regulation (of private electricity companies) or no notion of a separation between the ownership of electricity assets and their regulation—for example, where a self-regulating government ministry owns the assets. So, the regulation axis also embodies the concept of separation between the ownership and regulation of assets.

Five major organisation models are identified: the ministry model, the corporatised model, the regulated model, the market model and the laissez-faire model. These ownership and regulatory models occupy the edges and corners of the diagram.

Because of the natural monopoly characteristics of transmission and distribution networks, the need for electricity markets to be created by a government imposing by law a set of market rules, the desire of most governments to regulate the environmental impacts of the industry, and the political importance of reliable, accessible and affordable electricity supply, there is a variety of approaches to electricity sector governance, and few examples of uncomplicated 'textbook' models. This is particularly so for the market model.

The United Kingdom and some sub-national jurisdictions experimented with the full market model in the 1990s. Barker et al. (1997) discussed in detail power market governance and regulation by comparing the governance and regulatory arrangements of power pools operating at the time in England and Wales, Victoria (Australia), Alberta (Canada) and Scandinavia. Since the turn of the century, new goals—including on renewable energy, facilitating new nuclear build and climate mandates—have increasingly been implemented via additional regulatory or fiscal constraints.

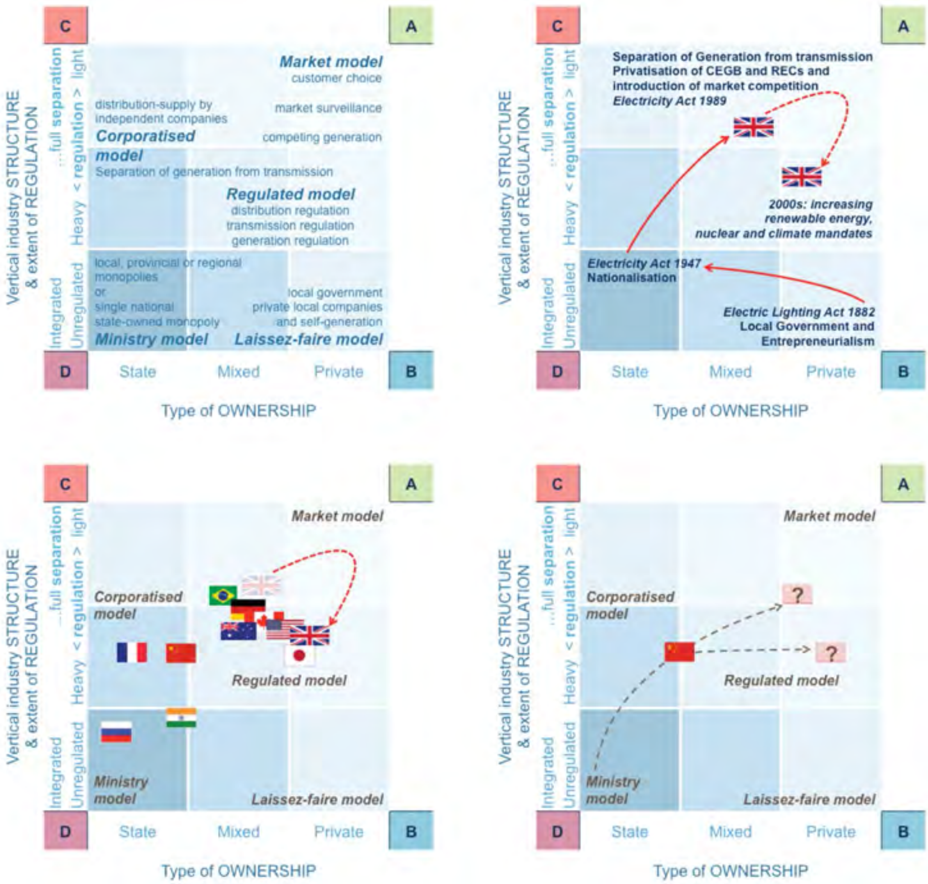

Figure 8.7 Power sector models, 10 comparator countries, UK pathway since 1882 and recent and possible future pathways for China

Source: Authors' diagrams, based on industry knowledge and publicly available information.

Conditions required for a competitive wholesale market

The industry structure and requirements for true competitive conditions in the wholesale market include the following.

Competitive sourcing of fuel

If there is no competitive choice of upstream fuels for power generation, competition between generators will be less effective.

More than adequate generation capacity

If the system reserve is not greater than the size of the smallest generation company in the system, generation companies can bid strategically to drive up the price, thereby gaming the market. Explicit collusion, or price-fixing, which would be illegal, is not required. Publicly available information on the capacities and technical and economic characteristics of other plants, and observation of one another's behaviour in the bidding process, which is repeated every day, is enough. Even if this behaviour only applies for a relatively few peak demand hours on the system, the extremely high prices resulting at those times have the potential to cancel out the gains from competitive forces driving down prices at other times of the year.

