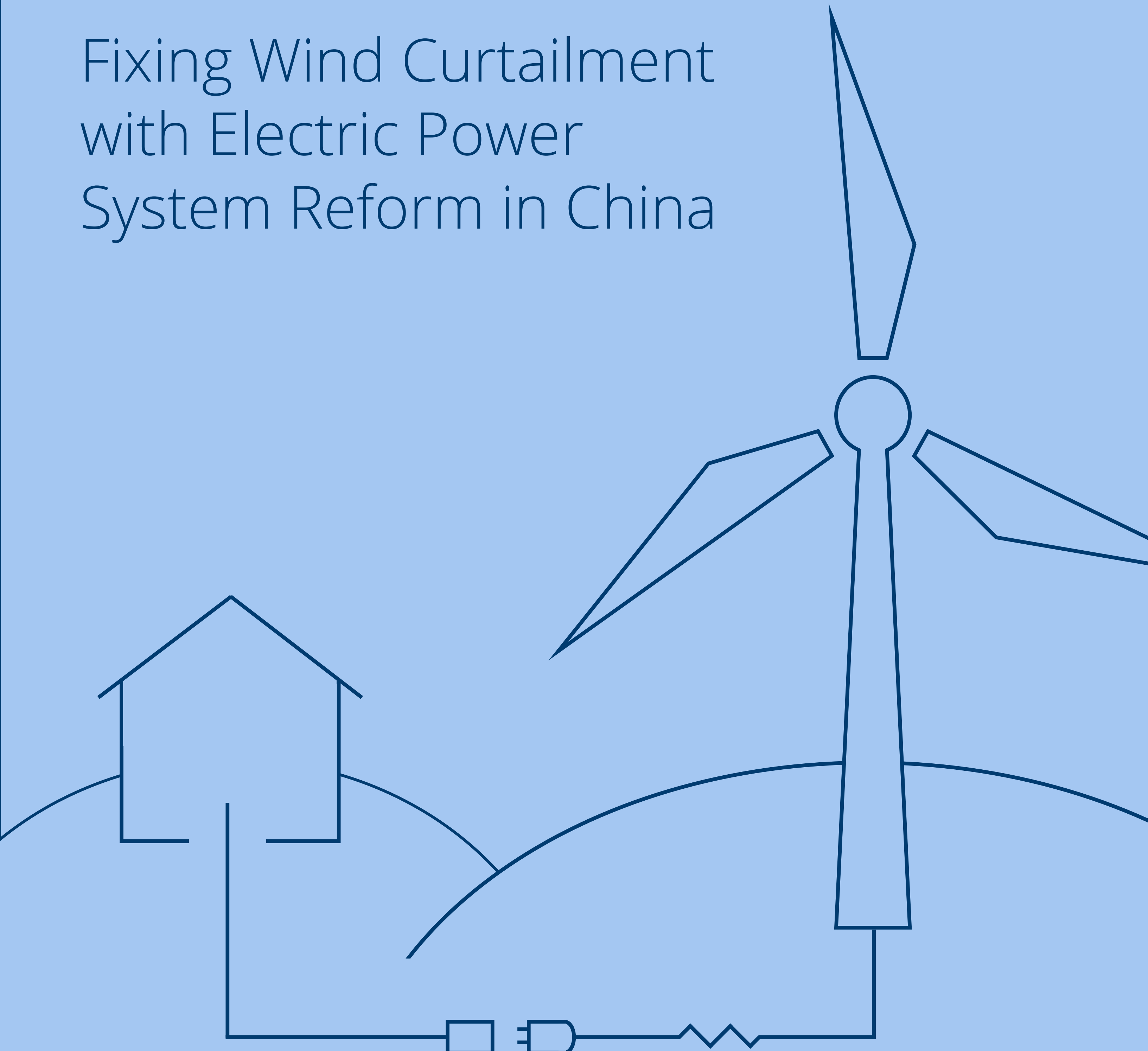
CHINA'S ENERGY IN TRANSITION SERIES

Fixing Wind Curtailment with Electric Power System Reform in China



Brookings-Tsinghua Center
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清华-布鲁金斯公共政策研究中心

