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China's Power Generation Dispatch

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RESOURCES FOR THE FUTURE

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Executive Summary

China is making major reforms to its electric power system, introducing more market elements into the dispatch system, which is dominated by administrative planning. The government hopes to make the system more energy efficient and less polluting, incorporating more renewables. Separately, the government also plans to introduce a National Carbon Emissions Trading System (ETS) in 2017. To analyze these complex reforms, it is important to understand the unique institutions that govern the power system. This report describes the state institutions and the electric power control system and provides an account of past reform efforts, including the changes made and the difficulties faced when implementing them within the existing governance structure. A companion report will present an analysis of the proposed changes and the interaction with the ETS.

In the United States, electricity dispatch is not the result of administrative decisions but the outcome of the supply decisions of individual generators mediated through both forward and spot markets. The spot market usually consists of day-ahead and real-time (balancing) markets supported by unit commitment and economic dispatch algorithms. China currently does not have a spot market for electricity, even though it started restructuring its power sector more than a decade ago. The commitment and dispatch of generators are guided by instructions from economic planning agencies within provincial governments. The main elements of the current dispatch system in China are the following:

Administrative Allocation

Administrative allocation of annual generation quotas by provincial governments. Toward the end of each calendar year, the provincial governments make a forecast of total electricity demand for the next year, and then allocate this demand to generators within the province and imports from outside the province. The allocation follows a "fair dispatch" principle, where generators in a given class, say coal-fired power plants, are allocated the same annual utilization hours. This fair dispatch rule was established in the 1980s, when the state monopoly was ended and private investment in generation was permitted. The intention was to guarantee an equitable chance of cost recovery for all investors. Provincial governments set benchmark feed-in tariffs for these assigned quotas, differing by generation technology. Transmission and distribution fees and retail electricity prices are also set by the government.

Forward Contracts

Forward contracts between eligible generators and big consumers within the same province. These have been allowed since 2002 in the first experiments with market mechanisms in the power sector. These contracts cover 2–10 percent of the total electricity demand in the provinces. Selected generation companies negotiate annual contracts with large industrial consumers on their own or sometimes have contracts imposed by the government. In countries with spot markets, the price realized in forward energy contracts will converge to average spot market prices because of risk-hedging behavior. In China, however, since there are no spot markets but regulated feed-in tariffs and retail prices, the bargaining process is quite different. Consumers always have the right to buy at the regulated retail price and will only accept a lower contract price. Generators are guaranteed the feed-in tariff only for their allocated quotas, and thus the forward contracts are attractive to them in that they allow sales beyond the quotas. This option becomes an instrument for provincial

governments to lower costs for important local businesses.

Generation Rights Trading

Trading of allocated generation quotas has been allowed since 2008. Under the 11th five-year plan (2006–2010) for reducing pollution and improving energy efficiency, small generators were scheduled to be closed (decommissioning up to 77 gigawatts [GW]). As compensation, they continued to receive generation quotas for a grace period of three years, which they could sell to bigger, more efficient plants. Contingent on administrative approval, plants not facing decommissioning are also allowed to trade generation quotas. The approval process ensures that quotas are transferred to cleaner, more efficient units and not the other way around. Overall, generation rights trading helps improve economic efficiency and environment performance of generation dispatch, but only to a limited extent.

Cross-Jurisdictional Electricity Flows

Provincial governments are the primary authority over the electricity system for two reasons: the incentives facing the governments and the incentives of the national grid companies. Since the investment deregulation of the 1980s, provincial governments play a major role in authorizing, administering, and financing power infrastructure projects. Given that everyone buys electricity, and given the sensitivity to household welfare, the sector becomes an integral part of planning by local governments, which often own the generation assets outright. Provincial governments and provincial grid companies assume joint responsibility in guaranteeing reliable electricity supply, and thus any major technological or institutional change is scrutinized carefully. For all these reasons, they are reluctant to surrender control over power sector affairs.

The central government would like more inter-provincial flows to improve overall efficiency, allowing power to flow from low-cost provinces to high-cost ones. From 2003 to 2006, the State Electricity Regulatory Commission (SERC) ran a pilot regional electricity market in the Northeast covering Liaoning, Jilin, and Heilongjiang, which ended amid resistance. Each province wanted cheaper electricity but did not want to see utilization hours drop for its generators. As the pilot progressed, volatile spot market prices and pressure from risk-averse generators and consumers drained the political will of both the SERC and provincial governments. Since then, inter-provincial trading occurred only to implement top-level energy strategies, such as the allocation of electricity from major hydroelectric projects (e.g., the Three Gorges Dam) and the west-to-east and north-to-south electricity corridor projects. The central government has not yet garnered the necessary political capital and legal status to create a set of institutions that can supersede provincial control over generation dispatch. These central-local relations are major barriers to power system reform to improve efficiency.

The second factor causing the fragmentation of dispatch zones is the political economy of the grid system. While the State Planning Commission wished to have strong regional grid companies that could oversee inter-provincial flows, the State Power Company argued for a strong national grid company. The compromise resulted in a unified dispatch along multilevel management, which splits responsibilities among national, regional, and provincial grid companies. The State Grid Corporation operates the largest interties, while five subsidiary regional grid companies manage the 330–550 kilovolt (kV) lines. Provincial grid companies control the provincial networks (220 kV lines) and assist in implementing annual generation plans. The Southern Grid Company was set up as an

independent regional company to experiment with more integrated regional dispatch operations. However, by 2012, the State Grid Corporation centralized its powers and turned the regional companies into branch offices, and the effort to institutionalize regional dispatch organizations ended.

Energy Conservation Dispatch (ECD)

Eight provinces plus Shanghai have experimented with ECD, an innovative dispatch rule proposed in 2007 aiming to prioritize clean energy over coal-fired generators and to utilize coal-fired generators following a merit order based on fuel efficiency and emissions. The algorithm used was very similar to that of economic dispatch, except that in economic dispatch, generators are ranked in increasing bidding prices, whereas in ECD, generators are ranked first by fuel efficiency and then by emissions levels. Despite quite promising energy savings, full-scale implementation was stalled in all pilot zones after a short period of experimentation because of the political power of established interests. Meanwhile, nonpilot provinces were encouraged to experiment with similar mechanisms. Most of them ended up using a differentiated generation quota scheme, a rule that marginally adjusts coal-fired units' generation quotas according to their unit capacity, fuel efficiency, or emissions levels.

1. Introduction

Generation dispatch is the central decision making process in modern electric power systems that acquires generation resources and maintains instantaneous balancing of power supply and demand. Its goal is to maintain system reliability, which can be achieved at different economic and environmental costs depending on how the dispatch is actually carried out. In advanced market economies, generation dispatch usually refers to a sequence of procedures including long-term contracts between generators and utilities, day-ahead bids for unit commitment supplying power at particular prices, hourly bids, and real-time economic dispatch. Ultimately, the sequence would acquire the least-cost combination of generation resources to meet real-time system loads. The resulting real-time price reflects the scarcity of electrical energy at that moment, given all the system constraints.

Generation dispatch in China is carried out quite differently than in its western counterparts. The two key components of China's generation dispatch are generation planning and real-time dispatch. Generation planning is an administrative planning procedure that determines each generator's electricity production in a given year based on annual demand forecasts. It is conducted primarily by economic planning commissions at provincial government level, which allocate quotas of generation hours to the generation companies. After annual generation plans are made, they are handed over to power grid companies, which translate them into quarterly, monthly, and daily unit commitment schedules based on grid topology and updated load forecasts. Grid companies are to take extra care in designing these unit commitment schedules so that generators' year-end utilization hours will best approximate their allocated generation quotas. In real time, eventually, system operators dispatch generators according to finalized daily unit-commitment schedules.

The above description is a simplification of China's generation dispatch process. To illustrate the complexity of the real process, a more complete characterization with both longitudinal and horizontal dimensions is needed. On the one hand, the rules governing dispatch have evolved alongside China's power sector reform in the past two decades. An investigation into the historical context is necessary to obtain a full understanding of

how the dispatch rules relate to different stages of the reform. On the other hand, since generation dispatch is a function of supply and demand, how each province builds and uses its generation fleet depends largely on its resource endowment and economic conditions. Given that generation planning is a decision at the provincial level, it should be expected that different provinces will dispatch generators differently, and this heterogeneity should be properly accounted for.

This report characterizes China's generation dispatch process in its technical, historical, economic, and political contexts for a non-Chinese audience that is somewhat familiar with electricity market issues and would like to learn about the Chinese system and the reform process. The aim is to enable the reader to appreciate the current reform proposals and the challenges to improving efficiency and reducing pollution. We describe the factors that determine the annual utilization of coal-fired power plants during the various stages of past reform, and then discuss the proposed plans to reform the electricity system, including greater roles for markets and renewables. We hope this will be a useful addition to the existing literature on China's power sector reform, the majority of which consists of either normative discussions on the goals and policies of the reform (e.g., Yeh and Lewis 2004; Ma and He 2008; Williams and Kahrl 2008; Ngan 2010; Kahrl et al. 2011) or empirical analysis on its efficiency effects (e.g., Du et al. 2009; Zhao and Ma, 2013; Gao and Biesebroeck 2014).

To our knowledge, only three published studies (Gao and Li 2010; Kahrl et al. 2013; Zhong et al. 2015) have focused exclusively on China's generation dispatch process. All three have simulated the Energy Conservation Dispatch mechanism (described in Section 4.5) and estimated its energy-saving potential compared with planned generation dispatch. Others have mentioned only a few relevant aspects of China's generation dispatch. As discussed below, China's generation dispatch process is part of the broad political economy of the country's power sector. Understanding this process provides insights into the nature of China's power sector reform, its medium- and long-term goals, and the incremental approach taken to implement the reform.

While previous studies have predominantly treated the reform as a change in economic institutions and modeled different stakeholders as if they exist in a market-based economy, this report argues that there is a strong political dimension that roots the reform in China's governance and regulatory structure. Provincial governments have used the generation dispatch process more as an administrative tool to mobilize resources, meet national energy policy initiatives, and achieve distributional objectives than as a market institution aimed at efficient use of resources through economic incentives. This situation will likely change, but only incrementally in the medium term as China pushes forward along a path laid out in the recent power sector reform decrees and proposals.

2. Basic Electricity Dispatch Concepts

Before we delve into the details of China's generation dispatch practices, it might be helpful to review a few concepts that are fundamental to understanding any dispatch process. Readers who are less familiar with the techno-economic features of the electricity system can find a summary in the remainder of Section 2.

2.1. Economic Dispatch

An electric power system typically has several power plants, with each plant having several generating units. At any point in time, the total electricity demand is met by the available generating units in the different power plants. The costs of the system are

usefully divided into two types: variable costs (fuel, labor and other operating costs, and transmission losses) and fixed costs (capital cost of generators and transmission system). Economic dispatch refers to the determination of output of each generating unit in a way that minimizes the overall variable cost of the system to serve the load at a given point in time, given the fleet of available generators and transmission system. A market dispatch system is intended to achieve such economic efficiencies using a market made of independent generators.