Sufficient capacity at the transmission level

Sufficient capacity at the transmission level is needed so that energy can flow unconstrained from generators to the areas of demand. Woolf (2002) argues that underinvestment in transmission costs much more than marginal overinvestment. If transmission capacity is insufficient, generators can gain monopoly pricing power in the constrained parts of the system. Transmission is widely considered to remain a natural monopoly, in any given geographic area, after the introduction of competition. However, it is possible to have 'merchant transmission' projects, where an investor builds a new transmission line to earn a return based on relieving congestion in the grid. Woolf (2002) set out 'recipes' for performance-based (incentive) regulation for regulators concerned about inadequate transmission investment, with the aim being a transmission system that reduces congestion and other costs for the consumer, improves reliability and reduces the potential for the abuse of market power.

Controlled demand growth

Demand growth must not be so rapid as to erode the reserve margin, otherwise competitive conditions will disappear faster than the industry is able to plan, build and bring online new capacity. This would likely have been a serious problem in China if market competition had been introduced in the early 2000s, for example.

Conditions required for a competitive retail market

Competitive sourcing of wholesale electricity

Competitive sourcing of wholesale electricity is required if customers are to be offered prices that reflect competitive wholesale prices. This was not the case, for example, in New Zealand in the early 1990s, when retail electricity competition was introduced.

Regulation of distribution costs

Appropriate regulation of distribution ('poles and wires') costs is required, as this remains a natural monopoly, for similar reasons that transmission is generally considered to have strong natural monopoly characteristics.

The policy choices for China's power sector

In the late 1990s and early 2000s, a number of international advisors and agencies, including the World Bank, encouraged China to reform its power sector by increasing the role of the private sector and introducing competition. China's 2002 reforms were influenced to a large degree by the UK example, as Zhang (2012) has said:

> The grid company's natural geographical monopoly has not changed as, no matter what, you cannot get grid companies [to] build transmission lines like a spider web everywhere. Hence how to enhance supervision and ensure fair transactions becomes [a] must. After a study trip by the then 'infrastructure department' to the UK, the Chinese government felt that the separation between power generation and the grid, as well as setting up an electricity supervision council is suited to China's situation. Hence, China's power sector reform has largely borrowed [from] the UK model and experience.

However, having put in place the industry structure that would enable full wholesale competition along the lines of the then UK power pool, or the Australian NEM, China has paused in its reforms. The electricity crisis and market failure in California in 2000–01—which involved blackouts, market manipulation, declaration by the state governor of a state of emergency, and several major corporate bankruptcies—were probably influential in this respect. In any case, the Chinese Government's decision not to press blindly ahead with full-blown electricity market competition, or large-scale privatisation of the generation sector, now appears wise, given the challenges of the investment that was required to meet double-digit demand growth during the 'golden decade' that followed, and the success of the industry in meeting that challenge. It would have been difficult to meet the policy goals of ensuring a safe, reliable and efficiently priced supply of electricity under such conditions. In the meantime, in markets from Australia to the United Kingdom and the United States, the role of the competitive market has become increasingly constrained by policies to promote renewable energy, to reduce carbon dioxide emissions and, in the case of the United Kingdom, to underwrite new nuclear power investment.

In the past few years, the rate of growth of China's economy, energy system and electricity demand has slowed to more moderate levels. Power demand is still growing faster than in developed economies. Many developed countries, including Australia, have recently been experiencing a decline in power consumption and peak demand, due to a combination of policy support for distributed renewable energy, improved energy efficiency and the closure of energy-intensive industrial facilities no longer able to compete.

While China's annual growth rate has slowed, and energy efficiency continues to improve, its low electricity intensity per capita compared with other countries suggests that considerable generation and transmission capacity investment will still be required before the power system is mature (Wensley et al. 2013). Estimates vary, but this point is unlikely to be reached before 2025, and possibly not until 2035 or later.

Yang (2015) identifies the current period, from 2008 to 2020, as a transition from the first 30 golden years after Deng's second revolution to the 30 years from 2020 to 2050 in which China will achieve major milestones in energy, the economy and the environment.

