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Power Market Reform in China: Motivations, Progress, and Recommendations†

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Highlights

- The background and motivations driving China's power sector reform are summarized.
- An overview of the current progress of China's market construction is provided.
- Key challenges related to China's power sector reform are discussed.
- Recommendations for China's future power market development are provided.

Abstract—China's electricity demand has grown rapidly over only two decades and is currently the largest in the world. This was largely owing to a framework of regulation in which governments regulated prices and quantities, and there was ample incentive for investment. As the growth in electricity demand has slowed and the use of renewable energy has been impeded

by integration-related challenges, China has embarked on a new round of power sector reform, with a focus on market construction. Considering four years of market experiments at the provincial level, we review the backgrounds and goals of the reforms, as well as the current progress toward meeting the initial targets. Then, we discuss the key challenges to be overcome to achieve complete implementation of the reforms, with special emphasis on the system of dispatch. We recommend that China's reforms, in order to achieve the goal of market-based competition, must embrace short-term markets, a greater role for independent regulation, compatibility with renewable energy, and inter-provincial coordination.

Keywords: power sector; power market; market reform; electricity; deregulation; China

1 INTRODUCTION

Beginning around 2000, China's power system began growing very rapidly, achieving annual generation growth rates of 12.2% in the first decade and 7.1% in the second decade, compared to the world average of 2.5%. China overtook the U.S. in 2011 to become the world's largest power sector. In 2017, the total electricity generation in China reached 6,495 TWh, accounting for 25% of the world's total (BP, 2018), as shown in Figure 1.

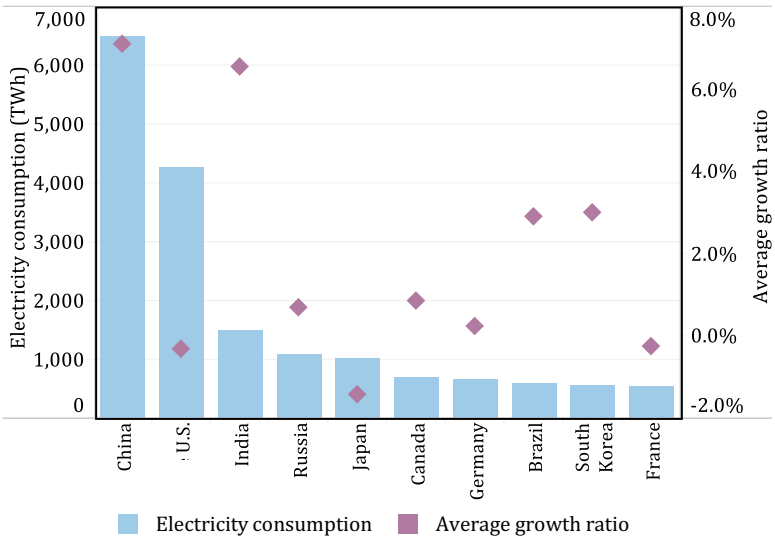

Figure 1 Annual electricity consumption and average growth rate (2008–2017) of top 10 countries by electricity consumption. Source: BP (BP, 2018)

Compared to the development of the industry, China's market-based power sales mechanism remains in its infancy. Although China took the necessary steps of vertically unbundling grid and generation companies in the last round of power sector reform that began in 2002, sales have since largely gone through the state-owned grid companies, and the prices of electricity on the supply and demand sides have been strictly regulated by the government. As the central issue for China's power sector in the last few decades has been the gap between the rapidly growing demand and a shortage of power supply, the primary goal for power industry development was to stimulate generation and transmission investments, with almost no consideration for market efficiency improvement.

However, the traditional power industry structure has become incompatible with China's new economic and industrial environment of lower but more sustainable growth, denoted by the government as the "New Normal" (Chen and Groenewold, 2018). Accordingly, certain major problems have emerged, such as low generation asset utilization, low energy efficiency, high

pollutant emissions, and the serious curtailment of renewable energy. Inefficiencies have been amplified for industrial and commercial customers by cross-subsidies embedded in regulated (plan-based) sales that help lower prices for agricultural and residential users (Yang et al., 2018). To address these problems, the Central Committee of the Communist Party of China (CCCPC) and the State Council of China (SCC) jointly issued the "Several Opinions on Further Deepening Electricity System Reform" in March 2015 (CCCPC and SC, 2015), commonly referred to as "Document No. 9" . This officially marked the beginning of China's new round of power sector reform, hereinafter referred to as "the new reform".

The tasks of the new reform are extensive and include (1) promoting the reform of the electricity pricing mechanism, (2) establishing the market-based electricity transaction mechanism, (3) establishing relatively independent power exchange centers, (4) promoting the reform of annual generation planning, (5) promoting the reform of the electricity retail market, (6) promoting the reform of distributed renewable generation, and (7) further improving market supervision. A detailed description of Document No. 9 can be found in the review by Zeng et al. (Zeng et al., 2016b). The most fundamental and significant content of Document No. 9 is the goal of establishing a "fair, normative, efficient, competitive, open-access, and non-discriminative" electricity wholesale market to trade electricity through a market-based mechanism (NDRC and NEA, 2015d).

Since the advent of the new reform, China's power market construction has made some obvious achievements. At present, all provinces and autonomous regions in China have established power exchange centers to support market-based electricity transactions and to construct the wholesale forward market. Among them, eight provinces and autonomous regions have made rapid progress and have begun construction and trial operation of the wholesale spot market. In 2018,

the sum of all market-based electricity transactions in the wholesale forward market in China was 2,065 TWh, accounting for 30.2% of the total Chinese electricity consumption (CEC, 2019a).

With the continuous advancement of power sector reform, China has now entered a crucial period for both the reform and power market construction. At this juncture, it is useful to provide a comprehensive review of current progress, analyze existing problems, and consider the direction of future development. In recent years, there have been some studies discussing the motives, measures, and significance of China's power sector reform. Soon after the release of Document No. 9 and prior to its implementation, Zeng et al. reviewed Document No. 9 in consideration of the aspects of the pricing mechanism, planning mechanism, renewable energy utilization, and the responsibility of grid companies (Zeng et al., 2016b). Alva and Li provided perhaps the most detailed summary of the context and key aspects of the new reform (including supplementary documents), as well as emphasizing international experiences relevant to the reform process (Alva and Li, 2018). Wu et al. discussed the power market reform in China from the perspective of accountability relations between the central and provincial governing authorities (Wu, 2019). Wu et al. investigated the effect of imbalance settlement design in China's spot power market with large proportions of long-term non-financially contracted electricity (Wu et al., 2020). From a regulatory economics perspective, several "pitfalls" of China's electricity market pilots (prior to spot market introduction) have been analyzed, focusing on contract structure, system operation, and regulation (Davidson and Pérez-Arriaga, 2020).

Transitioning from China's traditional regulation to a wholesale market has the potential to generate large stranded costs (Lin et al., 2019). Yuan et al. proposed three alternative designs of coal generation subsidies under the market reform circumstances to overcome the effects of stranded costs (Yuan et al., 2019). Liu and Jin identified the interactions among electricity, fossil

fuel, and carbon market prices in Guangdong province, offering implications for the co-development of power market reform and emissions trading schemes (Liu and Jin, 2020). There have also been several studies analyzing how the new reform could influence various aspects of power system operation, such as demand-side management (Zhang et al., 2017), renewable energy integration (Guo et al., 2019b; Xu et al., 2018; Zhang et al., 2018), retail market operations (Bai et al., 2015; Peng and Tao, 2018), financial market construction (Fan and Qu, 2019), and interregional electricity transmission (Zeng et al., 2016a).

Recent studies also provide further empirical analyses on general topics related to the power market reform, e.g., market power mitigation (Guo et al., 2019a), renewable energy participation in the market (Du et al., 2019), stranded coal assets (Ansari and Holz, 2020; Bos and Gupta, 2019), and compatibility with other markets (Zhao et al., 2018). These studies do not exclusively focus on China, but are highly relevant to certain important issues that have emerged in China's power market reform, as we discuss later.