2.2. Unit Commitment (UC)

Economic dispatch gives the optimum allocation corresponding to one particular load configuration on the system. The total load in the power system and its geographic distribution varies throughout the day and reaches different peak values from one day to another. (There is also variability in supply, such as when the wind speed changes in a system with wind power.) Different combinations of generators are to be connected in the system to meet this varying load. The dispatcher has to decide in advance the sequence in which the generator units are to be brought in or ramped up as the load increases. Similarly, when the load decreases, the operating engineer needs to know the sequence in which the generating units are to be ramped down or shut down completely. The problem of determining the order in which the units should be brought in or shut down over a period of time, say one day, so the total operating cost on that day is minimized is known as the unit commitment (UC) problem. That is, the UC problem is economic dispatch over a day. One may similarly define UC problems over a week, month, or year.

The simplest dispatching decision would be to run all the units at levels that meet the maximum daily load throughout the day; however, this is such a costly, and polluting, solution that it is never employed. Choosing which units to ramp up, and by how much, is a complicated calculation due to the complex operating characteristics of the system as summarized below.

2.3. Typical Constraints in UC Optimization

- *Supply Capacity Sufficient to Cover Load*. Enough units are committed to meet the forecast demand.
- *Spinning Reserve*. Some generating capacity has to be kept running as spinning reserve to meet unexpected increases in demand and to ensure power supply in the event that a generating unit suffers a forced outage.
- *Generator Minimum Up/Downtime*. A thermal unit can undergo only gradual temperature changes, and this means that a few hours are required to shut the unit down or bring it back online. The unit thus has a minimum uptime constraint, meaning that once the unit is running, it cannot be turned off immediately to save on fuel even if the electricity is not needed. It also has a minimum downtime constraint, requiring a few hours before it can be recommitted. Most coal-fired generation units face strict minimum up/downtime constraints. These constraints are greatly relaxed for modern natural gas generators, which can more easily adjust to rapid load changes and follow startup/shutdown commands.
- *Crew Constraint*. A plant always has two or more generating units. It may not be possible to turn on more than one generating unit at the same time because of nonavailability of operating personnel.
- *Transition Costs*. There are startup and shutdown costs for each unit. For

example, to bring an offline unit online, additional fuel and effort are needed to warm the boiler and synchronize the unit to the grid before it can start injecting electricity into the system. This additional fuel and effort are significant, especially for big coal-fired units. These transition costs are not part of a simple variable cost calculation of cents per kilowatt hour (kWh). If companies are compensated only by the normal fuel cost per kWh, then these transition costs are major uncompensated costs if they are ordered frequently by the dispatcher.

- *Minimum Operation Levels*. Technical constraints on boiler operations mean that power output cannot be less than some minimum operation level, typically 30–50 percent of capacity for a coal boiler.
- *Hydro Constraint*. The operation of hydro units depends on the availability of water. Moreover, hydro projects are multipurpose, and irrigation and flood control requirements may take precedence over power generation.
- *Nuclear Constraint*. Nuclear plants have to be operated as a baseload plant—that is, they must be operated continuously.
- *Combined Heat-and-Power Constraint*. Combined heat-and-power (CHP) plants are cogeneration power plants that produce both heat (steam) and electricity. Because of the high thermal efficiency associated with producing heat and electricity at the same time, this technology has wide application in both power and nonpower sectors. Industries such as refineries, chemical plants, and food processors often need heat and steam on a continuous basis. An industrial firm with a CHP plant may have excess electric power for sale at competitive prices. CHP plants are also used at the district level to provide steam or hot water to residential complexes and are often higher in the unit commitment schedules.
- *Must-Run Units*. The injection of power has a stronger effect on the voltage and frequency near the point of injection than at farther distances. When a local power network is not sufficiently connected to the main grid, the generation units in the local network become “must run” because they are needed to provide voltage and frequency regulation.
- *Fuel Supply Constraint*. In the past, with transportation bottlenecks, some plants have not received enough coal.
- *Transmission Line Limitations*. Transmission capacity was a major factor in dispatch decisions. Inefficient plants may have to be run because there are not enough lines to transmit from more efficient units. Reserve should ideally be spread around the power system to avoid transmission limitations, often called “bottling” of reserves.

2.4. Long-Term Optimization

Over a longer horizon, the social optimization problem is the determination of the investment path for generating units and transmission facilities. These capital infrastructures can last for decades, and investment decisions today must be made with uncertainty about future prices of the different fuels and different generation and storage technologies.

3. China's Generation Dispatch Organization

A succinct characterization of China's generation dispatch organization would be unified dispatch along multilevel management.[1] As Kahrl and Wang (2014) put it, this organizational structure is "a compromise between the need for physically centralized dispatch and the prerogatives of local governments to manage local generation and loads." To understand this compromise, one needs to consider both technical and political aspects. Kahrl and Wang (2014, Section 2) give an excellent description of the technical aspects, and we summarize it in Section 3.1. We then discuss the political aspect in Section 3.2.

3.1. Technical Primer of the Organizational Structure

The word *dispatch* should first be recognized as a technical term that refers to the coordination and control of all power system devices by the dispatch organizations (DOs). In China, DOs are the Power Dispatch and Communication Centers within power grid companies at five different levels: national, regional, provincial, prefectural, and county.[2] DOs at each level of this hierarchy have distinct jurisdiction and functions. Table 1 provides an overview of this hierarchy, showing the division of responsibilities for three key functions: generation planning, real-time dispatch, and load management. As a general rule, DOs at a lower level are required to follow instructions from those at a higher level, which makes the national DO the highest in command. One exception is China Southern Power Grid Company's Dispatch Center, whose operation is independent of the State Grid Corporation of China (SGCC) and covers Guangdong, Guangxi, Yunnan, Guizhou, and Hainan.[3]

Unified dispatch is achieved through procedures that institutionalize coordinated planning and real-time dispatch among DOs. The three principal actors within this hierarchy are national, regional, and provincial DOs, among whom responsibilities are divided according to geographic boundaries and voltage levels. The lion's share of scheduling and balancing supply and demand is conducted within provinces by provincial DOs, which manage all 220 kV provincial transmission lines plus all generators connected to these lines. This is a result not only of power grid topology but also of China's governance structure, as explained in the next paragraph. On top of provincial DOs' operations, regional DOs operate higher-voltage (330—500 kV) provincial interconnections and dispatch generators across provinces. Finally, the national DO, SGCC's dispatch center, has jurisdiction over regional grid interconnections (super- and ultrahigh-voltage transmission) and generators that are dispatched across regions.

[1] In Chinese, it refers to "统一调度，分级管理". For details in Chinese, see 《电网调度管理条例》、《电网调度管理条例实施办法》.

[2] Provinces are equivalent to states, and there are about 330 prefectures and 1,500 counties in China today.

[3] With the exception of China Southern Power Grid Company and its provincial subsidiaries, all regional and provincial grid companies are subsidiaries of SGCC. Prefectural and county power supply companies are mostly branch companies of corresponding provincial grid companies, with some exceptions having mixed public-private ownership.

TABLE 1. THE FIVE-LEVEL HIERARCHY OF DISPATCH ORGANIZATIONS

Level	Host	Jurisdiction			Key Functions
		Voltage Level	Geographic	Generators	
National DO（国调）	State Grid Corporation of China (SGCC)	above 500 kV	Regional interties	Large thermal or hydropower transmission across regions	Inter-regional generation planning; inter-regional real-time dispatch
Regional DO（网调）	Regional grid companies	330-500 kV	Provincial interties	Pumped hydro storage (primarily)	Inter-provincial generation planning; inter-provincial real-time dispatch
Provincial DO （省调）	Provincial grid companies	220 kV (330-500 kV terminal substations)	Bulk provincial power system	All large generators not controlled at national or regional levels	Intra-provincial generation planning; intra-provincial real-time dispatch; provincial load management
Prefectural DO （地调）	Prefectural power supply companies	below 220 kV	Local power network	Small local generators	Prefectural load management
County DO（县调）	County power supply companies	below 110 kV	County power network	Any remaining generators	County load management

Source: Kahrl and Wang (2014).

Given that DOs are the entities that send out dispatch commands, one might think that grid companies are in charge of deciding the annual utilization rates of generators. This is a frequent misunderstanding of China's generation dispatch process. On the one hand, grid companies do have the authority to acquire ancillary services for the grid in real time. They can bring generators on- and offline or move electrical energy across provincial borders on very short notice. However, most ancillary services, such as load following and voltage/frequency regulation, are only temporary measures and do not require persistent output from the service providers. They are also mostly actions that do not increase total energy use,[4] and thus they

[4] Instantaneous load fluctuates randomly. The unit that is providing the load-following service needs to ramp up above its normal output level when system load jumps up and ramp down below normal when system load falls. Averaging over time, the additional energy that the unit injects into the system for the purpose of providing the load-following service is zero (as compared with its total energy injection at normal output levels). The value of the load-following service provided by a unit is its capability to ramp up and down on command, not the value of net energy injection associated with it.

are not the typical revenue-generating activities for generation companies.[5]

On the other hand, what really determine the effective energy outputs of generators (and thus their revenues) are the long-term unit commitment plans that specify which generators get to serve the base load and which are to be dispatched as marginal generators. Since the forward electricity markets are rather incomplete and limited in scale, committing generation units to meet forecast demand is primarily the result of annual generation planning, an administrative planning procedure carried out by provincial governments. Provincial Economic and Information Commissions (EICs) develop plans that specify the annual generation output for each generator in the coming year, usually by October. They often consult the technical experts from provincial DOs along the process, and they finalize the plans in December. Given that there are no regional-level governments in China's governance structure, this also explains why balancing of supply and demand is mostly achieved within provinces.

Annual generation plans are not just guidelines; they are administrative instructions that set hard annual generation hour targets for every generator. The rationale for setting these targets is primarily distributional. As explained in the next section, generators of the same type (e.g., coal-fired, hydroelectric, wind, solar) are allocated roughly the same annual hours in an attempt to guarantee an equitable opportunity for cost recovery. Accordingly, grid companies are responsible for implementing annual generation plans using unit commitment schedules and real-time dispatch commands. They are required to maximize target completion rates, which are defined as

$$Target\ completion\ rate = \frac{Actual\ ann.\ generation + Ann.\ lost\ generation}{Ann,\ generation\ target}$$

where annual lost generation is the generation lost through the generator's own fault.[6] Also, as stipulated in a 2003 State Electricity Regulatory Commission rule,[7] achievement of target completion rates should be approximately the same across generators.

Approaches to determine annual generation plans vary among provinces. Consider coal-fired power plants as an example. A common number of "base hours" is usually given to all generation units within a province. The number of base hours varies with the overall supply-and-demand balance; overcapacity will lead to lower utilization of all units. The hours also vary with national renewable energy policy, as provinces are required to suppress the output of coal power plants to accommodate renewables. At a certain point, some provinces were selected to experiment with Energy Conservation Dispatch, during which time they abandoned the annual generation planning and dispatched coal power plants in the order of their fuel efficiency and environmental performance (more in Section 4.5).