Fixing Wind Curtailment with Electric Power System Reform in China

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Abbreviations

12th FYP	The 12th Five-Year Plan
BEOA	Bureau of Economic Operations Adjustment
BTC	Brookings-Tsinghua Center for Public Policy
CEC	China Electricity Council
CHP	Combined heat and power
DOP	Department of Price
ERF	The electric power regulatory framework
GDP	Gross domestic product
GenCOs	Generation companies
GridCOs	Grid companies
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
MOF	Ministry of Finance
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NREL	National Renewable Energy Laboratory
PV	Photovoltaic
SASAC	State-Owned Assets Supervision and Administration Commission of the State Council
SERC	State Electricity Regulatory Commission
SOEs	State-owned enterprises
UHV	Ultra-high voltage

Executive summary

Wind curtailment is the reduction in electricity generation below what a system of well-functioning wind turbines are capable of producing. It represents a significant loss in economic and energy efficiency. In 2016, the wind electricity curtailment in China amounted to 49.7 TWh, enough to cover the total annual electricity consumption of Bangladesh, with a population of 163 million. If the abandoned wind electricity were fully utilized as a substitute for coal, China could have reduced its CO_2 emissions by 42 million tons, close to the total emissions of Bulgaria. The severity of China's wind curtailment problem reflects underlying problems in the country's electricity regulatory regime. In the context of ongoing reforms in the power sector, addressing the issue of wind curtailment could also support the transition towards renewable-friendly institutional arrangements.

The recurrence of China's wind curtailment problem underscores the vulnerability of China's electricity regulatory regime. While China's wind power development has been plagued by wind curtailment from the early days, the problem was alleviated in 2013 and 2014 following government pressure for better grid connections. However, with economic deceleration and the resultant low growth in electricity demand, the wind curtailment rate bounced back in 2015. The wind curtailment rate—the ratio of curtailed electricity to total wind generation—typically exceeds 20% in wind-rich provinces in China, ten times that of most other countries. In some countries, severe wind curtailment only occurs temporarily but can be mitigated after a few years through the expansion of transmission networks and market design and optimization. In contrast, wind curtailment in China has persisted and even worsened in recent years, which suggests institutional causes.

Lieberthal and Oksenberg coined the term "fragmented authoritarianism" to explain the political economy of China's electric power system. The electric power sector is a typical natural monopoly, with a rigid hierarchy, and is dominated by state-owned enterprises (SOEs). Investment, electricity production, and allocation in the power sector are still largely controlled by the government, mostly at the provincial level. Although China initiated two rounds of power-sector marketization reform in 2002 and 2015, the role of price signals remains limited and state control over the electricity system remains strong. The electricity regulatory regime has been and will remain guided by a dual-track approach, with both central planning and market forces at play, but with an increasingly important role for the latter.

In this report, we focus on electric power regulatory framework to explain the wind curtailment problem in China, and probe into its root causes. Our analysis utilizes the concept of "fragmented authoritarianism," and highlights the lack of coordination in this sector. We use two case studies to illustrate the institutional causes of wind curtailment in different regions. Under the current top-down system, fragmented electric power regulation is identified as the fundamental cause of China's wind curtailment problem.

Fragmentation in electric power regulation exists at both the vertical and the horizontal levels. At the vertical level, regulatory authority is assigned to the central government and the provincial governments. While the central government sets national policies, individual provincial governments determine power generation and allocation within their respective jurisdictions. At the horizontal level, regulation responsibilities are scattered among different ministries or departments of the central and local governments. Decision-making authority is even more fragmented within each ministry or department. Moreover, state-owned grid companies and generation companies have strong bargaining power under this system. The scattered allocation of power and responsibilities in both the central and provincial governments lead to departmentalism and difficulty in coordination.

Electric power regulatory fragmentation heavily impacts power planning and inter-provincial power transaction. Planning authority is shared by different government departments and state-owned enterprises, which results in various mismatches of planning both at the vertical level and the horizontal level. Lack of coordination results in transmission constraints, system imbalances, as well as overcapacity, ultimately leading to wind curtailment. Inter-provincial barriers in power transaction are a typical problem caused by independent provincial electric power regulation. Such an institutional arrangement limits power generation and allocation within a province. This is detrimental to provinces that are key national energy bases, such as wind-rich provinces in the north. Inter-provincial barriers also make it difficult for trans-provincial and trans-regional electricity transactions: power-receiving provinces are unwilling to take electricity from other provinces, especially when their own power generation is abundant under economic deceleration.