Four years into the new reform, with market experiments underway and deepening in all provinces—and several in advanced stages—this paper gives a critical snapshot of reforms in action, as well as a retrospective look back on reformers' motivations and the progress toward meeting these goals. Our focus is on power market construction, and we elaborate on key factors as well as clear descriptions of the various market types and how they relate to operations. To this end, we examine very recent developments in Guangdong's pilot spot market. Finally, we conclude with a comprehensive set of recommendations including, but not limited to, market design, transition mechanisms, and interactions with other energy and climate regulations.

The remainder of this paper is organized as follows. In Section 2, we analyze the background and motivations behind the new reform. In Section 3, we describe the expected post-reform power

market structure and summarize some important events during the reform. In Section 4, we provide details on the progress of reform and discuss the power exchange center, market participants, and wholesale markets, including the forward market, spot market, and ancillary services market. In Section 5, we summarize the challenges currently faced by the construction of wholesale markets. In Section 6, we provide recommendations for the future development of China's power market. Section 7 concludes this review.

2 BACKGROUND AND MOTIVATIONS

2.1 Background of China's power system

The development of China's power sector has always accompanied the rapid development of China's economy. From the opening of China's electricity market in the late 1970s until the 1990s, China's power sector was a vertically integrated monopoly that also maintained regulatory functions. Electricity prices were mainly regulated, and there usually existed a shortage of the power supply. In 1997, the Chinese government achieved the institutional reform of power investment, and the tight supply was initially relieved.

To break the business model of a vertically integrated power sector and form a new market-based pattern of power resource allocation, the Chinese government launched the previous round of reform in 2002 to shift the power industry from "vertical integration" to "single buyer" (SC, 2002). Since then, the former State Power Corporation (SPC) has been split into two major power grid companies, five major power generation groups, and four significant power auxiliary groups; their structure has been presented in detail by Alva and Li (Alva and Li, 2018). Subsequently, China's power market structure has gradually shifted into the structure shown in Figure 2. The sole grid company (GridCo) is in charge of purchasing electricity from generator companies (GenCo) and selling to consumers at regulated prices. The transmission company (TransCo) and

the distribution companies (DisCo) belong to the GridCo, and there is no clear internal demarcation. To increase trading efficiency further, the government allowed GenCos and select large industrial consumers to conduct direct power purchasing (DPP) in some provinces (SERC, 2004). However, after the last round of reform, the power sales mechanism in China is still highly regulated in terms of both price and quantity.

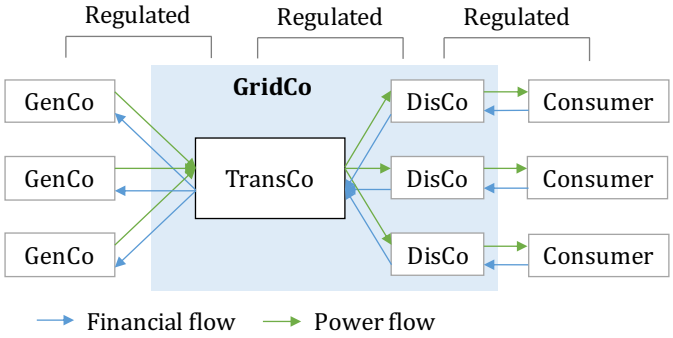

Figure 2 Power market structure before the new reform

On the one hand, electricity prices are regulated and determined by the government. Before a power plant is constructed, a GenCo must submit the economic information for this project to the local government. Then, a negotiation occurs between the local government and the GenCo to determine whether the power plant should be built and what the on-grid price would be. Once the on-grid price is determined and the power plant starts to run, there is limited scope to adjust the on-grid price. Thus, GenCos cannot easily compete by adjusting their prices.

On the other hand, the quantity generated is also regulated and determined by the government in compliance with the "fair dispatch rule" (Gao and Li, 2010). Specifically, local government departments (generally the provincial commission of the economy and informatization) assess the electricity consumption in the second year and allocate a total power generation amount to each power plant based on an approximately equal quota rule. Then, the

generators sign an annual generation contract with the government based on the allocation and the regulated on-grid prices approved by the provincial development and reform commission. Under this "fair" principle, for example, thermal power generators with different technologies and costs share similar capacity factors. In actual operation, the GridCo must formulate the dispatching schedule based on the annual contracts and dispatch the generators based on the dispatching schedules. In fact, the space for adjustment in real-time operations is small, which makes it difficult to integrate variable renewable energy.

The absence of a market-based sales mechanism also results in a lack of incentives to provide related products other than energy. In the traditional regulated power sales mechanism, for example, there is no market-based ancillary services market. The provision of ancillary services[1] is seen as an obligation of the GenCos in accordance with the dispatch instructions, but without appropriate rewards. In the short term, owing to the lack of strict assessment and profitable rewards for providing ancillary services, the GenCos prefer to provide energy, which is more profitable, and attempt to use information asymmetry to avoid ancillary service liability, such as reporting false information about their generators' operation status (Zeng et al., 2014). In the long term, owing to the lack of guidance from price signals, the incentives for flexible investment are reduced, resulting in insufficient ancillary service resources.

The absence of a market-based pricing mechanism also hinders interregional and interprovincial transactions. To solve the problem of uneven resource distribution, China proposed the "west-to-east power transmission" to transport the electricity produced in the west to the east by constructing UHV lines, thereby achieving a broader range of resource optimization. However, without a market-based sales mechanism, it is often difficult for the sending and receiving

[1] Ancillary services refer to additional requirements for stable electricity system operation, such as frequency regulation and reserve generation.

provinces to reach an agreement, making it particularly problematic to efficiently transport renewable energy over long distances. It is estimated that 40% of China's renewable energy curtailments come from the impact of interprovincial transaction barriers (Shu, 2017).

Despite its many disadvantages, China's highly regulated power sales mechanism has been effective in an environment of rapid economic and electricity demand growth and long-term scarcity of electricity supply. In this context, the regulated power sales mechanism generated stable generation revenue expectations, attracted capital to achieve rapid capacity growth, and ultimately met the power demand of China's economic development with limited shortages. However, in recent years, as China's development entered a "New Normal," slowing demand has exposed many problems with the inefficient regulated power sales mechanism. In order to shift from meeting rapid demand growth to promoting more efficient economic and social development, in 2015, China launched the new round of power sector reforms.

2.2 Motivations of the new reform

Countries choose to restructure their traditionally vertically integrated electric utilities for various reasons, which can depend on the level and pace of economic development, availability of finance for new investment, industry structure, and governmental institutions (Williams and Ghanadan, 2006). In the case of China, many problems existed before the new reform, which have been discussed in many studies, such as the distorted pricing mechanism and inefficient utilization of renewable energy (Zeng et al., 2016b; Zhang et al., 2018). Because the new reform encompasses many components and is the result of a long deliberation process with a large group of stakeholders involved, there are several underlying motivations. As participants in policy-making of the new reform, we analyzed all relevant government reform documents, including the 2015 announcement and supplementary documents (see Table 4), key government official statements, and industry data

and performance trends, and identified four key, direct goals of the new reform:

- Increase generation asset efficiency
- Decrease energy consumption and pollutant emissions
- Develop renewable energy
- Decrease industrial electricity prices

2.2.1 Increase Generation Asset Efficiency

In the past decade, China has maintained average annual growth rates in new capacity as high as 9.2% (see Figure 3). However, this increase in capacity was not accompanied by a corresponding growth in demand, resulting in dramatic declines in thermal generation capacity factors. From 2011 to 2016, the annual capacity factors of thermal power decreased from 57.9% to 46.6% (CEC, 2012, 2017). Furthermore, the capacity factors of power generation equipment in China are significantly lower than those in other large countries, such as the U.S. (see Table 1).