[5] Feed-in tariffs in most provinces are benchmarked to per-unit energy prices only. Few provinces would pay generators a separate capacity price to reflect these load-following capacities. Generators do get compensation when they are called on to provide grid services such as spinning reserves, voltage and frequency regulation, and load following, but such compensation usually covers only the corresponding operating cost (not the capital cost). Therefore, providing ancillary services in China is not a typical revenue-generating business, if it is at all.

[6] Annual lost generation includes forced outages, forced output reductions, coal shortages, and poor coal quality.

[7] "Interim Provisions on the 'Transparent, Fair and Impartial' Rule on Generation Dispatch."

On top of base hours, there are a few market and nonmarket mechanisms through which coal power plants can gain additional generation hours. Their ability to use these mechanisms depends on their technical characteristics, economic and financial standing, and political influence. Overall, a variety of factors jointly determine the annual utilization hours of coal-fired power plants. Section 4 discusses these factors in detail, along with the relevant policies.

3.2. Political Underpinnings of the Organizational Structure

Provinces came to be China's primary dispatch zones today because of two factors: the incentives facing the provincial governments and the incentives facing the national grid company. It is important to understand both factors to appreciate the challenges of reforming the system. One should note that the Chinese government system devolves a lot of power to the provincial and local levels. Management of major economic sectors and enforcement of pollution control regulations both fall under provincial purview.

Since the investment deregulation of the 1980s, provincial governments play a major role in authorizing, administering, and even financing power infrastructure projects. Given that every household and every enterprise buys electricity, the sensitivity to social welfare and the large revenues involved pushed the sector to become an integral part of local government planning. Siting, land use, financing, and granting power purchase agreements are all subject to direct or indirect control by provincial administrations. Meanwhile, most, if not all, provincial governments directly invest in and own generation assets. The fact that power infrastructure investments boost local employment, tax revenues, and electrical equipment manufacturing gives provincial governments the incentive to retain close control over the sector. Sales of electricity also generate a stable revenue stream for provincial governments, and setting retail prices is a far-reaching instrument of local economic control. Last but not least, provincial governments and provincial power grid companies assume joint responsibility in guaranteeing a reliable electricity supply, and thus any major technological or institutional change is scrutinized carefully. We may thus conclude that the economic and political stakes are so high that provincial governments have been, and will continue to be, reluctant to surrender their control over power sector affairs.

As an illustration of this situation, consider the reform experiment in 2003. The central government wished to see more inter-provincial flows to improve overall efficiency, allowing power to flow from low-cost provinces to high-cost ones. From 2003 to 2006, the State Electricity Regulatory Commission (SERC) experimented with a regional pilot electricity market.[8] This market consisted of the three northeastern provinces: Liaoning, Jilin, and Heilongjiang. The agency faced great resistance from the three provincial governments, each of which wanted cheaper electricity for its consumers from the

[8] The State Electricity Regulatory Commission was the electricity industry regulator from 2003 to 2013 but was overshadowed by the National Development and Reform Commission (NDRC). The SERC was dismantled in 2013, when its functions were folded into the National Energy Administration (NEA). Currently, the NDRC and NEA jointly regulate China's power sector. The NDRC plays the dominant role in rulemaking, price regulation, and designing reforms. The NEA assumes major responsibility in operationalizing reform guidelines, coordinating the establishment and operation of electricity markets, monitoring performance, and implementing and enforcing regulations.

regional system but did not want lower utilization hours for its generators. Unification of dispatch zones and locational marginal pricing would typically generate winners and losers. Net-importing locations will see lower prices but also lower demand for its generators, while net-exporting locations will see increased utilization hours but face pressure for higher prices. The difficulty in unifying generation dispatch is one of the many situations in which concerns about distributional effects trump potential collective gains. As the pilot program progressed, volatile spot market prices and pressure from risk-averse generators and consumers drained the political will of both the SERC and provincial governments, and the experiment ended.

For a decade after 2006, no more attempts were made to formally institutionalize regional spot electricity markets in China.[9] There was inter-provincial trading of electricity, but mostly as a way to implement top-level energy strategies. For instance, the central government issues orders on how electricity from major hydroelectric sources (e.g., the Three Gorges Dam, the Gezhou Dam) is allocated among the provinces. Other examples are the regional energy initiatives, such as the west-to-east and north-to-south electricity corridor projects, in which resource-abundant provinces and load pockets negotiate long-term contracts. The lion's share of electricity trade between provinces is guided by administrative orders from central and provincial governments.[10] This again highlights the pivotal role of governments—especially provincial governments—in breaking the barriers to trading electrical energy across provinces. The central government clearly hopes to alter the fragmented dispatch practice and does exercise its authority to facilitate an allocation that is more efficient by undertaking large infrastructure projects. Nevertheless, it has not yet succeeded in creating a set of institutions that can supersede provincial government control over generation dispatch activities.[11] This adds one more layer of complexity to further transforming China's power sector; establishing regional dispatch zones and regional power markets will inevitably run into profound challenges that are deeply rooted in the structure of central-local government relations.

The second factor contributing to the fragmentation of the power dispatch zones is the political economy of the power grid companies. When power generation assets were divested from the State Power Company (SPC) in 2002 (see Section 4.1), there was intense debate about the organization of the remaining transmission and distribution

[9] In July 2016, China announced plans to unify dispatch operations in the Beijing-Tianjin-Hebei ("Jing-Jin-Ji") capital region. The plan is to first unify annual generation scheduling and forward energy contracting, and then experiment with a regional spot market if the circumstances allow.

[10] For instance, in 2010, 77% of total electricity traded across provincial borders was guided by central and provincial governments' administrative orders (*National Electricity Trading and Market Supervision Annual Report 2010*, p. 13, in Chinese).

[11] In the United States, for comparison, pursuant to the Federal Energy Regulatory Commission's Orders No. 888 and No. 2000, states and the industry have worked collaboratively to establish independent system operators (ISOs) and regional transmission organizations (RTOs). Each ISO and RTO subsequently developed full-scale energy and ancillary service markets in which generators in different states can bid against and compete with each other.

business.[12] The State Planning Commission argued for establishing six regional power grid companies with managerial responsibilities and would invest in grid interconnections between provinces and operate them.[13] Provincial grid companies could then be designated as either branch companies or direct subsidiaries of the regional companies, and would operate the provincial power grids. A national holding company would be established, and it would appoint board members for the regional companies. A different proposal was promoted by an influential policy consulting firm hired by the SPC;[14] under it, the SPC would retain control over inter-provincial transmission operations. Six regional power grid companies could be established as either branch companies or subsidiaries of the national company, while provincial grid companies would be designated as direct subsidiaries of the national company. The capacity of the regional companies would be more limited in this scheme.

A compromise was reached to have unified dispatch along multilevel management, essentially a hierarchical structure that splits managerial responsibilities among national, regional, and provincial power grid companies. The SGCC was established and charged with the responsibility to build and operate the largest grid interties between regions (above 500 kV). Five regional grid companies were established as subsidiaries of the SGCC,[15] and they were to own and operate grid interties between provinces that are 330–500 kV. Provincial grid companies were established as subsidiaries of the corresponding regional company; they would assume control of the bulk transmission networks within provinces (mostly 220 kV), which were much better developed and more complete than interties between provinces at that time. They were also to coordinate with, and assist, provincial governments in making and implementing annual generation plans. Separately, the China Southern Power Grid (CSPG) was established as a sixth regional grid company, but independent of the SGCC. The CSPG owns the corresponding provincial grid companies. The independence of CSPG was the product of bargaining between the central government and strong provincial governments over the control of state assets.[16] Overall, the Southern Grid was set up to experiment with more integrated regional dispatch operations. Both

[12] The debate was among China's top-level decision-makers. There has not been any official documentation of this decision-making process; however, the information presented in this and the following two paragraphs are abstracted from Chapters 5 and 7 of *Big Ship Turn-around*, a semi-autobiography by Jipeng Liu of the China University of Political Science and Law. The book documents his consulting firm's involvement in establishing, reorganizing, and eventually dismantling the State Power Company. Liu is known as China's leading specialist in the reorganization and corporatization of state sectors, and he contributed to the corporatization of many state sectors, as well as the establishment of China's stock market. 有关拆分国家电力公司、组建国家电网公司决策过程的信息来自刘继鹏教授《改革论著三部曲之三——大船掉头》。详细内容请参照《大船掉头》第二篇第五章和第七章。

[13] The State Planning Commission was the predecessor of the NDRC.

[14] This is the consulting firm of Jipeng Liu, discussed in note 12.

[15] The five regions were the Northeast, North, East, Central, and Northwest.

[16] Reportedly, the Guangdong provincial government strongly opposed transferring locally owned assets to the central government. Consequently, CSPG was set up as a joint venture between central and provincial governments, with the rich and populous Guangdong province being the dominant shareholder.

grid companies are now overseen by the State-Owned Assets Supervision and Administration Commission of the State Council (SASAC), which appoints the top executives.

The bargaining and compromising over the organization of the power grids suggest one crucial lesson: despite the intent to foster more efficient dispatch operations at the regional level, the central government is reluctant to relinquish control over power grid affairs and leave them completely to the regional and local authorities. A national company, be it a management company or a pure holding company, seems to be Beijing's requirement in any proposed organizational structure. This concern was shared and used by the national company, SPC at the time, to lobby for an arrangement that reduces the possibility that it would be dismantled. In particular, during the negotiations, the SPC pushed for a design where the regional companies are wholly owned subsidiaries.[17] This design, which effectively granted the national company the capacity to unilaterally restructure the regional companies, was adopted. The new national company, the SGCC, quickly reorganized the five regional grid companies, beginning in 2011, transforming them from subsidiaries to branches. By the end of 2012, the SGCC had not only transferred most of the regional companies' assets to the corresponding provincial companies but also centralized most of their managerial duties. By July 2016, all but the Northern China regional power grid company had lost their independent status and had become regional branch offices of the SGCC.[18] Ultimately, the hope to formally institutionalize regional dispatch organizations died.

4. Generation Dispatch Policies and Reforms

4.1. A Brief History of China's Electricity Reform

In Appendix Table A1, we give a chronological list of the major policy changes and events in the electric power sector. We discuss the details below, but let us first summarize the highlights. The Ministry of Electric Power owned and operated the entire electricity system up to 1985, when independent power producers were allowed. The "fair dispatch" rule was established in 1987 to grant an equal opportunity for cost recovery for all generation investments. With only minor adaptations since then, this rule still dictates most dispatch orders today. In 1996, the State Power Company was established, the ministry was abolished, and

[17] An alternative design was to set up joint ventures between the national company and provincial governments, with the national company being the dominant shareholder in each regional company.