The problem of fragmented planning has been partially solved by a five-year plan in the power sector in 2016. Inter-provincial barriers remain an unsolved institutional problem. In this report, the authors propose the establishment of regional spot power markets as soon as possible, in order to build a market friendly to renewable energy and to break down inter-provincial barriers. At the early stage, regional spot markets can be responsible for the trade of incremental wind power and other power. Ultimately, all spot transactions should be included in the regional markets, and medium- to long-term transactions can be conducted in the provincial markets. In the long term, China should further proceed with its power market reform, with a focus on the construction of auxiliary service trading mechanisms. In this way, the wind curtailment problem can be solved under a mature power market.

Introduction

China is a leader in renewable energy investment. Specifically, wind energy has played a pivotal role ever since China began investing in renewable energy in the early 2000s.

In 2010, China overtook the U.S. to lead the world in wind power installation. In 2016, China's newly installed wind power capacity accounted for 37.7% of the global market share, while its cumulative installations constituted 31.9% of the global market (IRENA, 2017). Within China, wind power accounted for 9% of total power capacity and 4% of total electricity generation in 2016.

However, despite China's leadership in installed wind power capacity, its wind energy electricity output is lower than that of the U.S. (Lu et al., 2016; Lewis, 2016). Among the causes of lower wind power generation, wind curtailment has risen as the most prominent. Wind curtailment is the reduction in electricity generation below what a system of well-functioning wind turbines is capable of producing. While China's wind development has been plagued by curtailment issues since 2010, the year 2016 saw especially severe wind curtailment, amounting to 49.7 TWh and a national average curtailment rate of 17.1% (NEA, 2017).

Wind curtailment has resulted in a significant loss of economic and energy efficiency. In 2016, China's wind curtailment figure exceeded the total electricity consumption of Bangladesh, a population of 163 million. Lost sales by power producers amounted to 18.7 billion RMB (or 2.7 billion USD). This is equivalent to the government's total poverty-elimination fiscal transfers to China's two western provinces, designed to benefit over a quarter-million people. If the abandoned wind electricity were fully utilized as a substitute for coal, China could have reduced its CO_2 emissions by 42 million tons, close to the total emissions of Bulgaria.

Furthermore, the wind curtailment issue has great significance for China's policymaking in the power sector. In November 2016, in response to curtailment, the National Energy Administration (NEA) announced a reduction in its wind installation target for 2020 from 250 GW to 210 GW. Furthermore, the causes of curtailments in solar, hydro, and even nuclear power are similar to those for wind. Thus, solutions to wind curtailment may be applicable in other sectors.

International experience indicates that the wind curtailment rate typically ranges from 1% to 3% of potential wind generation (Bird et al., 2016). However, the wind curtailment rate in China exceeds 10% in most years, with provinces like Gansu, Xinjiang, and Jilin witnessing curtailment rates of 43%, 38%, and 30%, respectively, in 2016 (NEA, 2017). In other countries, serious wind curtailment can be significantly mitigated over a few years through transmission network expansion and market design. For example, Italy and Texas (a U.S. state) experienced wind curtailment rates of 10.7% and 17.1%, respectively, in 2009, but those were reduced to rates of less than 2% within three to four years (Bird et al., 2014; 2016). However, China's wind curtailment has remained high for more than seven years and worsened in 2015 and 2016, which may indicate more complicated causes.

Many factors have been identified as responsible for wind curtailment in China. These include: (1) technical limitations of electricity grids (Davidson et al., 2013; 2016a); (2) power system inflexibility and system balance problems (Lu et al., 2016; Fan et al., 2015; Zhang et al., 2016; Pei, et al., 2015; Xiong et.al., 2016); (3) transmission constraints (Fan et al., 2015; Zhang et al., 2016; Pei, et al., 2015; Shu et al., 2017); (4) limited local electricity demand and a mismatch between transmission capacity and wind capacity development (Zhang et al., 2016; Wu, et al., 2014; Shu et al., 2017); and (5) insufficient planning coordination, grid management policies, and other institutional reasons (Luo et al., 2012; 2016; Zhao et al., 2013; Wu et al., 2014; Davidson et al., 2016b).

The above factors cannot fully explain the complexity of China's wind curtailment issues. For example, while individual factors have been studied, less research has been done on the correlation and interaction between factors. Furthermore, questions such as why wind curtailment has continued increasing despite numerous Chinese government measures remain unanswered. Some research has tried to connect wind curtailment with political economy interests; however, it is difficult to understand these interests completely without understanding the institutional arrangements.