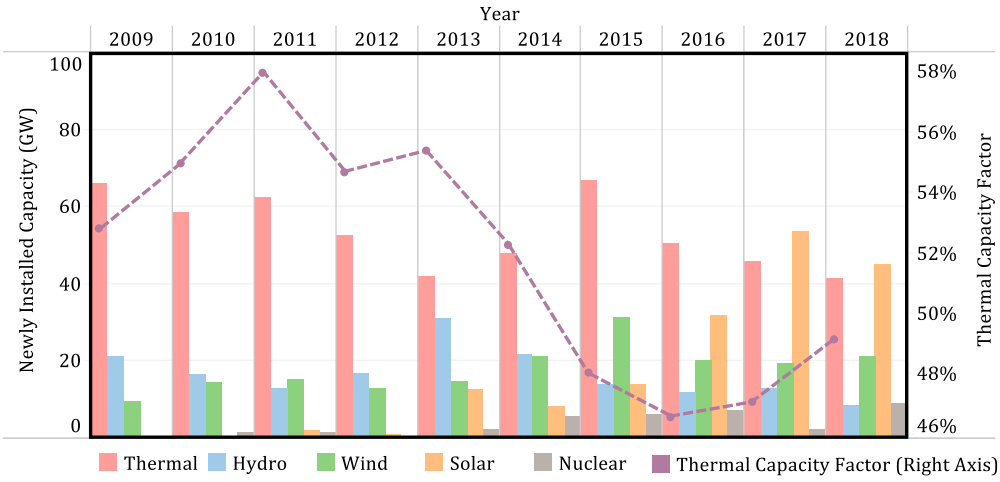

Figure 3 Installed capacity and capacity factor of thermal generators

Source: CEC (CEC, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019b)

Table 1 Capacity factors by generation type in China and the U.S. in 2017

Fuel Type	Coal	Gas	Nuclear	Hydro	Wind	Solar
China	48.3%	30.6%	79.1%	39.6%	21.2%	10.3%
The U.S.	53.7%	51.3%	92.2%	43.1%	34.6%	25.7%

Source: CEC (CEC, 2018; EIA, 2019)

The situation is more serious in certain Chinese provinces, such as Henan and Guangdong. In 2018, the capacity factors of thermal generators in these provinces were only 44.4% and 46.8%, respectively (CG, 2019). In comparison, in the PJM power market in the United States, the capacity factor of thermal generators reached 54.7% in 2018 (IMM, 2019).

The main reason for the excessive investment in China's power generation assets lies in the investment approval mechanisms and price setting rules of the traditional Chinese regulated power sales mechanism. Without a market-based electricity price serving as a reference, local governments generally cannot make informed decisions on electricity price setting or generation planning, which might result in distortions in the on-grid price and inefficient generation capacity investment. In past decades, owing to the rapid growth in power demand, even if the power generation capacity were rapidly expanding, an acceptable capacity factor could be guaranteed. However, in recent years, the growth rate in power demand has gradually slowed, and the problem of overinvestment has become acute, resulting in the efficiency of power generators being reduced substantially.

Therefore, an essential goal of the new reform is to establish a comprehensive power market system that provides price signals for power supply investments at different times and in different locations, and effectively improves the capacity factor of power generation assets.

2.2.2 Decrease Energy Consumption and Pollutant Emissions

Since China's "Eleventh Five-Year Plan" (2006–2010), "energy conservation and emissions

reduction" has been an important criterion for the development of China's energy system. Achieving this goal has often relied on the elimination of inefficient production capacity (Chen et al., 2011). According to the "Thirteenth Five-Year Plan for Electricity Development" (NDRC and NEA, 2016a), the average unit coal consumption for electricity supply by 2020 must decrease to 310 g/kWh, and the emissions of sulfur dioxide and nitrogen oxides must decrease by 50%.

However, the traditional regulated power sales mechanism has, to some extent, affected the realization of the "energy conservation and emissions reduction" goal. As a problem stemming from the "fair dispatch rule" mentioned earlier, the average coal consumption rate in electricity production was 366 g/kWh in 2006, which is 50 g/kWh higher than the level in the advanced world (Gao and Li, 2010).

To address this problem, some provinces in China have implemented the energy-saving power dispatch (ESPD) reform, which sets the dispatch merit order of generators based on their energy efficiency (i.e., fuel consumption) level to best achieve the target of energy-efficient and low-emissions power generation. In 2012, the national average coal consumption for electricity generation decreased to approximately 325 g/kWh, which was 11.2% below that in 2006 (Zhong et al., 2015).

However, several issues hinder the direct application of ESPD across the whole country. First, there are still some inefficient generators protected by local governments and grids, thereby weakening the effects of ESPD. Second, the dispatch merit order is an average metric, which is usually adjusted on an annual basis. Without a real-time metric, the optimization for low coal consumption cannot be guaranteed. Third, because ESPD is a fuel-based, not cost-based, dispatch mechanism, system costs are not necessarily minimized.

Establishing a comprehensive power market mechanism offers a way to solve this problem.

Because efficient and renewable generators usually have more competitive operation costs, they are more likely to be cleared in a market-based power sales mechanism, which will achieve a balance between economic operations and environmental conservation.

2.2.3 Develop Renewable Energy

To achieve China's sustainable development goals, the Chinese government has formulated a number of policies supporting renewable energy (SGCC, 2018). In recent decades, the installed capacities of wind power and solar energy have respectively increased by 44% and 191% annually, which are far higher than the global average growth rates (Shu, 2018). According to the "Thirteenth Five-Year Plan for Electricity Development" (NDRC and NEA, 2016a), renewable energy must account for 31% of the total generated electricity and 39% of the total installed capacity by 2020. By the end of 2018, China's clean energy installed capacity had reached 696 GW, which represented nearly 30% of the world's total installed capacity (IRENA, 2019). Its annual clean energy generation reached 1,776 TWh (CEC, 2019b), which was more than the total electricity consumption in the Middle East and Africa (i.e., 1,693 TWh) (Enerdata, 2019). The fractions of wind power in major Chinese wind provinces are comparable to other major wind regions in the world (see Table 2).

Table 2 Fractions of wind power based on the shares of consumption in major Chinese wind provinces and three major wind regions in 2018

Country	Ireland	Spain	China	U.S.	China	China	China
Province or region	/	/	Inner Mongolia	ERCOT	Gansu	Ningxia	Xinjiang
Wind fraction	29.3%	19.0%	18.8%	18.6%	17.8%	17.6%	16.8%

Source: China (NBS, 2019; NEA, 2019b), Ireland (EirGrid, 2019), Spain (REE, 2019), the U.S. (Wiser and Bolinger, 2019)

With the large deployment of renewable energy, curtailment has become a key issue in China's power sector. In 2016, the curtailment ratio of wind was 17.1% (Qi et al., 2019), and the total curtailed renewable electricity was close to 110 TWh, which equaled the full-year electricity consumption of the Netherlands in 2016 (BP, 2018). In some provinces, renewable energy curtailment was much more severe. For example, in 2016, three provinces had wind curtailment ratios over 30%, and two provinces had solar curtailment ratios over 30% (see Table 3).

Table 3 Renewable curtailment ratios for selected Chinese provinces in 2016

Province	Gansu	Xinjiang	Jilin	Inner Mongolia	Heilongjiang	Liaoning	Ningxia	Shanxi	Qinghai
Wind curtailment	43%	38%	30%	21%	19%	13%	13%	7%	/
Solar curtailment	30.0%	30.2%	/	6.1%	/	/	6.2%	6.5%	8.3%

The reasons for renewable curtailment are complex. First, in the traditional regulated power sales mechanism, coal-fired generators receive an annual government-set quota that should be met by grid companies through its dispatch (discussed below). Second, renewable energy curtailment is uncompensated, and in the absence of a short-term market or optimization, on-grid prices for

renewable energy, which are 0.40–0.57 RMB/kWh (57–81 $/MWh) for wind and 0.55–0.75 RMB/kWh (78–107 $/MWh) for solar, are thus higher than those for coal-fired generators, 0.26–0.45 RMB/kWh (37–64 $/MWh), which does not provide appropriate incentives to maximize integration (NDRC, 2016, 2017a, b). Third, the lack of short-term optimization of energy and ancillary services leaves potential flexibilities and efficiency gains untapped. Fourth, interprovincial transaction barriers decrease the areas over which renewable energy can be integrated.

Therefore, an important goal of the new reform is to establish a renewable energy-friendly power market system to regain renewable energy price competitiveness, and to provide demand, support, and a platform for its integration.