[18] It is undisputable that these organizational transformations have both led to more centralization of authority within SGCC and undermined the institutional foundation to establish independent regional dispatch organizations. However, whether these two outcomes were the sole purpose of these transformations was debatable. An alternative narrative, backed by the SGCC and some independent observers, was that eliminating the independent, regional-level players would not impair the efficiency or capacity in coordinating regional dispatch operations but was intended to streamline the control of provincial grid companies and make them directly accountable to SGCC. The reason was that provincial grid companies reportedly developed close ties and rent-seeking opportunities with provincial governments, and that regional companies were often found to be colluding with provincial companies rather than improving transparency or holding provincial companies accountable. (*Source*: http://finance.sina.com.cn/chanjing/sdbd/20120410/145611788076.shtml, in Chinese.)

the regulatory functions of the ministry were taken over by the State Economic and Trade Committee. Generation divesture and competition in the wholesale market were proposed in 1998 and piloted in 6 provinces.

Generation assets were officially separated from the State Power Company in 2002 after the State Council issued China's first comprehensive power sector reform scheme. In the 11th five-year plan (2006–2010), strict SO_2 regulations were put in place, including the shutdown of small (<100 MW) power plants. In 2007, the Energy Conservation Dispatch rules were issued, followed by tradable generation rights in 2008 that allow the smaller inefficient plants to sell their rights to the more efficient companies. Direct contracts between power producers and large consumers started in 2004, and the direct contracting rules were revised in 2009 and 2013. Finally, on March 15, 2015, the second comprehensive reform, Decree No. 9, was issued. This decree lays out guidelines for establishing power market institutions, price deregulation, and promotion of clean energy. This was followed by various documents providing more detailed rules to implement the decree.

4.2. Allocation of Base Hours under Fair Dispatch (1987)

The base hours of a generator refers to the portion of annual generation hours allocated purely through administrative planning. This is distinct from the generation hours obtained by contracting with major consumers, trading in generation rights, or participating in wholesale markets. Under the fair dispatch principle, in each province, every coal-fired generation unit would get the same number of base hours to secure a minimum utilization rate. The number of base hours varies greatly across provinces, depending on the province's economic development and the corresponding balance of electricity supply and demand. Provinces with strong economic growth often see high utilization hours for all generators. The number of base hours also depends on the province's generation mix. The national strategic energy planning has led to a vast, but concentrated, deployment of wind and solar generation in a few provinces.[19] This recent renewable capacity has put great downward pressure on the utilization of fossil fuel power plants in those provinces.

As noted in Section 3, the power sector has always been regarded as being strategically important in China's planned economy. Before 1985, the sector was solely owned by the central government and operated as a vertically integrated monopoly. This alignment of management and ownership allowed generation dispatch to be decided by an economic cost minimization process (Gao and Li 2010). However, being the sole financier of the power sector has caused great fiscal stress for the central government, and this resulted in a persistent lack of investment in power generation. The problem worsened after the economy started to take off with the economic liberalization reforms in 1978. Occasional power shortages became chronic, so in 1985, the State Council issued an "Interim Provision on Providing Incentives for Power Generation Financing and Implementing Multiple Electricity Tariffs," which aimed at liberalizing the generation segment.

[19] According to the "Notice on Establishing Monitoring and Alert Mechanisms to Promote Sustainable Development of Wind Energy" (National Energy Administration Document, Renewable Energy (2016), No.196 and attachments), at least five provinces—Jilin, Heilongjiang, Gansu, Ningxia, and Xinjiang—evidently have wind energy overcapacity and are experiencing systemic wind curtailment. It has been suggested in the report that these provinces should halt investment in wind energy in the short term.（国能新能【2016】196号）.

The new rules in this 1985 document opened up electricity generation to diverse investors, including local governments, local state-owned enterprises, nongovernment entities, and foreigners (Zhao and Ma 2013). The rules also guaranteed a fixed payback period (usually 20 years) for all new generation projects by granting power purchase agreements (PPAs) between new generators and the state-owned grid companies. For each generator, its PPA would specify an annual minimum power offtake plus a predetermined feed-in tariff so that the required annual return on investment could be obtained (Kahrl and Wang 2014). As a result of these policies, China saw a rapid growth of independent power producers (IPPs), generation companies that did not have grid assets.

Meanwhile, to reconcile the claims by the existing and new generators, the old economic dispatch principle was abandoned, and in its stead, the new fair dispatch rule was implemented. Fair dispatch was the prototype of China's current generation dispatch process; it stipulated that the centerpiece should be generation planning, an annual administrative procedure that converts forecast electricity demand into generation quotas, and then evenly allocate the quotas to the generators. Coal power plants, in particular, regardless of their age, size, efficiency, or emissions levels, would all be allocated the same numbers of generation hours (Ding and Yang 2013). In the 1980s through the late 1990s, demand outstripped capacity and generators were running at high rates, and the even-allocation system could easily fulfill the minimum utilization rates specified in the PPAs of new generators.

The new generation dispatch rule was designed to encourage quantity rather than quality of generation capacity expansion. All project proposals had to go through an initial screening process for financial feasibility, and when in operation, all IPPs were required to report operating costs to the government for regulatory review. Nevertheless, there was no binding regulation that effectively punished inefficient operation and poor emissions control. The fair dispatch rule effectively isolated generators from explicit market competition and led to suboptimal expansion and utilization of China's generation fleet. It also created among power plant owners an entitlement mindset, the belief that everyone is entitled to an equal share of quotas regardless of performance.

4.3. Direct Contracting and the Power of Power Companies (2004)

While base hours are evenly allocated, one important factor that differentiates coal-fired generators' final utilization hours today is their ability to access forward electricity markets. Although the forward markets are still rather incomplete, they serve as venues for some generators to secure additional generation hours by signing long-term contracts. There are two major forms of forward electricity markets in China: direct contracting and inter-provincial/regional contracting, described below

Whether a generator can participate in one of these two markets usually depends on its economic resources and affiliation with the government. Given China's social and political context, state-owned enterprises are given more access than private companies. In particular, generation companies that are directly owned by the central government

have the largest bargaining power.[20] Besides ownership, a company's social and political influence also depends on its size, financial standing, and social responsibility, particularly at the provincial level.

4.3.1 History of Direct Contracting

The 1990s were a period of major transformations for China's economic institutions. To transition to a more market-oriented economy, top leaders decided to separate the operation of government from economic activity. The electricity industry was on this reform agenda, and in January 1997, the State Power Company (SPC) was established by order of the State Council.[21] The Ministry of Electric Power was disbanded in March 1998, and its administrative and regulatory functions were taken over by the State Economic and Trade Committee (SETC) (Gao and Biesebroeck 2014).

By the end of the 1990s, the new power sector policies had fueled a decade-long expansion of power generation assets, and China was effectively relieved of electricity shortages (Gao and Li 2010). In the meantime, however, this growing capacity had put a downward pressure on the utilization rates of all generators. The evenly allocated generation hours sometimes could not meet the minimum utilization rates specified in the power purchase agreements, and that created tensions between the IPPs and the government. Given that the newly established SPC owned almost half of the nation's generation assets and was also the sole power purchaser and grid operator (Ma 2011), there was a growing concern that it would abuse its monopolistic power to favor its own generators over IPPs (Woo 2005). To guarantee a level playing field, in November 1998, the State Council announced that further reforms were to break power generation off from SPC, first financially, then institutionally, and later to foster competition among generators.[22] Six provinces—Zhejiang, Shandong, Shanghai, Liaoning, Jilin, and Heilongjiang—were chosen to experiment with wholesale electricity markets.

Fair dispatch had to be adjusted to accommodate wholesale competition. In fact, Shanghai, Zhejiang, and Shandong implemented small-scale power pools in which participating power producers secured part of their total annual energy sales through power exchange. An even allocation of generation quotas still applied to nonparticipating power plants, which were still the majority. Overall, experimentation at this stage was too limited in scale; it did not induce a substantive change in the general generation dispatch rule, and fair dispatch continued to brew tensions among generators (Kahrl et al. 2013). In 1999, a hydroelectric power plant called Ertan, which was China's largest hydroelectric construction at the time, was forced to curtail output so that the guaranteed generation quotas to fossil-fuel generators could be met. This situation,

[20] The largest nine generation companies that are directly owned by the central government are known as the "Five Giants" and "Four Juniors." The Five Giants are China Huaneng Group Corporation, China Datang Corporation, China Huadian Corporation, China Guodian Corporation, and China Power Investment Corporation; the Four Juniors are China Resources Power Holdings Company Limited, Shenhua Guohua Electric Power, Guotou Huajing Electric Power Holdings Company Limited, and China General Nuclear Power Group.

[21] State Development Office (1996), "Notice of the Establishment of the State Power Company."《关于组建国电公司的通知》（国发【1996】48号）

[22] State Council General Office (1998), No. 146, "Opinions on Issues Regarding Further Power Sector Reform."《关于深化电力工业体制改革有关问题的意见》（国办发【1998】146号）

commonly referred to as the Ertan incident, marked the biggest manifestation of the deficiency of a purely planned generation scheduling. Causes of this incident were manyfold, but the major contributor was the inflexible fair dispatch rule, which made the power system unable to respond to changing economic conditions.

The Ertan incident prompted China's central policymakers to introduce market-based mechanisms into the power sector. In 2002, the State Council issued the "Electric Power System Reform Scheme,"[23] the groundbreaking policy document in China's power sector reforms. This reform required that the SPC be dismantled and its assets regrouped into five generation companies,[24] two grid companies (the State Grid Corporation of China and China Southern Power Grid Company), and four engineering service companies. Five regional grid companies were also established as subsidiaries to the State Grid Corporation of China, and they were charged with investing in and operating regional power grids.

Two of these regional grid companies, the East China Grid Company in 2003 and the Northeast Grid Company in 2004, were selected to implement pilot wholesale power markets. In each region, a group of generators accounting for 10–20 percent of total generation capacity was selected to participate in the trials. A two-part feed-in tariff structure with both capacity and output pricing was introduced to facilitate a competitive power pool.[25] Capacity prices were determined by the government based on average investment costs of different types of generators. Power output prices were derived as marginal prices out of competitive bids. Price caps and floors were also specified in both regional pilot markets (Ma 2011).

Full implementation of these pilot programs was stalled by a few serious obstacles. The reappearance of power shortages in some provinces plus the 2000–2001 California electricity crisis reminded policymakers of the risks associated with electricity market competition. Power purchase agreements signed during the 1990s that were still in force prevented generators from being fully engaged in competition. Unclear market rules and poor information disclosure also created conflicts among governments, generation companies, and grid operators. By early 2006, all wholesale market trials were terminated (Gao and Li 2010).

4.3.2 Direct Contracting

What remained from that era of restructuring and experimentation is a special mechanism called direct contracting. Along with the initiation of regional pilot programs, the State Electricity Regulatory Commission (SERC) issued in 2004 the "Interim Measures for Direct Contracting between Power Producers and Consumers,"[26] providing guidelines for consumers to directly negotiate and sign power purchase contracts with generators, which stood in contrast with the convention where forecast electricity demand

[23] State Council (2002), No. 5, "Electric Power System Reform Scheme."《电力体制改革方案》（国发【2002】5号）

[24] The Five Giants listed in note 22.