In this report, we adopt an electricity regulatory framework to analyze the wind curtailment problem and the underlying institutional causes. We will present an electricity regulatory framework using two case studies—Jiuquan in Gansu and Tongyu in Jilin. The former, Jiuquan City, is home to the first 10-GW wind power base in China. Jiuquan is located in the northwest and is a major focal point of the wind curtailment problem. The latter, Tongyu County, is part of a 10-GW wind power base in Jilin Province. Located in the northeast, Jilin Province has long been troubled by wind power curtailment.

The remainder of the report is divided into four sections. Section 2 introduces the wind curtailment issue in the context of wind energy development in China. Section 3 presents the electricity regulatory framework and describes the institutional reasons behind the general wind curtailment problem and the essential nature of the issue. Section 4 is an analysis of the two case studies of Jiuquan and Tongyu, which will provide supporting evidence. Section 5 offers conclusions and policy implications.

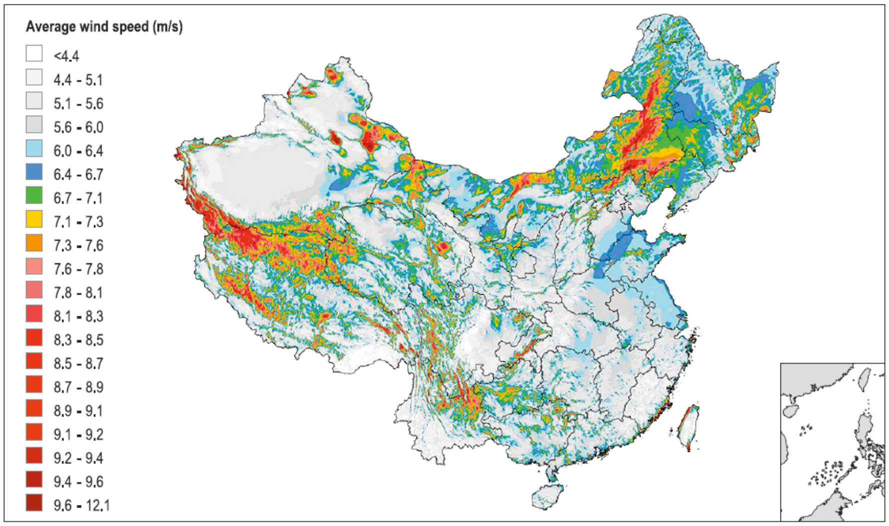
Wind energy development and the wind curtailment issue

Resource-based strategy for wind energy development

Although China has favorable natural conditions for wind power generation, the geographical distribution of wind energy resources is highly uneven (as shown in figure 2-1). Most of China's wind energy is concentrated in seven provinces in the "Three North" region—the northwest (Xinjiang and Gansu), northeast (Heilongjiang, Jilin, Liaoning), and north (Hebei, Inner Mongolia). However, these wind-rich provinces are economically underdeveloped and have lower electricity demand; they often need to export their wind power to other regions. While the best wind resource is located in the west and north, the electricity load centers are often thousands of miles away in the east and south.

Given these conditions, China adopted a resource-based wind power development strategy. This means concentrating wind capacity in resource-rich provinces and relying on long-distance electricity transmission and trans-regional dispatch to deliver wind power to the load centers. In 2012, the Chinese government decided to establish large-scale wind power bases.

Figure 2-1: Average wind speeds in China



Source: Adapted from IEA (2011), China Wind Energy Development Roadmap 2050, http://www.iea.org/publications/freepublications/publication/china_wind.pdf.