2.2.4 Decrease Industrial Electricity Prices

According to the 2016 statistics, the average electricity price of China's industrial and commercial enterprises was 107 $/MWh, which was higher than that of most developing countries and even some developed countries. For example, the average Korean industrial and commercial electricity price was 101 $/MWh, and the average U.S. industrial and commercial electricity price was 70 $/MWh (IEA, 2016). Considering China's relatively low resource and labor costs, its industrial and commercial electricity prices are even more expensive in comparison (Brandt and Rawski, 2019). High electricity prices have placed a heavy burden on the development of China's industry and commerce.

As discussed above, the regulated electricity price system, cross-subsidy policy, low utilization rate of power generation assets, high energy consumption per unit of power generation, and high curtailment of renewable energy all contributed to the relatively high industrial and commercial electricity prices in China. Therefore, an important goal of the new reform is to

establish a comprehensive and efficient power market system to decrease the transaction costs of the traditional regulated power sales mechanism and achieve the goal of further reducing electricity prices. Premier Li Keqiang set a goal of reducing the average price for industrial and commercial electricity by 10% in each of the last two years (Li, 2018, 2019).

3 REFORMS

China launched a new round of power sector reform in March 2015, aiming to build a comprehensive and efficient power market system. Once this round of reform has been completed, China's power market structure is expected to have transformed into that shown in Figure 4.

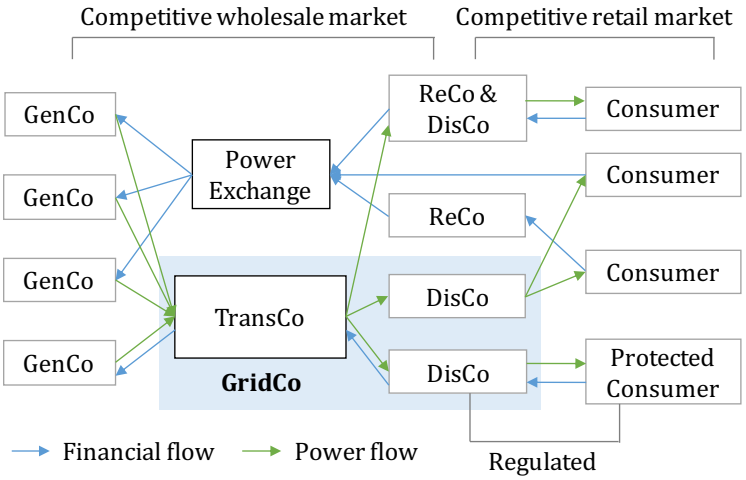

Figure 4 Expected post-reform power market structure

Trading in the power market is mainly conducted through the power exchange center, and the power dispatch, transmission, and distribution remain the responsibility of the GridCo. On the supply side, GenCos compete to sell electricity directly to retail companies (ReCos) and large consumers. On the demand side, the transmission and distribution networks are open to all market participants without distinction. Thus, the ReCos could participate in the market on behalf of

consumers without owning a distribution network or could choose to build a distribution system to serve specific consumers and avoid high transmission and distribution prices. In addition, for protected consumers such as residents, agricultural users, public utilities, and public services, the GridCo still provides regulated power supply services.

To achieve the goal of power sector reform, since 2015, various departments, principally the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA), have issued policies to promote the reform, see Table 4.

Table 4 Key milestones of the new reform (March 2015 to May 2019)

Time	Issuing Agency	Event	Significance
March 2015	CCCPC & SCC	Document No. 9 is issued (CCCPC and SC, 2015)	The document serves as a general outline of the new reform in China
November 2015	NDRC & NEA	Six documents supporting Document No. 9 are issued (NDRC and NEA, 2015a, b, c, d, e, f)	These documents provide standards on the reforms of transmission and distribution pricing mechanisms, the electricity wholesale market, electricity power exchange centers, annual generation plans, electricity retail market, and independent coal-fired power plants
December 2016	NDRC & NEA	Document "Basic Rules for Forward Power market" is issued (NDRC and NEA, 2016b)	The document gives guidance on DPP, interprovincial and interregional trading, and electricity contract transferring on yearly, monthly, and weekly time scales
March 2017	NDRC & NEA	Document "Notice on Orderly Relieving Generation and Consumption Plan" is issued (NDRC and NEA, 2017a)	The document requires a gradual decrease in annual generation planning for coal-fired generators, a gradual release of interprovincial transmission planning and the promotion of the priority generation rights of renewable energy
August 2017	NDRC & NEA	Document "Notice on Piloting the Spot Power Market Construction" is issued (NDRC and NEA, 2017b)	The document aims at gradually building a power market system combining the forward and spot markets. Eight provinces were selected as pilots to start the construction of the wholesale spot market: Guangdong, Shanxi, Gansu, Shandong, Sichuan, Zhejiang, Fujian, and Inner Mongolia
August to September 2018	BPEC & GPEC	Documents "Implementation Rules on Interregional and Interprovincial Electricity Forward Transaction in Beijing Power Exchange Center" (BPX, 2018) and "Implementation Rules on Interregional and	These documents establish official rules for interregional and interprovincial power transactions in forward markets

		Interprovincial Electricity Forward Transaction in China Southern Areas" (GPEC, 2018b) are approved by the NDRC & NEA	
August to December 2018	/	/	The wholesale spot markets in Guangdong, Shanxi, and Gansu started the operation simulation
May 15, 2019	/	/	The wholesale spot market in Guangdong conducted a trial operation with real settlements. The daily trading volume was 947 GWh, marking the beginning of operations in China's first wholesale spot market

4 PROGRESS

Since the launch of the new reform, all provinces in China have implemented policies to promote the construction of the power market. A typical reform path widely adopted by many provinces, such as Guangdong and Zhejiang, is as follows: (1) build a forward (physical) market, expand market access, increase the amount of market-based electricity trading, and cultivate participants' market awareness; (2) build an ancillary service market to provide services for frequency regulation, energy reserve, and others, and a peak regulation market might also be envisioned before the operation of a spot market, depending on the situation of renewable curtailment; (3) build a spot energy market closely integrated with the forward market, which could be a mixture of financial and physical contracts, achieving full market competition; (4) build a capacity market, financial forward markets such as futures and options, and others. The reform path is illustrated in Figure 5. At present, the provinces exhibiting the most rapid reform, such as Guangdong, Zhejiang, and Shanxi, have entered the third stage.

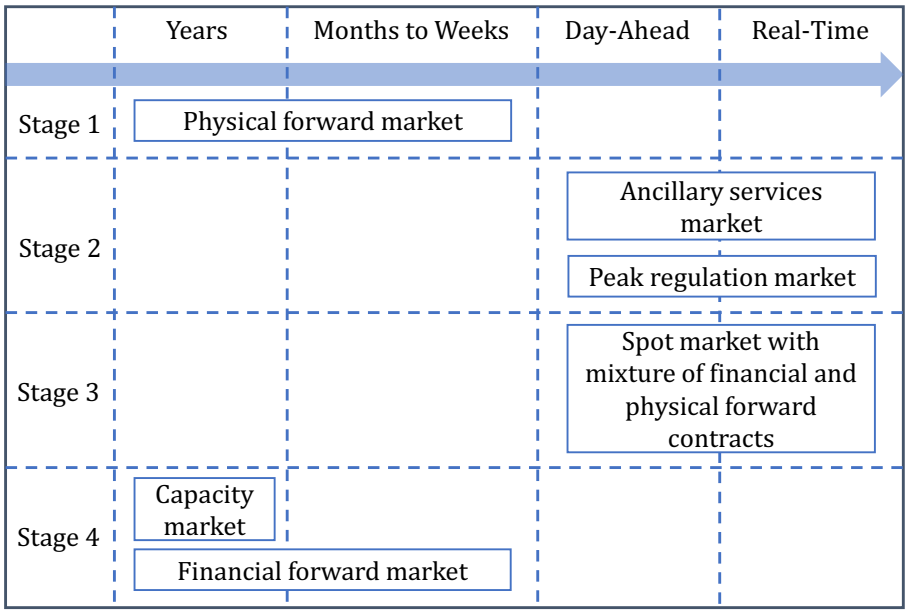

Figure 5 Typical power market construction path in Chinese provinces.