[25] For details, see State Council General Office (2003), No. 62, "Notice on the Electricity Price Reform Program from the General Office of the State Council."《国务院办公厅关于印发电价改革方案的通知》（国办发【2003】62号）

[26] 《电力用户向发电企业直接购电试点暂行办法》（电监输电【2004】17号）

was only passively allocated as quotas to generators. Negotiation and contracting were to be carried out within provinces, organized by provincial governments, and validated by power grid companies. The negotiated price became the feed-in tariff for the generator in place of the official tariffs set by the central government. The corresponding retail price was set at the negotiated price plus a predetermined transmission and distribution fee. Starting in 2004, the direct contracting process was carried out at the beginning of each year in a small number of provinces. This number grew as more provinces wanted to experiment with the new mechanism. Provincial governments were given the discretion to select eligible participants and supervise trading outcomes. The negotiated contracts from each province were then collected and reported to the National Development and Reform Commission (NDRC) for approval.

Direct contracting is a form of forward electricity markets. The policy's original intent was to experiment with competition and achieve some efficiency gains (Woo 2005). However, only a small portion of the entire generation fleet in each province was selected to participate, and the resulting scale of competition was rather limited. In addition, there was no spot electricity market in China to accompany the forward market. Such stand-alone, limited-scale forward contracting should not have been expected to deliver substantial improvements in efficiency.

Besides the limited scale and lack of spot markets, other design issues in the direct contracting policy also made its implementation problematic. Most important, the regulatory uncertainty could allow only incomplete contracts, thus giving generation companies more risks than incentives to participate in direct contracting. For instance, the 2004 policy document provided no clear guidance on how to reconcile planned hours with market hours, a process that could have important distributional implications. When a generator signed a forward power purchase contract with a consumer, it effectively committed part of its generation capacity to that consumer, reducing its overall availability for grid dispatch. Should this part of capacity have been excluded when annual base hours were allocated? If so, then generators would rather wait for the even allocation instead of committing to forward contracts, given that contract prices should always be lower than the benchmarked feed-in tariff for base hours.[27] If not, then it would be an infringement on nonparticipating generators' benefits, especially when provincial governments set up barriers of entry on this forward market. There was no clear rule on this issue until 2009, when two follow-up documents issued by SERC stipulated that contracted capacity should be excluded when allocating annual generation quotas.[28]

Besides the treatment of contracted capacity, there were other risks when generators participate in direct contracting. For one, a direct contract usually would not include a mechanism to adjust feed-in tariffs for fluctuating coal prices (Wang 2007).[29] Another example is that when contracts were not fulfilled, it was difficult to determine fault because of poor information sharing among

[27] Given that grid companies are the "provider of last resort for all consumers, consumers participate in direct contracting only if the contract price is lower than the regulated retail price.

[28]《关于完善电力用户与发电企业直接交易试点工作有关问题的通知》（电监市场【2009】20号）；及附件《电力用户与发电企业直接交易试点基本规则（试行）》

[29] China's coal-electricity linkage mechanism ("煤电联动" 机制) allowed each province to raise the benchmarked feed-in tariff for coal power plants if coal prices rose by a certain percentage.

generators, grid companies, and consumers. Even when fault could be determined, there were no clear rules for appropriate compensation.

Meanwhile, however, consumers and local governments loved the idea of direct contracting. The great autonomy given to provincial governments has allowed them to use the direct contracting process to bypass the central government's regulation over wholesale and retail electricity prices (Kahrl et al. 2013). Provincial governments reportedly have exerted political pressure over generation companies, requiring them to sign long-term contracts to sell electricity at a price lower than the official feed-in tariff. This was done as a measure to protect local energy-intensive industries. To compensate the generators for resulting losses, some governments used other measures to encourage participation, most commonly by guaranteeing more generation quotas for participating generators than for their nonparticipating counterparts. To a certain extent, direct contracting has devolved into a policy tool for local governments to reduce costs for large local industrial energy users.[30]

The direct contracting system also became a selection mechanism that favored large, state-owned coal-fired generators. This is because state-owned generation companies were capable of financing large, highly efficient coal-fired units at lower costs than private companies. They were also not as tightly constrained by their budgets as private companies were and thus were willing to take higher risks in markets. Therefore, it was often large state-owned generation units that got higher generation quotas by offering lower prices. Their greater utilization hours resulted in lower "levelized" costs of electricity (average lifetime cost) and further enhanced the advantage of these units.

The above situation was temporarily altered by China's national energy efficiency campaign between 2009 and 2011. During this period, the central government significantly increased its enforcement of energy efficiency regulations.[31] Most provincial governments refrained from subsidizing energy-intensive industries by assigning low prices to direct contracts. The scale of direct contracting programs also shrank during this period.[32]

Nevertheless, provincial governments continued to intervene in direct contracting beyond 2011. In fact, they were given a more important role in 2013, when the central government delegated the authority of final approval for direct contracting programs to them. This was part of the larger overall reform of China's governance structure wherein hundreds of central administrative and permitting functions were delegated to the provinces. The number of provinces that operated direct contracting programs grew to 24 within one year, which was a historical

[30] The price structure in China is unusual in comparison with those of many other countries in that prices paid by households are lower than prices paid by industrial enterprises (see Lin and Liu 2013).

[31] NDRC, SERC, and National Energy Administration joint issue (2009), No. 2474, "Notice on the Regulation of Electricity Trading Prices and Other Related Issues." 年发改委、电监会、能源局三部委联合发布《关于规范电能交易价格等有关问题的通知》（发改价格【2009】2474号); NDRC (2011), No. 1311, "Notice on Reinforcing Electricity Price Regulation." 年国家发改委发布《国家发展改革委关于整顿规范电价秩序的通知》（发改价检【2011】1311号）.

[32] In 2010, the total amount of electricity traded through direct contracting in all provinces accounted for only 0.2% of all electricity consumption across the nation. See "10-Year Review on Big-Consumer Direct Contracting" (2015), *China Electric Power News*, Chinese article available at http://news.bjx.com.cn/html/20150807/650683.shtml.

high since 2004. The supply-demand balance had also shifted, with growing overcapacity in many provinces due to weak growth in electricity demand coupled with a massive expansion of both coal and renewable generation capacity. As a result, from 2013 onward, direct contracting has been expanded in both scale and scope. Furthermore, with this overcapacity, it has become increasingly difficult for administrative generation planning to balance the interests of all generators. Consequently, direct contracting has become the more politically feasible approach, being a more decentralized option that realigns interests through competition.[33]

4.3.3 Inter-Provincial/Regional Contracting

The primary way for provinces to balance electricity supply and demand was by using generation resources within the province. Inter-provincial/regional contracting is a break from this convention, requiring generators in one province to serve consumers in another province by transmitting electricity through the provincial power grid interties. There are two reasons why inter-provincial/regional contracting can be important and valuable to power system operations. The first is that individual provincial power grids become more resilient to unpredictable disruptions by agreeing to share certain reserves and ancillary services with each other. Physically, this manifests as small but continuous power flows across provincial border lines. The second is that overall allocative efficiency can be improved by overcoming the jurisdictionally fragmented utilization of energy resources. When provinces with large energy resource endowments are allowed to sell electricity to other provinces, both sides are better off. This trade takes the form of cross-jurisdictional forward energy contracts.

Inter-provincial/regional contracts are mainly of these two forms: (1) agreements to share reserves and ancillary services, and (2) forward contracts to trade electrical energy. It is important to first note the difference between inter-provincial/regional contracting and direct contracting, and how this difference leads to different regulatory designs and outcomes. Direct contracting is a new market arrangement using existing physical infrastructure—strong and reliable provincial power grids—and is within the established institution of balancing electricity supply and demand within a province. In other words, it is an institutional reform that does not require technical changes and is implemented and regulated by provincial governments.

In contrast, inter-provincial/regional contracting is as much a technical innovation as a new market arrangement. Be it either the sharing of balancing services or carrying out forward energy contracts, it requires a high level of coordination among different provincial power grids, and this depends not only on the reliability of individual power grids but also on the constraints of the inter-provincial transmission lines. Moreover, the technical issues become more challenging when the two contracting parties are not in adjacent provinces and their transaction entails energy flow through the power grid of a third province. As a result, national and regional power grid companies are designated as the entities that assume primary responsibility in organizing and supervising inter-provincial/regional contracts. China, like most countries, does not have a level of political governance between the provincial level and the central government. This design feature was stipulated in the very first 2003 policy

[33] As stipulated in "Implementation Rules for Direct Trading between Electricity Consumers and Power Generation Enterprises in 2016 in Gansu Province" (Gansu Development and Reform Commission 2015, Issue No. 1189), all coal-fired units are to stop receiving allocated utilizations in 2016 and will need to secure generation offtake through direct contracting.

document that introduced the rules for inter-provincial/regional contracting,[34] and it stayed unaltered in the subsequent 2005 and 2009 revisions.[35]

Besides granting regulatory discretion to power grid companies, the 2003, 2005, and 2009 policy documents have been consistent in many other aspects. The most important features for the inter-provincial/regional contracts are as follows:

- These contracts are aimed at improving the allocative efficiency of energy resources by allowing cross-jurisdictional utilization of generation resources.
- Contracts should be based on market principles, which require voluntary participation and transparency.
- Contracts can be either forward energy contracts based on supply-and-demand forecasts or real-time balancing agreements that authorize cross-jurisdiction utilization of generation resources under certain circumstances.
- The contracting involves three parties: sellers, transmitters, and buyers. Sellers are eligible generation companies or grid companies acting on behalf of the generators. Transmitters are the grid companies. Buyers are either eligible "big consumers" or grid companies that act on behalf of electricity consumers. As a general rule, generators eligible for participating in these contracts are hydroelectric plants, coal-fired power plants over 200 MW, and nuclear power plants.
- The forward energy contracts may take one of three forms: (1) generators directly contract with eligible "big consumers" from outside their provinces, negotiating over designated regional/national electricity trading platforms that are operated by the corresponding power grid companies; (2) generators sign forward energy contracts with grid companies from other provinces/regions; or (3) generators allow grid companies to negotiate on their behalf with grid companies from other provinces.
- In principle, participation in inter-provincial/regional contracting is voluntary. Prices should be determined through negotiation unless specifically stipulated by the central government (e.g., the price of electricity from the Three Gorges Dam). The seller, transmitter, and buyer should agree on the three prices associated with the transaction: the feed-in tariff for the generator, the power transmission fee (including compensation for both the operating costs and the induced line losses), and the resulting retail price for the buyer. To the extent allowed by system security constraints, all parties should have access to the grid, regardless of whether grid companies are directly involved in the negotiations. Power transmission and distribution are provided as a public service to fulfill the contracts. In return, grid companies are entitled to charge for these services.
- The SGCC is responsible for organizing inter-regional contracting. The CSPG

[34] State Electricity Regulatory Commission (2003), "Provisional Rules for Optimal Inter-provincial Power Dispatch."《跨区跨省电力优化调度暂行规则》.