As this chapter goes to press:

> China's top planning body has published multiple documents stressing that market forces should decide how electricity is generated, transmitted and distributed. Specifics are still missing, and internal contradictions are still rife—the documents, for instance, push renewable energy that currently survives by government rules that subvert market forces. But if enacted, these ideas would mark the next step in electricity reform after Beijing in 2002 cleaved transmission and distribution away from generation. In theory, that allowed generation companies to compete, though in practice, Beijing dictated electricity prices. (Bhattacharya 2015: 28)

As it moves towards phase V of its power sector reforms, China is now in a good position to benefit from the evolving experience of other countries' experiments with power sector markets. Given the scale, geographic extent, regional nature and different stages of development across China's power system, it could be possible to experiment further with market approaches and enhanced regulation in some of the more mature parts of China's power sector and move to national implementation later. Such an approach would build on the foundation of the earlier reforms, and be consistent with China's general economic, political and social philosophy of making changes carefully and gradually—'crossing the river by feeling the stones', as Deng famously said.

References

Australian Energy Market Operator (AEMO) (2015), *About the National Electricity Law*, Canberra: AEMO. Available from: www.aemo.com.au/About-the-Industry/Legislation/National-Electricity-Law. Retrieved 11 May 2015.

Barker, J., Jr, Tenenbaum, B. and Woolf, F. (1997), *Governance and regulation of power pools and system operators: An international comparison*, World Bank Technical Paper No. WTP 382, Washington, DC: The World Bank. Available from: documents.worldbank.org/curated/en/1997/09/441122/governance-regulation-power-pools-system-operators-international-comparison.

Bhattacharya, A. (2015), China fires away at coal operators, *The Wall Street Journal*, Asia edn, 15–17 May: 28.

Bordie, R., Wilson, S. and Kuang, J. (2014), The importance, development and reform challenges of China's rail sector, in Song, L., Garnaut, R. and Fang, C. (eds), *Deepening reform for China's long-term growth and development*, Canberra: ANU Press.

Chinese Embassy to the United States (n.d.), *Chronology of Three Gorges project*, Washington, DC: Chinese Embassy. Available from: www.china-embassy.org/eng/zt/sxgc/t36515.htm.

Commonwealth of Australia (1974), *Trade Practices Act*, Canberra: Commonwealth of Australia. Available from: australiancompetitionlaw.org/legislation/1974tpaoriginal.html.

Commonwealth of Australia (2010), *Competition and Consumer Act*, Canberra: Commonwealth of Australia. Available from: australiancompetitionlaw.org/legislation/2010cca.html.

Council of Australian Governments (COAG) (1991), *Special Premiers Conference communiqué*, 30 July, Sydney. Available from: archive.coag.gov.au/coag_meeting_outcomes/1991-07-30/index.cfm.

Energy Policy Institute of Australia (EPIA) (2014), *Second submission to the energy white paper process: The institute's detailed comments and submissions on the EWP 'Issues Paper'*, Sydney: EPIA.

Fearon, P. and Moran, A. (1999), *Privatising Victoria's electricity distribution*, Melbourne: Institute of Public Affairs. Available from: ipa.org.au/publications/483/privatising-victoria's-electricity-distribution.

Gordon, A. (2005), Private conversation with Andrew Gordon, then a senior executive with International Power of the UK, responsible for China development.

Henney, A. (1994), *The privatisation of the electricity supply industry in England & Wales*, London: EEE Limited.

Henney, A. (2011), *The British electric industry 1990–2010: The rise and demise of competition*, London: EEE Limited.

Hyslop, P., Kelp, O. and Dundas, G. (2014), Modelling assumptions stakeholder workshop, ACIL Allens Consulting for the Warburton RET Review, Department of Premier and Cabinet, 23 April, Sydney.

Garnault, R. (2014), China's Role in Global Climate Change Mitigation, *China & World Economy*, 22 (5): 2-18.

Gillard, G. (1999), *Powercor Australia Ltd v Pacific Power* [1999], Victorian Supreme Court judgment, Melbourne. Available from: jade.barnet.com.au/Jade.html#!a=outline&id=72814. Retrieved 4 May 2015.

Government of South Australia (1996), *National Electricity (South Australia) Act 1996*, Adelaide: Attorney-General's Department. Available from: www.legislation.sa.gov.au/LZ/C/A/NATIONAL%20ELECTRICITY%20(SOUTH%20AUSTRALIA)%20ACT%201996.aspx.

Hawke, R.J.L. (1991), Building a competitive Australia, Ministerial statement, 12 March, Parliament House, Canberra. Available from: parlinfoweb.aph.gov.au/piweb/view_document.aspx?id=220386&table=hansardr.

Hilmer, F. (1993), *National competition policy review*, 25 August, Canberra: Commonwealth of Australia.

International Energy Agency (IEA) (2002), *World energy outlook 2002*, Paris: IEA. Available from: www.iea.org.

Jowett, A.J. (1984), The growth of China's population, 1949–1982 (with special reference to the demographic disaster of 1960–61), *The Geographical Journal*, 150(2): 155–70. Available from: www.jstor.org/stable/634995.