4.1 Power exchange center

According to the reform requirements, the power exchange center plays an important role in the power transaction procedures. All centralized power transactions should be conducted through the power exchange center. As for bilateral contracts, participants must submit their signed contracts to the power exchange center for a security check. Provincial market transactions are conducted through the provincial power exchange center, and interprovincial and interregional markets operate through the national power exchange centers. By the end of 2018, two national power exchange centers and 32 provincial power exchange centers (covering all provinces of mainland China) had been established.

The organizational structures of provincial power exchange centers can be divided into two categories: joint-stock enterprises controlled by the GridCo with other minority ownership stakes (e.g., Guangdong, Shanxi, Yunnan) and wholly owned subsidiaries of the GridCo (e.g., Zhejiang, Shandong, and Hebei).

Relying on the State Grid Corporation of China (SGCC) and China Southern Power Grid Corporation (SCG), China has established two national power exchange centers located in Beijing and Guangzhou. The national power exchange centers are mainly responsible for implementing interprovincial and interregional transactions and national directives.

4.2 Market participants

The market participants mainly include GenCos, ReCos, and consumers. Since the reform, the number of market participants has gradually increased, and by the end of 2018, the number of registered market participants in SGCC's areas exceeded 68,000, comprising 28,000 GenCos, 37,000 consumers, and 3,000 ReCos.

4.2.1 Generation Company

At present, most types of generation, such as thermal, hydropower, nuclear, wind power, and photovoltaic, can be traded in power markets, although market and participation rules generally vary. For example, several provincial power markets such as Hubei and Henan have minimum capacity limits on generators, such as restricting participation to plants larger than 200 MW.

An obvious oligopoly-dominated phenomenon occurs in most provincial markets, in which the largest GenCo occupies a significant market share, as shown in Table 5. Therefore, the largest GenCos could abuse their market power if not appropriately regulated.

Table 5 Market shares of the largest GenCo in several provincial markets (authors' own data)

Provincial market	Largest GenCo	Capacity Share
Zhejiang	Zhejiang Energy Group Company	58.5%
Shandong	China Huaneng Group Company	29.5%
Guangdong	Guangdong Energy Group	27.9%
Shanxi	Datong Coal Mine Group	22.0%

4.2.2 Consumers

Initially, only industrial and commercial consumers were allowed to participate in power markets, whereas other consumers, including residents, governments, and research institutes, continued to be supplied by GridCos at the regulated prices. There were also requirements for industrial and commercial consumers to participate in the market, such as minimum voltage levels or annual electricity consumption. For example, the current voltage level requirement for consumers in many provinces, such as Guangdong, Shandong, and Anhui, is 10 kV. The annual electricity consumption requirements for consumers in Henan is 10 GWh.

As power market construction progressed, the requirements for consumers were eased. Residents, agricultural firms, public utilities, and industrial power consumers with voltage levels below 10 kV were gradually allowed to participate in the market through the agency of ReCos.

The number of registered market-participating consumers has increased every year. Taking the Guangdong power market as an example, the number of registered consumers increased from 5,634 in 2017 to 9,148 in 2018. At present, the proportion of consumers participating in markets has reached 90% by number in Guangdong (GPEC, 2019).

4.2.3 Retail Company

There are two main ways for consumers to participate in the market: by direct transaction or through ReCos. The latter has been the major approach for consumers with small market shares: first, a consumer signs a contract with a ReCo, determining its electricity purchase prices and quantities; then, the ReCo participates in the wholesale market on behalf of the consumer. ReCos operate under loose requirements, and the main regulations focus on the ReCos' financial security and risk management.

As the volume of market-based electricity transactions continues to increase, the number of ReCos and their transactions as agents are also increasing. In 2018, the volume of agent transactions through ReCos exceeded 200 TWh, accounting for nearly 10% of the total market-based electricity transactions (BJX, 2019). In some areas, the ReCos have developed more rapidly. Taking the Guangdong power market as an example, 6,907 consumers participate in the market through ReCos' agent transactions (GPEC, 2019).

4.3 Forward market

One crucial mission of the new reform is to construct a power market that integrates a spot market with China's various forward markets (NDRC and NEA, 2015d). The spot market and the forward market are distinguished by their trading time scales: the spot market has transactions on a daily or shorter time scale, whereas the forward market sees transactions beyond the daily time scale.

At the beginning of the power sector reform, most provinces had insufficient conditions to run a spot market. Thus, most provinces launched a power market by first building a forward market. Without real-time optimization from the spot market, the contracts signed in China's forward markets are mostly in the format of physical energy contracts that determine only a price

and total amount of energy, which must later be decomposed into power curves and accurately implemented in the real power system dispatch. These are fairly different from both financial contracts and self-scheduling of physical contracts, which are used in mature power markets, such as PJM or CAISO in the U.S. Financial contracts, in particular, only affect transaction settlements and are not considered as an input to the power system dispatch.

There are two types of transactions in provincial forward markets: DPP and forward contract transfers. The former refers to the direct purchase and sale of electricity between GenCos and consumers or ReCos, and the latter refers to transferring DPP contracts, priority generation right contracts, and generation quotas.

DPPs mainly take the form of physical energy contracts. First, a contract is signed between a producer and a consumer to determine the amount and price of the transacted electricity. Then, after approval following the dispatch centers' safety checks, the contract becomes valid. The transacted electricity is only determined by energy quantity (kWh) and most often without a specific power curve (kW). Thus, the dispatch centers or participants must decompose the transacted electricity quantity into a monthly energy quantity and later into a daily energy quantity. The participants are allowed to further decompose the daily energy quantity into time-varying power curves and report to the dispatch center, or the dispatch center decomposes the daily energy quantity into time-varying power curves based on a historic profile of the system demand; this produces a daily dispatching schedule. In actual operations, the dispatch center will dispatch the generators based on the daily dispatching schedule, trying to ensure that the daily energy quantity is met exactly. In the case when the decomposed daily energy quantity is not exactly met, the deviation will be shifted into the daily energy quantities of later days. A detailed execution procedure for physical energy contracts is summarized in Figure 6.

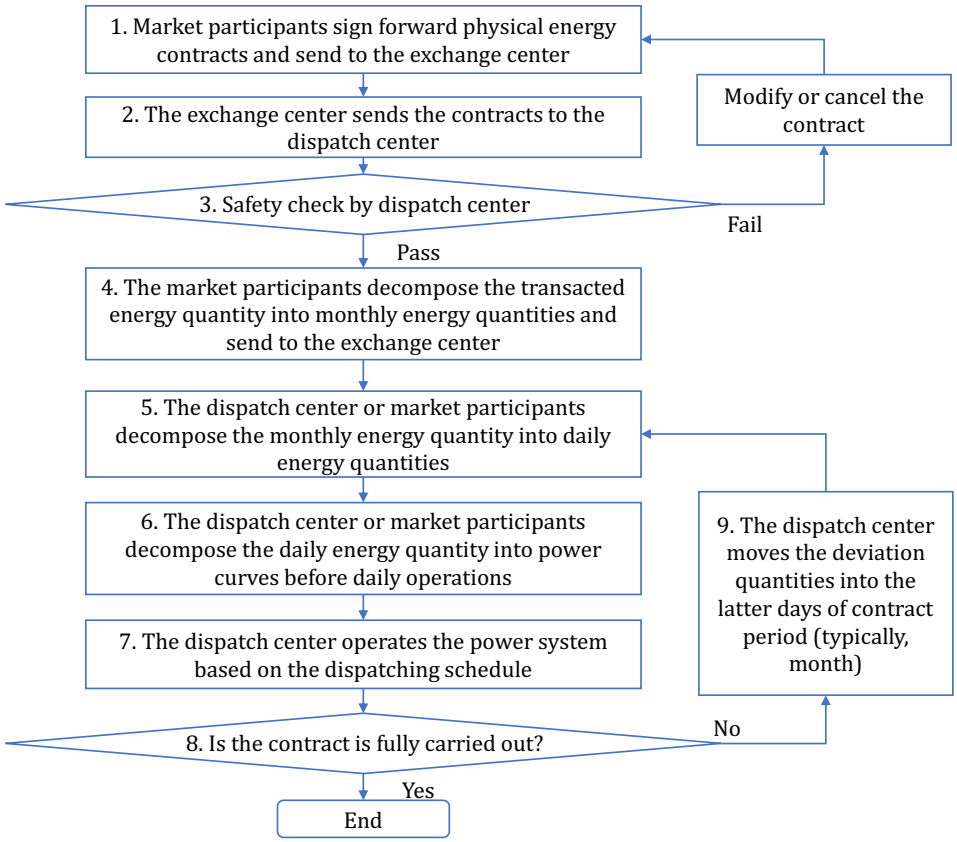

Figure 6 Execution procedure of physical energy contracts

It should be noted that spot markets around China are under construction. When a spot market is established, market participants will be allowed to choose an execution pattern from the physical or financial patterns for their forward contracts.