[35] NDRC and SERC (2005), Issue No. 292, "Guidelines for Promoting Inter-regional Electricity Trading." 国家发展改革委、国建电监会印发《关于促进跨地区电能交易的指导意见》的通知（发改能源【2005】292号); SERC issue No. 51, 2009, "Interim regulatory measures for inter-provincial and inter-regional electricity trading. 国家电力监管委员会关于印发《跨省（区）电能交易监管办法（试行）》的通知（电监市场【2009】51号）.

and regional subsidiaries of SGCC are responsible for organizing inter-provincial contracting. These grid companies are responsible for operationalizing and adapting the general rules to the specific circumstances and are required to report relevant outcomes to the SERC and (NDRC periodically. These last two agencies reserve the ultimate authority to oversee and intervene in the process.

Apart from the above common features, the rules for inter-provincial/regional contracting evolved toward a more market-oriented system between 2003 and 2009. There was a growing emphasis on the role of direct, voluntary negotiations between generators and large consumers. Fairness, transparency, and information sharing had also become more pronounced in the organization and regulatory process.

Despite the well-intentioned design and refinements to the 2003 policy document, implementation of inter-provincial/regional contracting achieved mixed results. On the one hand, there has been a rapid growth in the volume of electricity traded through this mechanism. In 2010, the total electrical energy traded through inter-provincial/regional contracting accounted for 17.5 percent in total national electricity production (excluding self-generation). Table 2 shows the volume of electricity traded as well as the contribution of different trading mechanisms in 2010.

TABLE 2. COMPOSITION AND CONTRIBUTION OF DIFFERENT ELECTRICAL ENERGY CONTRACTS

Form of contract	Energy (TWh)	Percentage (%)
Base-hour allocation	2,740	81.06
Direct contracting	8.04	0.24
Inter-provincial/regional contracting	592.5	17.53
Total national electricity production (excluding self-generation)	3,380	100
Generation rights trading	149.3	4.42

Source: National Electricity Trading and Market Supervision Annual Report (2010, 4) (《2010年度全国电力交易与市场秩序监管报告》).
Note: Percentages do not add up to 100 because there is a small portion of electricity production that is not formally planned or contracted, such as short-term emergency dispatch. Generation rights trading rearranges the allocation and contracts among generators.

Inter-provincial/regional contracting has also been an effective mechanism in carrying out many of China's national and regional energy strategies. For instance, the central government issues annual orders on how electricity from major hydroelectric infrastructure projects (e.g. the Three Gorges Dam, the Gezhou Dam, Ertan) should be allocated. These commands are executed through inter-provincial/regional contracting. Regional energy initiatives, such as the west-to-east and north-to-south electricity corridor projects, are also carried out in the form of inter-provincial/regional contracting. In fact, the lion's share of inter-provincial/regional contracting is guided by government planning, at both the central and provincial levels. Table 3 shows the different components in inter-provincial/regional contracting in 2010 as distinguished by the factors motivating the contract.

However, on the other hand, inter-provincial/regional contracting has created some undesirable outcomes, mostly due to the behavior of the grid companies. As explained previously, grid companies were granted great discretion in organizing the contracts, and some of them have abused this power for their own profit. A few examples are given here.

TABLE 3. COMPOSITION OF INTER-PROVINCIAL/REGIONAL CONTRACTING BY FACTOR OF MOTIVATION

Motivation		Energy (TWh)	Percentage (%)
Planned	Central and provincial governments' energy strategies	448.66	77.32
	Power grid companies' plans	19.18	3.31
Market	Negotiation	112.4	19.37

Source: National Electricity Trading and Market Supervision Annual Report (2010, 13) (《2010年度全国电力交易与市场秩序监管报告》).

First, the SGCC has unilaterally and forcefully executed some inter-regional contracts that did not align with the principle of improving the allocative efficiency of energy resources.[36] Rather, these contracts were motivated by the company's agenda to advocate for the Ultra-High Voltage (UHV) Power Transmission Grid, a large-scale and highly capital-intensive grid infrastructure project that can bring billions of new investments for the company. The cost-effectiveness of UHV and its feasible application in China are yet to be proved.

Second, some provincial grid companies have charged inappropriate transmission fees, either through an accidental miscalculation or intentionally.[37] The power transmission fee should be calculated based on both the financial contract and how the contract affects the physical power flows.[38] However, some grid companies based the calculation purely on the financial contract, which led to overpricing and double counting. Some even arranged artificial hedging contracts with each other solely for the purpose of collecting power transmission fees.

Third, there have been occasions where a generator was forced by the grid company in its province to contract with the grid company in another province. This is due to two factors. For one, the grid company on the buying side has the incentive to use inter-provincial/regional contracting to bypass central government's regulation over the within-province feed-in tariff. Given that grid companies are the ultimate retailers of electricity in China and that retail electricity price is regulated by the government, it is always better for a grid company to buy electricity from another province where some generator offers a lower price. The second factor is that the grid company on the selling side gains by charging power transmission fees. These factors lead the two grid companies to collude in a way such that one forces a generator in its jurisdiction to sell electricity to the other at a low price. There are reports of provincial grid companies negotiating inter-provincial/regional contracts without the consent of the generators.[39]

Last but not least, investments in interprovincial and interregional transmission lines have been lagging behind the rapid development of wind and solar energy, particularly in Northwest, North, and Northeast China. Because of these transmission constraints, the great potential for using interprovincial/regional contracting to expand balancing areas, and therefore

[36] See *National Electricity Trading and Market Supervision Annual Report* (2010, 21) 《2010年度全国电力交易与市场秩序监管报告》; 《2012年上半年全国跨省区电能交易与发电权交易监管报告》第8页专栏; 《2015年全国电力调度交易与市场秩序监管报告》专栏16第2条。

[37] See *National Electricity Trading and Market Supervision Annual Report* (2010, 22, 23) 《2010年度全国电力交易与市场秩序监管报告》; *Electricity Trading Regulation in Central China Report* (2014, 2, "Problems")《2014年电力交易秩序驻点华中监管报告》第2页"存在问题".

[38] When the energy flow entailed by the contract coincides with the direction of existing power flow, the contract further congests the transmission line, raises line losses, and thus should compensate the grid company for this effect. When the energy flow entailed by the contract is opposite the direction of existing power flow, the contract actually reduces the stress and losses on the transmission line, and the grid company should pay for this effect (or at least not receive any payment).

[39] *National Electricity Trading and Market Supervision Report* (2015, box 16, item 5) 《2015年全国电力调度交易与市场秩序监管报告》.

increase the integration of renewables, has remained underutilized.[40]

Undesirable outcomes like these led policymakers to revise the rules for inter-provincial/regional contracting. In 2011, along with the national energy efficiency campaign and the entrenchment of electricity price regulation, the NDRC stipulated that interprovincial/regional contracts were to use the electricity prices (including the feed-in tariff, power transmission fee, and retail price) set by the agency.[41] This was intended to remove the power grid companies' control over these prices, which were supposed to be determined by negotiations. In 2012, the SERC issued a new policy document that provided revised rules for interprovincial/regional contracting.[42] Following are the most important revisions:

- The SERC and its regional branches are responsible for implementing and directly supervising the process of interprovincial/regional contracting in their respective jurisdictions. Power grid companies do not have the authority to interfere with, mandate, or regulate the actions of other market participants.
- Except for those decreed by the central government annual plans, all inter-provincial/regional contracts should be through either centralized match-making or bilateral negotiations.[43] Generators are encouraged to directly participate in either process. Grid companies are not allowed to sign inter-provincial/regional contracts on behalf of the generators without their explicit consent.
- During centralized matchmaking, the bids of coal-fired power plants should be arranged in an order that reflects the following factors: the bidding quantity, fuel efficiency, emissions rates, and feed-in tariff. Clean energy (hydro and nuclear) and renewables (e.g., wind and solar) should be prioritized over coal-fired power plants.
- During centralized matchmaking, sellers should submit the regulated feed-in tariff as the bidding price. During bilateral negotiations, the seller's feed-in tariff and the formula used to calculate the power transmission fee are nonnegotiable.

Clearly, the new rules were aimed at curtailing the grid companies' control over inter-provincial/regional contracting and to give the authority back to the government agencies, particularly the SERC. To a certain extent, these measures mitigated the adverse consequences of inter-provincial/regional contracting, but they did not solve the problems permanently. More fundamentally, regulation of electricity prices presents China with a dilemma: there is a trade-off between relaxing price regulation to enable efficiency-improving market transactions and entrenching price regulation to fight market power and arbitrary intervention by local governments. This dilemma is the root of the

[40] *Inter-provincial Electricity Trading and Generation Tights Trading, Half-Year Report* (2012, 9) 案例见《2012年上半年全国跨省区电能交易与发电权交易监管报告》第9页专栏。

[41] NDRC (2011), Price Inspection No. 1311, "NDRC Notice on the Rectification of Electricity Price Regulation"《国家发展改革委关于整顿规范电价秩序的通知》（发改价检【2011】1311号）.

[42] SERC Market Office (2012), No. 151, "Basic Rules for Inter-provincial and Inter-regional Power Trading (Pilot)"《跨省跨区电能交易基本规则（试行）》（办市场【2012】151号）

[43] Centralized matchmaking is the matching of sellers' bids and buyers' offers over a centralized trading platform. Each match results in a forward energy contract between the buyer and seller.

undesirable outcomes in many market-oriented experiments in the power sector, and it cannot be solved by simply altering the design of a few trading mechanisms. As Tsai (2014) has noted, these problems speak to some of the institutional deficiencies in China's power sector, the principal-agent issues in the governance structure, agency capture, and lack of effective regulation and enforcement by the regulatory agencies.

Taking the above into account, one can make the following hypotheses about which generators were more likely to be involved in interprovincial/regional contracting and thus to raise their annual generation hours:

- From 2003 to 2012, power grid companies had great control over the inter-provincial/regional contracting process. Therefore, generators that had stronger affiliations with grid companies were more likely to have access to this market. These include the ones owned by grid companies and the ones that belonged to large state-owned enterprises owned by the central government. Generators that were owned by local governments or privately owned are expected to have had less access to inter-provincial/regional contracting. However, smaller and less political powerful generators may also have succumbed to abusive pressure from grid companies and been forced into unfavorable inter-provincial/regional contracts.
- From 2003 to 2012, generators in provinces along the route of SGCC's UHV transmission grid were more likely to export electricity by inter-provincial/regional contracting. A more specific hypothesis would require knowledge of the layout and completion dates of the segments of the UHV lines.
- Given the major revision in the rules for inter-provincial/regional contracting in 2012, between 2012 and 2015, generators with larger unit capacity, higher fuel efficiency, lower emissions rates, and in provinces with lower benchmarked feed-in tariffs for coal-fired power plants are expected to have had more access to inter-provincial/regional contracting.

Throughout this period, central government planning set a major portion of the inter-provincial/regional contracts. Therefore, generators that were involved in national and regional energy strategies are expected to have had more access to interprovincial/regional contracting.

4.4. Differentiated Quotas and Generation Rights Trading (2007)

Another factor that differentiates the final utilization hours of generators is their capacity. Some generation dispatch policies in China explicitly favor large coal-fired units. Such policies include the differentiated generation quota scheme, generation rights trading, and direct contracting, as explained below. By taking advantage of these policies, large coal-fired generators are expected to acquire more annual generation hours than small ones.