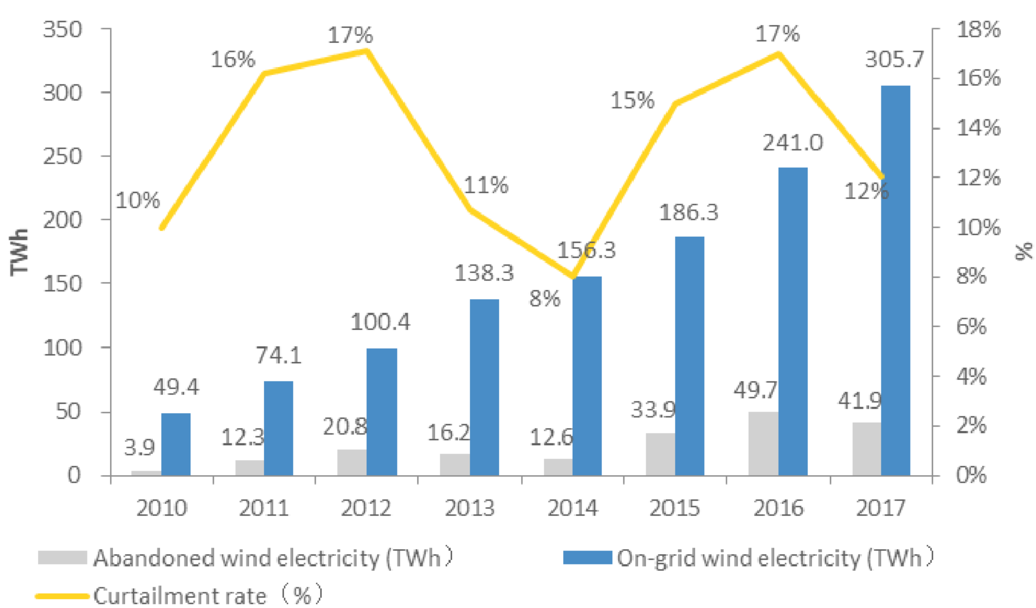
Of the nine proposed 10-GW wind power bases in the 12th Five-Year Wind Power Development Plan,[1] seven are located in the Three North region, where there is limited local electricity demand. In 2016, wind power capacity in the Three North region accounted for 71.5% of total wind power capacity in China. China's resource-based organization of big wind power bases has imposed a great challenge on wind integration.

Wind curtailment: Two waves and the "Three North" provinces

Wind curtailment appears to be a recurring problem in China. As shown in Figure 2-2, since 2010, there have been two waves of high wind curtailment. The first wave occurred from 2010 to 2012 when the national wind curtailment rate increased from 10% to 17%. The problem was significantly mitigated in 2013 and 2014 through governmental efforts to expand transmission infrastructure. However, with economic deceleration and the resultant low growth in electricity demand, the wind curtailment rate bounced back in 2015. These variations in the wind curtailment rate suggest a variety of factors underlying this enduring problem.

Moreover, wind curtailment problems differ across provinces. Provinces in the Three North region have been most seriously affected by wind curtailment. In 2016, wind curtailment in these provinces accounted for 99% of national curtailed power generation. As a result, the wind power generated in these provinces was only 67.9% of the total wind generation in China, despite accounting for 71.5% of total wind installation. As shown in Table 2-1, wind curtailment rates were above

Figure 2-2. Time series of China's wind curtailment and wind energy development



Source: Wang, 2014; NEA, 2014; 2015; 2016a; 2016b; 2017; 2018.

1 The nine 10-GW wind power bases are Hebei, Western Inner Mongolia, Eastern Inner Mongolia, Jilin, Gansu, Xinjiang, Jiangsu, Shandong, and Heilongjiang.

20% in Inner Mongolia, Jilin, Gansu, and Xinjiang, while wind power installation in these provinces accounted for about 20% of the power mix. Meanwhile, Hebei and Ningxia also had wind penetration rates of around 20%; however, the curtailment rate in these two provinces were roughly 10%, much lower than that of the previously mentioned four provinces. Thus, given these variations, the solutions need to be adapted for different provincial circumstances.

Since 2016, the Chinese central government has issued a series of policies to tackle the wind curtailment problem. These policies and measures include:

(1) Guaranteed minimum purchase hours for wind power: According to the policy issued in June 2016, for provinces with serious wind curtailment, a minimum number of utilization hours for wind farms should be guaranteed in provincial power generation plans. Grid companies should also prioritize wind farms for power purchases.

(2) Monitoring and warning mechanism: In July 2016, NEA started to assess each province in terms of the seriousness of its wind curtailment and the prospects for further wind power development. For provinces with serious wind curtailment, new wind power projects would not be approved, and the construction of approved projects would be postponed.

(3) Trial quota on renewable development and utilization: In January 2017, NEA issued a non-hydro renewable quota for power generation companies and provinces. Since June, green certificates have been issued to power generation companies and electricity venders that meet the quota, which then can be traded.