In 2018, the amount of transacted electricity in the provincial power markets was 1,688 TWh, accounting for 81.8% of the total amount of forward-transacted electricity (CEC, 2019a). Figure 7 shows the market-based trading power and proportion in some provinces in China with data available (CEC, 2019a).

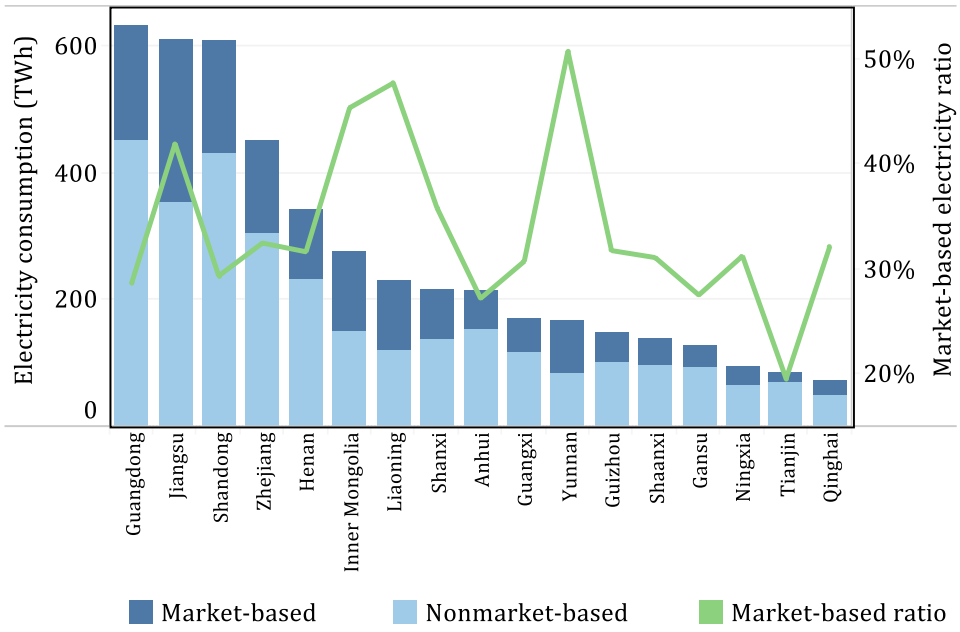

Figure 7 Electricity consumption and proportion of market-based power transactions in select provinces in China (CEC, 2019a)

It can be observed that four provinces have market-based trading ratios greater than 40%: Yunnan, Liaoning, Western Inner Mongolia, and Jiangsu. The provinces with market-based trading power exceeding 100 TWh are Jiangsu, Guangdong, Shandong, Zhejiang, Western Inner Mongolia, Liaoning, and Henan.

Interprovincial and interregional forward markets include power transactions between two power grids, interprovincial and interregional DPPs, and interprovincial and interregional forward contract transfers. Specifically, the content of the DPP and forward contract transfers are essentially the same as those in the provincial forward market. The power transactions between two power grids mainly refer to policy-based electricity transactions such as west-to-east power transmission. In 2018, 347 TWh of electricity was transacted in the interprovincial and interregional forward markets, of which the electricity sold in the Southern Grid through west-to-east power transmission was 217 TWh and mainly represents clean energy from Southwest China.

4.4 Spot market

In 2017, the NDRC & NEA issued a document proposing the construction of several pilot power spot markets around China, including South China (starting with Guangdong), Western Inner Mongolia, Shanxi, Gansu, Shandong, Zhejiang, Fujian, and Sichuan. At present, the tentative market construction schemes and market operation rules of spot markets in most of these provinces have been initially completed, and some provinces have started simulation and trial operation of spot markets. To provide a clear view of China's spot market, this review adopts the Guangdong spot market as an example.

Guangdong is the province with the largest economy and electricity consumption in China. In 2018, its total electricity consumption reached 632 TWh, which was approximately 10% of China's total. In addition, the Guangdong spot market is China's fastest-growing spot market and is conducting trial operations with real settlements.

According to the spot market operating rules issued by the Guangdong Power Exchange Center (GPEC, 2018a), the power spot market in Guangdong province shares many similar characteristics with the power pool model represented by the PJM power market (Ott, 2003; PJM, 2019). These similar features include a market clearing price in the format of a locational marginal price (LMP), market participants submitting bids and offers, two stages of a day-ahead market and a real-time market, and a forward contract that works similarly to financial contracts and only has effects on market settlements.

However, the Guangdong spot market also has several major differences from other markets: (1) **Limited generator participation**: At present, only coal-fired and gas-fired generators are allowed to participate in the market. Nuclear power, wind power, photovoltaic power generators, and generators outside Guangdong are not allowed to participate in the market at this time and are

still dispatched in the traditional mode. Their output is only used as the boundary condition for market clearing. (2) **Limited consumer participation**: Currently, the bids from consumers only include declared demand quantities without prices. (3) **Average price used for demand settlement**: To decrease the risk of high and fluctuating prices in the preliminary stages of the spot markets, LMPs are only used for settlement on the supply side, and weighted average prices are used for settlement on the demand side. (4) **No virtual bidding:** There is no virtual bidder, as is common in the power pool market, in the Guangdong spot market. All market participants in the spot market are entities that truly generate or consume electricity. (5) **No co-optimization of ancillary services**: Ancillary services are not co-optimized with the spot energy market. Specifically, the Guangdong spot market first clears the spot energy market and then clears the ancillary services market. (6) **No separate real-time auction**: The same offers and bids submitted by market participants in the day-ahead market are used for the real-time market, without an opportunity for adjustment. (7) **Narrow bidding price ranges**: The price ranges of bids and offers are much narrower than those in common power pool markets. For example, bidding prices for generators are mainly constrained to the ranges from zero to twice their regulated on-grid prices.

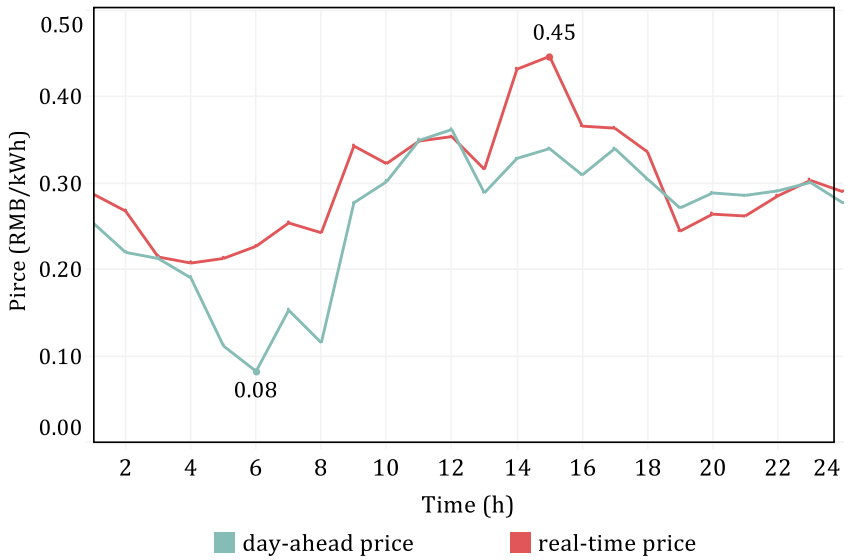

Figure 8 Average prices in Guangdong spot market on May 15, 2019

On August 31, 2018, the Guangdong power trading exchange center first launched a market simulation operation for evaluation (not for settlement). On May 15, 2019, the Guangdong power trading exchange center began market operation with results used for settlement. The average price curves of the day-ahead and real-time markets in the spot market on May 15 are shown in Figure 8. The clearing prices of the Guangdong spot market range from 0.08 RMB/kWh (12 $/MWh) to 0.45 RMB/kWh (65 $/MWh), and the real-time prices are mostly higher than the prices of the day-ahead market. The large divergence between day-ahead and real-time prices during certain hours is mainly due to the lack of a separate real-time auction and limited participants.