4.4.1. Differentiated Generation Quota Scheme

The differentiated generation quota scheme refers to an administrative rule that adjusts the annual base hours of the generators according to their technical specifications, allocating more generation hours to units that are larger, more efficient, and less polluting. No particular national policy document defines this rule; rather, it is a concept that was developed out of energy conservation practices at the provincial level. As explained in Section 4.5, provinces that were not selected to run pilot Energy Conservation Dispatch programs in 2007 were encouraged to innovate and experiment with mechanisms

that conserve energy and reduce emissions. So far, there have been some common practices across provinces to implement this scheme.[44] They reward additional base hours to units that have the following attributes:

- are large
- have above provincial average fuel efficiency (units with below average fuel efficiency get reduced base hours)
- have desulfurization facilities
- are integrated coal-byproduct utilization (IGCC) units
- are combined heat-and-power cogeneration units

Of the above criteria, unit capacity is the one used most by the provinces. For instance, in the Fujian 2014 annual generation plan, coal-fired units around 300 MW were given 100 more base hours than units below 135 MW; coal-fired units around 600 MW were given 150 more base hours than 300 MW units.[45] Similarly, in the Shanxi 2014 annual generation plan, coal-fired units of 200 MW were given 3,300 base hours; units around 300 MW were given 100 additional base hours; units between 500 MW and 600 MW were given 200 additional base hours.[46]

4.4.2. Generation Rights Trading

The economic and environmental shortcomings of equally allocating generation hours became more salient as larger, more efficient coal-fired power plants were brought online in the early 2000s. One response was the shutdown of small thermal units in the 11th five-year plan (2006–2010). In 2007, the NDRC stipulated the decommissioning by 2010 of the following categories of coal-fired units:[47]

- below 50 MW
- below 100 MW and over 20 years old
- below 200 MW and serving beyond the designed lifespan
- standard coal consumption rate within the bottom 10 percent of all coal-fired units in a given province or within the bottom 15 percent nationally
- failing to meet emissions performance standards
- under other decommission orders by law, regulation, or administrative policy

Shutting down these units was extremely difficult because of the losses imposed. As a measure of compensation, the policy allowed decommissioned units to be included in annual generation planning during a grace period of no more than three years. These units would be allowed to transfer their

[44] For example, see Shanxi Province Economic and Information Commission (2013), "Notice on Regulation of Power Output of Provincial Generation Enterprises"; "Fujian Province 2008 Annual Generation Adjustment Plan"; Fujian Province 2014 Annual Generation Adjustment and Control Plan" 《山西省经信委关于下发2013年省调发电企业发电量调控目标预案的通知》；《福建省2008年度差别电量发电调整计划表》；《福建省2014年度差别电量发电调控计划调整情况表》

[45] "Fujian Province 2014 Annual Generation Adjustment and Control Plan" 《福建省2014年度差别电量发电调控计划调整情况表》。

[46] "Shanxi Province 2014 Annual Generation Targets" 《山西省2014年度省调发电企业发电量调控目标预案》。

[47] State Publication (2007), No. 2, "NDRC and Energy Office of the State Council: Opinions on the Acceleration of the Shut-down of Small Thermal Power Units" 《国务院批转发展改革委、能源办关于加快关停小火电机组若干意见的通知》（国发【2007】2号）

generation quotas to active units and would be compensated for such transfer. This was the initial form of generation rights trading.

Later in 2007, generation rights trading was officially proposed by the SERC as a mechanism to trade generation quotas.[48] All generators, not just those destined for closure, were allowed to engage in intra-province trading and later inter-province trading. The prerequisite for trading in generation rights was that quotas must flow from less efficient, high-emitting units to more efficient, low-emitting ones or from coal-fired units to nuclear, hydro, and renewables. Since large coal-fired generators were not only technically more efficient but also constructed more recently and installed with emissions abatement devices, they usually had more opportunity to buy generation rights than small ones. As explained in Kahrl and Wang (2014), trades could be done as simple transfers between units within a single generation company, be negotiated bilaterally, or be arranged over a centralized matchmaking platform. To the extent that such trades are beneficial for all participating parties, they could lead to overall energy conservation and emissions reduction.

Generation rights trading have led to some improvements in the economic and environmental performance of electricity production. Between 2010 and 2011, a 0.6 percent reduction in coal-fired power plants' average heat rates (about 60 Btu/kWh) was attributable to trading in generation rights (Kahrl and Wang 2014). However, what this policy alone achieved in improving overall dispatch efficiency was rather limited, for several reasons. First, the incentives to trade could be inconsistent with improving resource efficiency or emissions control. As Ma (2011) notes, the feed-in tariff structure does not fully compensate for the costs of operating control equipment, and high-emitting coal-fired units could be more profitable than cleaner ones.[49] Similarly, coal-fired generators would rather use than sell their quotas to renewables at lower prices. As a result, generation rights trading had remained limited in both scale (share of total thermal generation) and scope (inclusion of renewables). Between 2007 and 2011, the total volume of energy traded through trading of generation rights was less than 5 percent of total thermal generation. This share peaked at 4.9 percent in 2009 and fell back to 2.8 percent in 2011, mainly because compensation for decommissioned coal-fired units was sharply reduced after their grace period expired (Kahrl and Wang 2014). Trading volume not related to shutdown compensation had not seen much growth.

Second, just as was the case with direct contracting, generation rights trading was often subject to administrative intervention

[48] "Interim Measures for Regulating Generation Rights Trading"《发电权交易监管暂行办法》，电监市场[2008] 15号。

[49] Each province in China uses a system of benchmarked feed-in tariffs for coal, gas, nuclear, hydro, wind, solar, and biomass generation units. Generators in the same category receive the same feed-in tariff. Coal-fired generators with desulfurization facilities receive an adder on top of the benchmarked rates. When this adder cannot cover the pollution control cost, generators with pollution control become less profitable than the ones without.

from provincial governments.[50] Even though trading is supposed to be voluntary, some provinces assigned particular buyers and sellers while excluding other generators from participating. Last but not least, implementation issues such as unreasonable transmission line-loss charges reduced the incentives to trade.[51]

4.4.3. Direct Contracting

As explained in Section 4.3, provincial governments have the authority to develop their own implementation plans for direct contracts between generators and consumers. In most cases, participation in this market is not open to everyone. For instance, in 2014, both Shanxi and Gansu stipulated that only coal-fired units with 300 MW capacity and above could participate in direct contracting.[52] That same year, Jiangsu imposed an even higher 600 MW requirement.[53]

4.5. Energy Conservation Dispatch (2007)

In response to the tightening energy supply and worsening environmental conditions, China launched a national energy-efficiency campaign as part of its 11th five-year plan. The campaign demanded that all sectors engage in energy conservation and emissions reduction so that from 2006 through 2010, China would reduce the energy consumption per unit GDP by 20 percent and achieve a 10 percent reduction in criteria-pollutant emissions. As part of the joint effort, a series of new policies were enacted to bring energy efficiency and emissions control to the power sector. These policies have supported a massive expansion of renewable energy generation in China. They also added new mechanisms to the existing generation dispatch process to increase the utilization of efficient and clean generators.

4.5.1. Details of the Energy Conservation Dispatch

In 2007, the State Council issued the "Measures for Energy Conservation

[50] *2015 Special Report on Energy Conservation Dispatch in Central China and East China*（2015年华中华东区域节能减排发电调度专项监管报告） Case 1: "In 2014, Henan and Hubei provinces mandated government approval for trading in generation rights. Henan province, in particular, mandated a prolonged approval process involving both provincial and prefectural authorities." Case 2: "In 2014 the Sichuan provincial government imposed administrative pricing on generation rights trading, which violated relevant regulations."

[51] *2012 Half-Year National Report on Inter-provincial Power Trading and Generation Rights Trading* gives the example of the Shanxi Power Grid Company charging 1.5% of total traded quotas for transmission line loss, which was inconsistent with the physical flow of the traded energy.《2012年上半年全国跨省区电能交易与发电权交易监管报告》.

[52] "2014 Implementation Rules for Electricity Consumers to Directly Contract with Generation Companies in Gansu Province" 《甘肃省电力用户与发电企业直接交易试点实施细则（2014版）》; Shanxi Economic and Information Commission (2013), "Notice on Application to Participate in Direct Contracting between Electricity Consumers and Generation Companies" 《山西省经信委关于申报参加2014年电力用户与发电企业直接交易的通知》（晋经信电力字【2013】490号）.

[53] "2014 Provisional Rules for Electricity Consumers to Directly Contract with Generation Companies in Jiangsu Province"《江苏省电力用户与发电企业直接交易试点暂行办法（2014版）》.

Electricity Dispatch (Pilot),"[54] a document cosigned by the NDRC, the Ministry of Environmental Protection, SERC, and the National Energy Administration (NEA). A new mechanism called the Energy Conservation Dispatch (ECD) was proposed to supersede the planned generation scheduling and dispatch procedure. ECD stipulated that the utilization of generators should be based on their fuel efficiency and emissions rates. More specifically, it provided the following merit order for the different categories of generators:

1. Renewables that cannot be used to perform grid services because of intermittency, including wind, solar, tidal and some hydroelectric units
2. Renewables that can be used to perform grid services, including hydroelectric, biomass, and geothermal units; waste-to-energy incinerators
3. Nuclear power generators
4. Combined heat-and-power cogeneration units; integrated coal-byproduct utilization generators
5. Natural gas turbines; coal-gasification power plants
6. Other coal-fired power plants
7. Gasoline and diesel generators

Based on the above order, provincial governments were required to produce a priority order table of all available generators within the province. Coal-fired units in the same category were to be prioritized in order of increasing heat rates. Where heats were identical, coal-fired units were to be further prioritized by increasing emissions levels. Heat rates and emissions levels were taken initially from nameplate specifications and later from real-time performance data once monitoring devices were available. The priority order table was to be prepared by November 20 each year and updated quarterly with additions and retirements of generation units (Kahrl et al. 2013).

ECD called for ending the use of annual generation schedules and instead required provincial governments to prepare preliminary annual, quarterly, and monthly unit commitment plans based on load forecasts and availability of generators. These preliminary unit commitment plans were then handed over to power grid companies, which would translate them into day-ahead unit commitment schedules according to the priority order table, grid topology, security constraints, and generator ramp rates. In real time, power grid dispatch centers were obligated to use the generators included in the day-ahead unit commitment schedules to the maximum. Wherever the infrastructure allowed, coal power plants were to be dispatched in the order of increasing incremental heat rates.