Kain, J., Kuruppu, I. and Billing, R. (2001), *Australia's national competition policy: Its evolution and operation*, E-Brief, Canberra: Parliament House. Updated 2003. Available from: www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Publications_Archive/archive/ncpebrief.

Keating, P.J. (1992), One nation, Prime Ministerial statement, 26 February, Parliament House, Canberra. Available from: parlinfoweb.aph.gov.au/piweb/view_document.aspx?id=446942&table=hansardr.

NERA Economic Consulting (2007), *The wholesale electricity market in Australia*, June, Report to Australian Energy Market Commission, Canberra. Available from: www.aemc.gov.au/Media/docs/The%20Wholesale%20Elec%20Market%20in%20Aust%20-%20NERA-dfc9ce45-8398-4d43-896b-1fca0311779e-0.pdf.

Parliament of the United Kingdom (1947), *The Electricity Act*, Westminster. Available from: www.legislation.gov.uk/ukpga/1947/54/pdfs/ukpga_19470054_en.pdf.

Parliament of the United Kingdom (1957), *The Electricity Act*, Westminster. Available from: www.legislation.gov.uk/ukpga/1957/48/pdfs/ukpga_19570048_en.pdf.

Parliament of the United Kingdom (1989), *The Electricity Act*, Westminster. Available from: www.legislation.gov.uk/ukpga/1989/29/contents.

Patten, C. (1998), *East and west: China, power, and the future of Asia*, London: Times Books.

Peng, W. and Pan, J. (2006), Rural electrification in China: History and institution, *China & World Economy*, 14(1): 71–84.

People's Republic of China (PRC) (1996), *Electric Power Law*, Beijing. English translation available from: www.lehmanlaw.com/resource-centre/laws-and-regulations/environment/electric-power-law-of-the-peoples-republic-of-china-1996.html.

Pritchard, B. (2015), Private communications, Resources Law International, Sydney.

Sun, Y.-S. (1922), *The international development of China*, New York and London: The Knickerbocker Press. Available from: www.gutenberg.org/ebooks/45188.

United Nations Food and Agriculture Organization Statistics. Available from www.fao.org.

Unite Nations Development Program Statistics. Available from data.un.org.

Wensley, S., Wilson, S. and Kuang, J. (2013), China's energy demand growth and the energy policy trilemma, in Garnaut, R., Fang, C. and Song, L. (eds), *China: A new model for growth and development*, Canberra: ANU E Press.

Wilson, S. and Wang, L. (2002), Implications for Hong Kong of China power market development, China Light and Power 'Regulating Electricity' Conference, 17 October, Hong Kong. Slides available on request from the author.

Wilson, S., Nair, C., Schmieg, M. and Lewington, P. (1999), *Interconnection and competition study*, November, ERM Energy for the Hong Kong Government Economic Services Bureau, Hong Kong.

Woolf, F. (1996), The unbundling and rebundling of transmission and market related functions, *The Electricity Journal*, 9(10): 44–51.

Woolf, F. (2002), *Global transmission expansion: Recipes for success*, Tulsa, Okla.: PennWell.

World Bank Database. Available from: data.worldbank.org.

Xinhua (2013), Former electricity regulator leads national energy watchdog, *Xinhua*, 26 March. Available from: www.china.org.cn/china/2013-03/26/content_28361852.htm.

Xu, S. and Chen, W. (2005), The reform of electricity power sector in the PR of China, *Energy Policy*, 34(2006): 2455–65. Available from: probeinternational.org/library/wp-content/uploads/2010/10/The-reform-of-electricity-power-sector-in-the-PR-of-China.pdf.

Yang, Y. (2012), *China energy outlook*, Beijing: Energy Research Institute, National Development and Reform Commission.

Yang, Y. (2015), China's energy outlook, Keynote address to Energy State of the Nation Conference: Energy Policy, Energy Markets—Getting the Priorities Right, 20 March, Energy Policy Institute of Australia, Sydney.

Zhang, G. (2012), Interview, 12 March, *South China Energy Observation*, [in Chinese]. Translated by the authors. Original available from: i.ifeng.com/news/news?ch=rj_bd_me&vt=5&aid=32928811&mid=20nbxI&p=10.

Zhou, X. (n.d.), *Power system development and nationwide grid interconnection in China*, Beijing: Electric Power Research Institute.

Zhou, X. (2010), An overview of power transmission systems in China, *Energy*, 35(11): 4302–12.

This text is taken from *China's Domestic Transformation in a Global Context*, edited by Ligang Song, Ross Garnaut, Cai Fang & Lauren Johnston, published 2015 by ANU Press, The Australian National University, Canberra, Australia.