In addition, to promote renewable energy integration further, the Beijing and Guangzhou Power Exchange Center also organized interprovincial and interregional day-ahead incremental transactions, specifically for sending renewable energy from West China to East China on a daily basis. This market is operated as follows. On the day before the operation day, each provincial GridCo submits their expected interprovincial renewable energy supply and power demand. Then, the national power exchange centers clear the markets and determine the interprovincial dispatch

schedule for the operation day. On the operation day, the national power exchange centers continuously adjust the market clearing results based on the deviations of the renewable energy supply and power demand, thereby producing the final interprovincial dispatch schedules. These will be sent to each GridCo to serve as the boundary conditions for provincial power optimization. The volume of interprovincial and interregional day-ahead incremental transactions through the Beijing Power Exchange Center in 2018 reached 9 TWh (BJX, 2018).

4.5 Ancillary services market

Ancillary services are an essential part of maintaining safe and stable operation of the power system, consisting of frequency regulation, automatic generation control, reactive power regulation, energy reserves, and black start, among others. Because there are no market-based ancillary services in the traditional regulated power sales mechanism, an **ancillary service regulated transaction** mechanism was proposed by the government for market participants to make payments for ancillary services (Zeng et al., 2014).

In 2018, 4,176 GenCos provided ancillary services, with a total installed capacity of 1,325 GW (69.7% of total generation capacity). The total payment for ancillary services was $1.40 billion, equivalent to 0.54% of the total payment for electricity generation. Comparatively, the cost of ancillary services in the PJM market in 2018 was $654 million, equivalent to 2.2% of electricity generation costs (IMM, 2019). This suggests that regulated ancillary services in China are undercompensated. Frequency regulation and reserves account for 43.8% and 45.0%, respectively, of total ancillary service costs (see Table 6).

Table 6 Annual costs of various ancillary service types in China in 2018. Source: NEA (NEA, 2019a)

Type of ancillary service	Frequency regulation	Reserve	Voltage regulation	Others
Cost (million dollars)	612.6	630.3	151.9	6.3

In 2017, the NEA issued a document (NEA, 2017) requesting the construction of ancillary service markets and further identifying eight provinces or regions, including Northeast China, Shanxi, Fujian, Shandong, Xinjiang, Ningxia, Guangdong, and Gansu, as pilots for ancillary service reforms.

To provide a clear view of China's ancillary service market, this review adopts Shanxi's reform as an example. In 2017, the Shanxi Energy Regulation Office (SERO) released the construction plan for an ancillary service market (SERO, 2017), stating that a co-optimized ancillary service and energy market would be built in two stages:

(1) First stage (2017–2018): Start the construction of ancillary service market including frequency regulation and explore the market-based operation mechanism of reactive power compensation and black start ancillary service.

(2) Second stage (2019–2021): When the spot market is operating, the reserve product will be introduced into the ancillary market. Then, the Shanxi power exchange center will co-optimize the operation of the spot energy market and the ancillary market, which includes reserve and frequency regulation. At the same time, reactive power compensation and black start ancillary services will be transacted based on market-based bilateral negotiation transactions.

4.6 Peak regulation service

In China's traditional power dispatch, there is an additional category of service designed to assist with managing supply and demand on a daily basis in the presence of significant physical

energy contracts as well as renewable energy. This "peak regulation" service is typically classified as an ancillary service in China, although it is distinct from common understandings elsewhere of ancillary services. Uncompensated peak regulation happens as a normal process of decomposing energy quantities into power curves as shown in step 6, Figure 6. Compensated peak regulation may be called upon when the system is in the valley period and generators must be dispatched further down. This may increase heat rates and costs of generators, and owing to the lack of a short-term market or cost minimization, additional incentives are given to thermal generators that reduce output during these periods (Alva and Li, 2018).

In 2014, Northeast China established a day-ahead market for peak regulation services that allows for one-sided bidding from allowable thermal generators to indicate their desired price per kWh for reducing outputs below the administrative thresholds, typically 50–54% of the rated capacity. The clearing price for peak regulation is determined by the marginal thermal unit required in real-time given the load and renewable energy availability. Compared to the former regulated compensation price for peak regulation, significantly more thermal generators participated in the market and reduced their power outputs. For example, from 2017 to 2018, an additional 3 GW of power generation space was opened up in total for wind power (Alva and Li, 2018). Part of the reason for this was the much higher compensation received by coal plants: during the first three years of operation, the average peak regulation price was 0.43 RMB/kWh (61 $/MWh), which was on par with the on-grid tariff for generated electricity (Liu et al., 2017). In 2018, with the expansion to several other regions of China, the total size of peak regulation service reached $767.7 million.

5 CHALLENGES

During the rapid development of the power sector reform of China, several challenges have appeared, such as legal and regulatory barriers for power markets, appropriate methods for

addressing stranded costs, difficulty in motiving consumers to participate in markets, pressure to avoid future potential localized power shortages, market participation rules to allow high renewable penetration, and difficulty in integrating power markets with diverse designs.

5.1 Legal and regulatory barriers

Although the central government has issued many documents on power sector reform, these are highly general, leaving significant autonomy in formulating power sector reform programs to provincial governments, which are also the primary overseers of the new markets. Relevant supporting laws specifying regulatory authorities and enforcement are still insufficient. The lack of strong independent regulatory supervision creates loopholes for rent-seeking, and few avenues for recourse by affected parties. Many markets begin trial operation prior to making the designs accessible to a wide range of actors. Transparency is also needed in the implementation of traditional power dispatch because, for example, the power curve decomposition shape of regulated electricity has a direct impact on spot market prices and the fairness of market operations.

5.2 Stranded generator costs

There many problems with stranded costs that need to be resolved. For example, in the traditional regulated power sales mechanism, when the government approves GenCos' applications for power plant construction, they are guaranteed average generation hours as determined by each year's demand and supply. The average number of generation hours might fluctuate between years, but remains roughly consistent for different generators. Power market reforms create competition by gradually decreasing these planned electricity contracts. In this case, some high-cost generators will generate less and may find it difficult to recover their sunk costs. Designing competitive power markets given potential stranded costs is a problem affecting virtually all restructuring efforts elsewhere (FERC, 1996). In China, owing to the high levels of

over-permitting of generation capacity under traditional regulation—particularly in recent years (Ren et al., 2019)—fixed cost recovery is particularly challenging without substantial out-of-market payments to generators (Lin et al., 2019).

5.3 Protected consumer classes

Residential, agricultural, and various other classes of consumers receive cross-subsidies from regulated industrial and commercial consumer tariffs. These protected consumers currently do not participate in the market and have no incentive to do so, because their rates would likely rise on average. This issue is common in other developing countries that have provided low-cost electricity as a means of poverty alleviation (Jamasb, 2006). It will be necessary to mobilize more consumers to participate in the market to increase the quantity of supply and demand in the market and gain further efficiencies. However, it is currently challenging in China to address the social goals of protecting these consumers while introducing market mechanisms.

5.4 Threat of future localized power shortages

In the traditional regulated power sales mechanism, generation investment was controlled by the government and typically exceeded the rate of demand growth, leading to ample reserve margins. With the introduction of power markets, electricity prices have lowered, weakening the incentives for new generation investments and revealing potentially large overcapacity. At the same time, some areas in China have seen significant volatility, diverging from national trends in electricity demand growth. For example, while national growth was stagnant in 2015, demand in Shandong grew by over 20% (see Figure 9). Given the barriers to inter-provincial trade as well as the large distances over which supply and demand must be balanced, the potential for future localized power shortages under current low investment incentives cannot be ignored.