Table 2-1. Wind curtailment in the Three North provinces, 2016

	Abandoned wind generation (TWh)	Curtailment rate (%)	Proportion of wind power capacity (%)	Penetration rate (%)
Hebei	2.2	9%	18.8%	8.8%
Shanxi	1.4	9%	10.1%	5.4%
Inner Mongolia	12.4	21%	23.2%	11.7%
Liaoning	1.9	13%	15.1%	7.4%
Jilin	2.9	30%	18.6%	9.0%
Heilongjiang	2	19%	20.2%	9.6%
Shaanxi	0.2	7%	6.4%	1.9%
Gansu	10.4	43%	26.5%	11.2%
Ningxia	1.9	13%	25.6%	10.9%
Xinjiang	13.7	38%	22.9%	9.7%

Source: Source: CEC, 2017; NEA, 2017.

Unfortunately, the outcome of the above policies has been unsatisfactory. Despite the central government's assignment of minimum purchase hours to wind farms, six out of the nine provinces did not meet the requirements in 2016. Furthermore, from June to October 2017, more than 8 million green certificates were issued, but only 20 thousand green certificates were purchased. Lastly, in the most recent attempt to address hydro, wind, and solar power curtailment,[2] NDRC and NEA put forward a portfolio of policy tools, including the implementation of a renewable development and deployment quota, the optimization of power system structure and distribution, and the facilitation of spot market and ancillary market trade. However, the effectiveness of such a portfolio remains to be seen.

2 The Implementation Plan for Solving the Problem of Wind, Solar, and Hydro Power Curtailment (issued by NDRC and NEA in November 2017).

Wind curtailment in the electricity regulatory framework

Wind curtailment has occurred within the context of China's heavily regulated electricity system. The electric power sector is a typical natural monopoly, with a rigid hierarchy, and is dominated by state-owned enterprises (SOEs).

Investment, electricity production, and allocation in the power sector are still largely controlled by the government, mostly at the provincial level. Although China initiated two rounds of power-sector marketization reform in 2002 and 2015, the role of price signals remains rather limited and state control over the electricity system remains strong. The electricity regulatory regime has been and will remain guided by a dual-track approach, with both central planning and market forces at play, but with an increasingly important role for the latter.

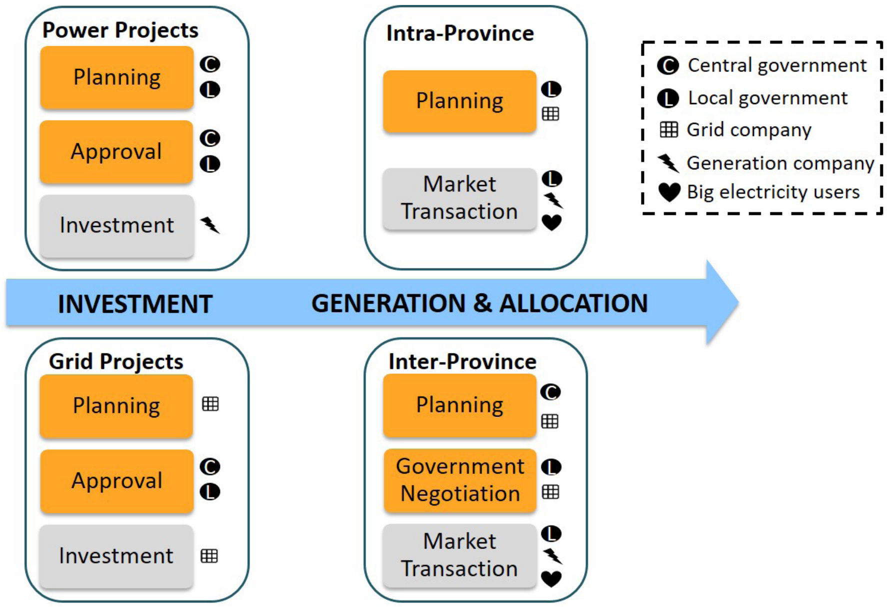
This paper follows the work of Lieberthal and Oksenberg, and analyses of China's wind curtailment problem through the "fragmented authoritarianism" framework. We argue that in addition to technical difficulties, the current wind curtailment problem is a result of the fragmented authority governing China's electric power system. Figure 3-1 summarizes such a conceptual model, which comprises key players and their roles in the investment, generation, and allocation of power. The key players include the central government, local governments, grid companies, generation companies, and big electricity consumers. In theory, such an institutional structure relies on decision making through bargaining, rule by consensus, and mutual accommodation. However, in reality, it is often subject to severe coordination problems. In wind power investment and distribution, lack of coordination results in transmission constraints, system imbalances, as well as overcapacity, ultimately leading to wind curtailment.