Ideally, the ECD should have been implemented by building a sophisticated optimization algorithm for dispatch commands. This algorithm should have had a structure similar to the one being used for economic dispatch in the United States, but instead of making cost minimization the objective function, ECD should have set its objectives to minimize fuel consumption and pollution emission. In addition, ECD should also have set constraints to represent the priority order of generators other than coal-fired units. If fully implemented and enforced, ECD should have significantly improved resource utilization, clean energy integration, and emissions control in China's power sector. However, given China's heterogeneous social-economic conditions across different

[54] State Council General Office (2007), No. 53, "Interim Measures for Energy Conservation Dispatch" 《节能发电调度办法（试行）》（国办发【2007】53号）

provinces, only five provinces were selected to implement ECD: Jiangsu, Henan, Sichuan, Guangdong, and Guizhou. In 2010, the pilot provinces were expanded to include Guangxi, Yunnan, and Hainan. Until enough experience was gained, the remaining provinces were not required to implement ECD; they were required only to experiment with other mechanisms that could have similar effects.[55]

Putting this new dispatch rule into practice proved to be extremely challenging, for several reasons. First, dispatching coal-fired power plants based on fuel efficiency and emissions level could result in utilization rates lower than those guaranteed by the power purchase agreements for some units. The ECD policy document did not provide clear guidance on how generators should be compensated when their required rate of return was not achieved. Second, implementing ECD would mean a complete overturn of the fair dispatch principle, which had evenly allocated generation hours for more than two decades and had made power companies accustomed to entitlements and averse to uncertainty and competition.

Third, the priority order table favors clean and renewable generators, making coal-fired power plants losers in the new game. As a result, implementation of ECD in the pilot provinces faced strong opposition from coal-fired power plants. Even after online monitoring systems were installed to measure these units' real-time fuel consumption rates, none of the pilot provinces consistently used an algorithm-based approach to strictly carry out ECD. After some experimentation, Jiangsu, Henan, and Sichuan all switched back to administrative planning in committing and dispatching generators.[56] ECD was never extended to the national level (Kahrl et al. 2016).

4.5.2. Differentiated Generation Quotas and Generation Rights Trading

Provinces that were not selected to run ECD pilots usually used differentiated generation quotas and generation rights trading to increase utilization of high-efficiency, low-emitting coal-fired generators. As discussed in Section 4.4, both mechanisms have features that favor coal-fired generators with higher fuel efficiency and lower emissions levels.[57]

5. Reform Proposals of 2015 and 2016

Given the obvious inefficiencies in the power sector, the government started the second comprehensive reform (the first being the one in 2002) by issuing Decree No. 9 on

[55] Many provinces used generation rights trading and differentiated generation quotas to increase the utilization of high-efficiency, low-emitting coal-fired generators.

[56] *2015 Special Report on Energy Conservation Dispatch in Central China and East China*.《2015年华中华东区域节能减排发电调度专项监管报告》，2015年5月。

[57] See, for example, "Shanxi Interim Rules for Generation Rights Trading" (Shanxi Electricity Market Regulation No. 165, 2013). The rules stipulate that coal units whose fuel consumption rate in 2013 was 10% or more above the provincial average would be instructed to sell their 2014 base generation hours. Also see "Spreadsheet for Adjusting 2008 Differentiated Generation Quota in Fujian Province," showing that coal units receive 50 fewer base hours if their fuel consumption rate is above provincial average; units with flue gas desulfurization equipment receive 100 more base hours that those without. 《山西省发电权交易规则（试行）》（晋电监市场【2013】165号）规定，供电标准煤耗高出上年全省平均水平10%的燃煤机组，其2014年的基数电量将列入年度发电权交易指导空间。福建省2008年度发电计划中，供电煤耗高于全省平均水平的减少50小时基数电量，脱硫机组比未脱硫机组多得100小时基数电量（见《福建省2008年度差别电量发电调整计划表》）。

March 15, 2015. "Deepening Reform of the Power Sector," issued jointly by the Central Committee of the Communist Party and the State Council, lays out guidelines for establishment of power market institutions, price deregulation, and promotion of clean energy. This was a short statement, which was followed by other documents providing more detailed rules to implement the decree; these are listed in Appendix Table A1.

Proposed reforms include establishing spot markets and power trading centers, introducing ancillary services trading, allowing retail competition, and tightening environmental regulation over power generators. Grid companies will also be transformed by adopting a new business model, with explicit prices for transmission and distribution based on service cost and performance.

Along with these power sector reforms, the central government plans to introduce a national carbon emissions trading system (ETS) in 2017. As in the seven pilot ETS programs that have been in operation since 2013, the electricity sector will be a major regulatory target under the national ETS. In other words, China will be institutionalizing electricity markets and carbon markets simultaneously—a rather unconventional approach that could entail unique challenges and opportunities. Since electricity market deregulation and carbon reduction are being implemented with different goals and motives, they will affect established interests in different ways, and an integrated approach will be needed to understand the interactions of these policies and guide the design of both markets. These complex changes will be discussed and analyzed in a separate report.

6. Conclusions

The ending of the monopoly by the Ministry of Electric Power in 1985 and introduction of independent generators led to a complete transformation of China's power system. In this report, we have documented the continuing series of reforms and regulatory changes to address the rapid changes brought about by double-digit economic growth. We have described how the nature of central-local government relations in China led to the evolution of a system in which provincial governments dominate dispatch decisions and autonomy over power sector affairs is vigorously defended. The importance of the political economy of power grid companies and how the State Grid Corporation of China exploits its monopoly are discussed; these companies were created when the generation assets of the State Power Company were separated in the 2002 reform.

Independent power producers were allowed in to deal with the power shortages of the 1980s and early 1990s. They were given rate-of-return guarantees, and "fair dispatch" was implemented to allocate base hours to all generators. Over time, when shortages turned to excess capacity in the 2000s, the deficiencies of this equal allocation of operating hours become apparent, and measures were needed to reconcile claims and increase overall energy efficiency. Efforts were made to introduce direct contracting between generators and consumers, bypassing the fixed prices and quotas set by the authorities.

The 2000s were also a period of rapidly rising energy consumption and severe pollution, and thus energy efficiency measures and pollution control introduced for the whole economy applied especially strictly to the power sector. Generation rights trading made some modest improvements but was not widely used. The Energy Conservation Dispatch system was tried but faced intense opposition, and some pilot programs ended.

The government issued the second major reform, Decree No. 9, in March 2015, followed by more detailed implementing

documents. The government also plans to introduce a national carbon emissions trading system (ETS) in 2017, one that will cover the electricity sector. The power sector reforms and ETS are designed by separate agencies and would have complex interactions that may not have been expected when they were laid out.

We hope the review of the institutions and history of reform in this report are helpful in analyzing and guiding the design of this complex set of policies aimed at improving efficiency, reducing pollution, and reducing CO_2 emissions. We plan to contribute such a discussion of the proposed reforms in a future report.

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Appendix

TABLE A1. A CHRONOLOGICAL LIST OF MAJOR EVENTS IN THE ELECTRIC POWER SECTOR IN CHINA

Year	Event #	Event	Policy Document
1985	1	Liberalization of power generation allowing independent producers and guarantee of cost recovery	《关于鼓励集资办电和试行多种电价的暂行规定》（国发【1985】72号）
1987	2	Supplemental details on cost-recovery feed-in tariffs; "fair dispatch" policy	水利电力部、国家经济委员会、国家物价局关于多种电价实施办法的通知》（水电财字【1987】101号）
1996	3	Establishment of the State Power Company; abolishment of Ministry of Electric Power (separation of government and business)	《国务院关于组建国电公司的通知》（国发【1996】48号）
1998	4	Pilots of power generation divesture and generation competition in Shanghai, Zhejiang, Shandong, Liaoning, Jilin, and Heilongjiang	《关于深化电力工业体制改革有关问题的意见》（国办发【1998】146号）
2002	5	"Power Sector Reform Scheme," State Council No. 5 (China's first comprehensive policy document guiding power sector reform); separation of generation assets from SPC	《电力体制改革方案》（国发【2002】5号）
2003	6	Supplemental details on reforming electricity prices; initiation of pilot wholesale markets, but termination by 2006	《国务院办公厅关于印发电价改革方案的通知》（国办发【2003】62号）
	7	Establishment of State Electricity Regulatory Commission	
	8	"Provisional Rules for Optimal Interprovincial Power Dispatch," the first document introducing rules for cross-provincial dispatch	《跨区跨省电力优化调度暂行规则》
2004	9	"Transparent, Fair and Impartial" rule on power generation dispatch	《关于促进电力调度公开、公平、公正的暂行办法》（电监市场【2003】46号）

	10	"Direct Contracting" Rules, interim measures for direct contracting between power producers and consumers	《电力用户向发电企业直接购电试点暂行办法》（电监输电【2004】17号）
2005	11	"Guidelines for Promoting Interregional Electricity Trading"	《关于促进跨地区电能交易的指导意见》的通知（发改能源【2005】292号)
2007	12	Decommissioning of small coal-fired power plants (11 FYP 2006–2010)	《国务院批转发展改革委、能源办关于加快关停小火电机组若干意见的通知》（国发【2007】2号）
	13	Introduction of "Energy Conservation Dispatch" in 5 provincial pilots	《国务院办公厅关于转发发展改革委等部门节能发电调度办法（试行）的通知》（国办发【2007】53号）
2008	14	Introduction of "Generation Rights Trading" (SERC 2008 No. 15)	《发电权交易暂行办法》（电监市场【2008】15号）
	15	Establishment of National Energy Administration (NEA) under NDRC	
2009	16	Revision of rules for direct contracting between power producers and consumers (SERC, NDRC, NEA 2009) (treatment of contracted hours versus base hours)	《国家电监会、国家发展改革委、国家能源局关于完善电力用户与发电企业直接交易试点工作有关问题的通知》（电监市场【2009】20号）
	17	Clarification and enforcement of electricity price regulations; enforcement of energy efficiency regulations	《关于规范电能交易价格管理等有关问题的通知》（发改价格【2009】2474号）
	18	Regulatory provisions on interprovincial/regional power contracting	《跨省（区）电能交易监管办法（试行）》（电监市场【2009】51号）
2011	19	Price regulations requiring contracts to use electricity prices set by NDRC	《国家发展改革委关于整顿规范电价秩序的通知》（发改价检【2011】1311号）
2012	20	Revised interprovincial/regional contracting rules forbidding grid companies to compel actions by generators	《跨省跨区电能交易基本规则（试行）》（办市场【2012】151号）

	21	Decentralization of regulation over direct contracting	《国家能源局综合司关于当前开展电力用户与发电企业直接交易有关事项的通知》（国能综监管【2013】258号）
2013	22	Takeover of SERC by National Energy Administration	
2015	23	"Deepening Reform of the Power Sector," Communist Party Central Committee Decree No. 9	《中共中央国务院关于进一步深化电力体制改革的若干意见》（中发【2015】9号）
	24	Recommendations for Implementing Decree No. 9, Supplemental Document No. 1-6	
	25	Guidelines for promoting clean energy integration	《国家发展改革委、国家能源局关于改善电力运行调节促进清洁能源多发满发的指导意见》（发改运行【2015】518号）
2016	26	"Guaranteed Renewable Electricity Offtake" provisions	《可再生能源发电全额保障性收购管理办法》（发改能源【2016】625号）
	27	Plan to unify dispatch in Beijing-Tianjin and Hebei	《国家能源局综合司关于做好京津冀电力市场建设有关工作的通知》（国能综监管【2016】445号）