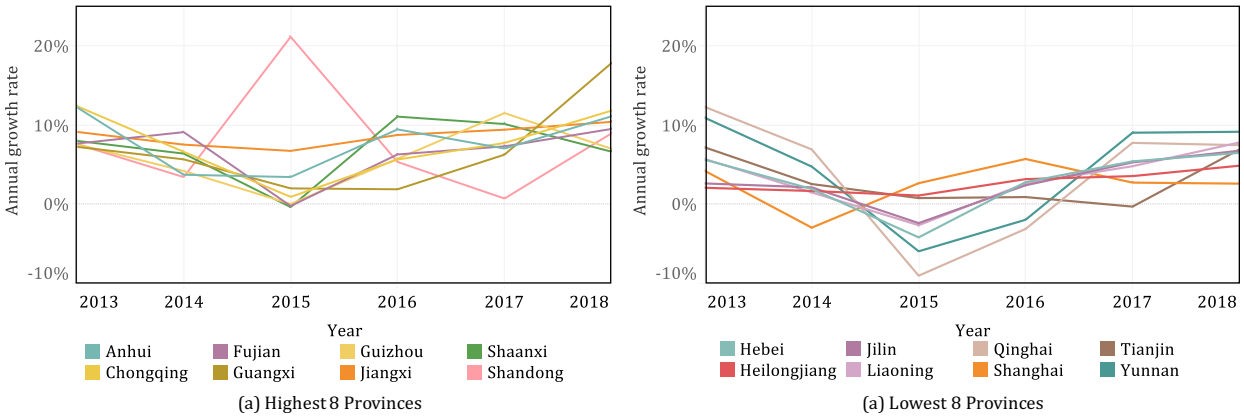

Figure 9 Annual growth rates of electricity demand in fastest and slowest growing provinces. Source: NBSC (NBSC, 2019).

5.5 High renewable energy penetration

Although renewable energy curtailment rates have shown some improvement over 2017–2018, continued expected growth based on government targets as well as lower long-term demand growth projections imply that this issue is far from resolved. In other systems, renewable energy is challenging the implementation of certain electricity market designs, given the range of political goals for the sector (Pollitt and Anaya, 2016). There is still debate in China as to the nature of renewable energy's participation in the market, which could have long-term consequences for both the efficiency of the market as well as curtailment. If renewable energy does not participate in the market, its scheduled power output will follow the traditional dispatch mechanism with all of its flaws outlined above. If renewable energy does participate in the market, Chinese regulators will need to determine rules on bidding, forecasts, and imbalance management. In either case, its low operational costs and supply volatility will lead to an overall decline in market prices as well as greater uncertainty for other market participants.

5.6 Diverse power market designs

Thus far, power markets in China have been designed and constructed by provincial

governments in various ways, including among the eight spot market pilots. For example, the power spot markets in Guangdong and Zhejiang are more focused on the optimization of the whole system (consisting of a large, mandatory pool with financial forward contracts), whereas the spot markets in Sichuan and Fujian are more focused on adjustments in the daily dispatching plans (more akin to an imbalance mechanism with significant physical forward contracting). The high diversity and potential incompatibility among the rules of provincial power markets will make it difficult to integrate them and accomplish a higher level of optimization in the future.

6 RECOMMENDATIONS

The new reform has been in place for four years. In the context of a completed provincial forward market and the trial operation of certain provincial spot markets, we propose a series of recommendations for China's future power sector reform.

6.1 Enhance market regulatory institutions and establish a legal framework

First, the strength of central regulatory officials in the NEA and NDRC in overseeing local market designs should be further increased. For example, regulatory officials should have strengthened authority to evaluate—and reject if necessary—the detailed rules for provincial market construction to prevent loopholes that allow rent-seeking. Second, the construction process, detailed designs, and operating data of provincial markets should be selectively open to the public to ensure third party market monitoring and appropriate social supervision. Third, the related laws and regulations need to be revised according to the issued documents, providing a legal and stable foundation for power sector reform.

6.2 Confront stranded cost problems with transparent transition guarantees

Without a doubt, many prospective market participants view with hesitation—and may oppose—changes to the regulatory regime that would affect both future and existing investments. Whereas the risks of all new investments after market reforms are inaugurated should be borne by market participants—arguably, this should apply to new facilities since 2015—investments (e.g., in generator plants) made prior to market regulation require transition mechanisms that help mitigate the potential for stranded costs. Ideally, these should be transparent, time-delimited, and not affect proper market functioning.

6.3 Reduce the role of the government in price and plan setting

Although 30% of electricity consumption is transacted through market-based methods, a large volume of electricity is still transacted under traditional regulation. Governments need to further decrease their role in price and plan setting by reducing the volumes of annual generation plans, raising upper limits on market transactions, reducing intervention in the price-setting of power markets, and liberalizing the entry barriers for consumers to participate in the market. These changes will lead participants, both GenCos and consumers, to participate in the market more competitively, thereby helping to achieve efficient outcomes. The transaction volumes in the forward markets will increase, which will reduce the deadweight loss from the double-track market system. In addition, a high level of market-based transactions will also facilitate the smooth adoption of spot markets.

6.4 Establish a comprehensive power market system

Most electricity markets in China are based on physical forward contracts that must be carried out by the grid in its scheduling operations. A spot market is necessary for dispatch to efficiently respond to changing supply and demand conditions. In addition, a comprehensive

power market system would also include ancillary services and complementary forward markets. The introduction of this suite would simplify the current system and make certain transient trading products, such as peak regulation, obsolete. On this basis, other supportive markets that are crucial in mature power market systems elsewhere, such as capacity markets, financial transmission rights, and virtual bidding could then be integrated into China's power market system.

6.5 Design mechanisms in consideration of renewable energy

To adapt to the high penetration of renewable energy in several provinces, the power market mechanism should be designed in full consideration of the characteristics of renewable energy. First, renewable energy should be allowed to participate in the market. Second, to address the intermittent and uncertain characteristics of renewable energy, markets should be designed with significant granularity in location (i.e., nodal) and time (i.e., sub-hourly dispatch, with possible intraday markets). With the high competition from low operating costs and renewable-friendly market mechanisms, renewable energy will be easily cleared in the power market, thereby decreasing renewable energy curtailment. Third, markets for distributed renewable energy also need to be built, and these could fairly evaluate the value of distributed renewable energy and properly compensate renewable energy suppliers.

6.6 Integrate provincial markets into regional markets

To achieve a higher level of resource optimization, it is necessary to integrate provincial markets into larger regional markets. This requires two steps. First, the interprovincial and interregional linkages and transactions must be expanded, thereby increasing the connections among the provincial markets. Second, the market rules in neighboring provincial markets must converge, especially with respect to the market type, transaction sequence, and settlement models.

6.7 Improve compatibility with other new regulations

Independent of the power market reform, there are other important new regulations to be introduced that mainly target the power sector, e.g., the national CO_2 emissions trading scheme led by the Ministry of Ecological Environment and the renewable portfolio standard led by the NEA. Therefore, it is crucial to coordinate the design of these polices to ensure that policy interactions with the power market reform would not undermine the overall economic efficiency. For example, the national emissions trading scheme must account for indirect emissions from electricity use for industrial firms if the power market reform has not deregulated the industrial electricity price to pass through the increased cost of electricity generation when both the thermal power and industrial sectors are included in the emissions trading scheme. The renewable portfolio standard also needs to incentivize more interregional transmission to reduce the overall costs to increase the share of renewable energy in China's grid at the national level.

7 CONCLUSIONS AND POLICY IMPLICATIONS

China's experimental reforms of power markets at the provincial level have made great strides toward achieving the goals of the 2015 reform agenda—to increase generation efficiency, reduce pollution, develop renewable energy, and lower industrial electricity prices. These experiments have also revealed many challenges that are faced when transitioning away from a largely government-directed regulatory regime. Whereas markets are important, the exact nature of the market as well as the supporting institutions, such as the regulator, matter even more. We find ample room for deployment of markets toward achieving these objectives, but the pathways must emphasize China's historical context—dispatch mechanisms, inter-provincial coordination, and investments under traditional regulation—to be successful.

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