Key players and their roles

Central government

China's central government plays a steering role in the country's power sector. With respect to planned electricity regulation, the central government approves national goals for capacity development (for both generation and transmission), plans inter-regional electricity exchange, and determines general electricity system dispatch rules and on-grid tariff levels. For the ongoing marketization reform, the central government formulates general regulations and policies, designs market trading rules and trading products, and supervises the market. NDRC coordinates the drafting of

Figure 3-1: An electric power regulatory framework showing key players and their involvement



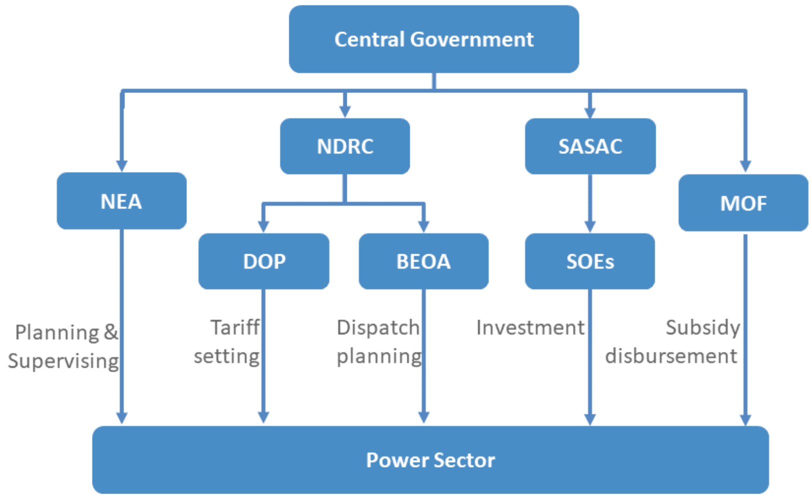
marketization reform policies in the power sector, although more than nine ministries participate in the work.

Wind power development suffers from departmentalism and lack of coordination due to the central government's scattered functions and division of management. As seen in Figure 3-2, NEA sets the development goals for both generation and transmission of wind power and then chooses the strategies to achieve them.[3] The Department of Price (DOP) of the NDRC determines the incentives to develop wind capacity, primarily through adjusting the level of feed-in tariffs. The Bureau of Economic Operations Adjustment (BEOA) directs and approves provincial annual power generation and allocation plans, and initiates plans for cross-province power exchanges. The State-Owned Assets Supervision and Administration Commission of the State Council (SASAC) supervises the assets of energy SOEs (i.e., both grid companies and generation companies), while the Ministry of Finance (MOF) disburses subsidies from feed-in tariffs for wind electricity generation.

Management is greatly fragmented even within individual ministries, leading to a lack of coordination among different bureaucracies. For example, despite the importance of coordinating plans across

3 For example, the Energy 12th Five-Year-Plan (2011-2015) sets the goal of 100 GW in wind capacity development in 2015 and 200,000 kilometers of transmission lines with voltage of 300 kV or more (State Council, 2013).

Figure 3-2: Scattered role of the central government



Note: NEA—National Energy Administration; NDRC—National Development and Reform Commission; DOP—Department of Price; BEOA—Bureau of Economic Operations Adjustment; MOF—Ministry of Finance; SASAC—State-Owned Assets Supervision and Administration Commission of the State Council.

renewable energy sources, such a coordination mechanism was absent from the 11th and 12th FYPs (2006–2015); instead, separate plans for thermal power, hydro power, wind power, nuclear power, solar energy, and biomass energy were issued by different departments within NEA. Furthermore, there were no national grid plans issued during that period, and grid projects were approved on an individual basis by NEA. Such departmentalism weakens the effectiveness of central government and increases the cost of coordination among different bureaus, resulting in mismatches of planning at both the vertical and horizontal levels.

Local government

The local government plays a dominant role in China's regulatory framework, particularly in intra-province power generation and allocation. Provincial governments mirror the central government and implement national policies at the local level. Specifically, they determine the provincial development goals (e.g., power investment), make annual power generation and allocation plans, and approve power projects within their administrative jurisdiction. Provincial governments also negotiate inter-provincial power transfers, in conjunction with the corresponding provincial grid companies. Finally, provincial governments also dominate local electricity marketization design and supervise the market under the general framework set up by the central government.

It is important to differentiate between the provincial government and the municipal government. Municipal governments bear much of the responsibility for local economic development. In the wind-rich Three North region, wind turbine manufacturing is strongly favored by the municipal governments, because it is supported by national policies and can boost capital investment, tax revenues, and employment. Most municipal governments use a strategy of exchanging wind resources for manufacturing industry. During the bidding process, municipal governments usually invite big energy companies to set up manufacturing factories with the promise of prioritizing wind development. While municipal governments devote great attention to wind power development and manufacturing, they tend to neglect the issues of wind electricity consumption and curtailment.

Grid companies (GridCOs)

Grid companies (GridCOs) are responsible for power dispatch, transmission, distribution, and electricity sales in China. There are two large, state-owned regional grid companies—State Grid Corporation and China Southern Power Grid Corporation. As subsidiaries of these companies, there are 5 sub-regional grid companies, 37 provincial and sub-provincial grid companies, and 431 municipal grid companies. One of the most important goals of the ongoing electricity marketization reforms is to divide different roles of grid companies. Under the new market design, power sale business will be conducted by electricity venders, and unified transmission and distribution prices will be verified by provinces and charged by grid companies. [4]

A grid company operates the electricity system within its designated geographical area (mostly within one province) and dispatches electricity in accordance with prescribed policies and technical standards. Guiding policies can come from both the central government and local government, which may sometimes contradict each other. In cases of contradiction, grid companies tend to lean towards local government. In terms of technical standards, the 2005 Renewable Energy Law requires that any integration of wind energy not adversely impact grid system reliability. Such a requirement grants GridCOs substantial discretion to define grid reliability.

According to the institutional assignments delineated in the 2002 electricity marketization policy, grid companies are to assist in national grid planning.[5] In actuality, two large GridCOs made separate regional five-year grid plans, while NEA failed to issue any unified national grid plan from 2006 to 2015. For example, the State Grid Corporation proposed 19 ultra-high voltage (UHV) long-distance transmissions as part of its five-year regional grid plan in 2011. This plan was submitted to NEA and NDRC, which debated the necessity and safety of such large-scale deployment of UHV technologies. Ultimately, NEA departments reached no consensus. Consequently, these UHV projects had to be slowly approved by NDRC on a case-by-case basis (Zhao, 2013; Caixin, 2011). Such lack of coordination between generation and transmission is often cited as a key factor

4 Opinions on the Implementation of Power Sales Side Market Reform (issued by NDRC and NEA in November 2015); Opinions on the Implementation of Transmission and Distribution Price Reform (issued by NDRC and NEA in November 2015).

5 According to the policy, "the main responsibility of State Grip Corporation is, ..., assisting with national grid planning entrusted by related government department" (Circular of State Council on Power System Reform Plan, 2002).

causing delays of wind power connection and transmission.

Generation companies (GenCOs) and big electricity consumers

Generation companies in China are mostly big state-owned enterprises. Following the 2002 electricity market reform, these SOEs have been dubbed the "Big Five and Small Four" GenCOs and often compete against each other at the provincial level. The investment activities of GenCOs are based on many factors, not just profit. Since most performance-evaluation indicators for state-owned GenCOs are related to the size of assets, companies are incentivized to expand in size. Sometimes, investment activities of GenCOs may appear irrational when judged by profitability. However, these decisions become rational when performance evaluation indicators are taken into account.

Wind energy development of GenCOs was supposed to be guided by a renewable energy quota, which was first proposed in the Medium and Long Term Renewable Energy Development Plan in 2007. Such a quota mechanism was a powerful deterrent to GenCOs, and higher feed-in tariff also made investment on wind power very attractive. Hence the competition in developing wind resources has been the rule of the game. At the county level, GenCOs compete to obtain land with good wind resources. At the provincial level, GenCOs compete fiercely for annual wind development quotas. For example, more than 300 GenCOs (including small local ones) were waiting in the pipeline to get their quota from the third batch of the Zhangjiakou Wind Base in 2016 (BTC interview, 2016).

Big electricity consumers, such as chemical manufacturers, are in a unique position to affect energy development. They are not directly involved in the energy policy-making process at the central level. However, as big local enterprises, they are key to local economies; they are thus very important players in local policy-making. For example, to maintain economic growth and protect big manufacturers, provincial governments have established electricity transaction centers and encouraged big customers (mostly in the manufacturing industry) to purchase electricity directly from power generators instead of grid companies. As a result, big customers in local areas benefit from lower electricity prices and survive through unfavorable economy conditions.

The scattered functions and confusion in the delegation of power and responsibilities among key players lead to departmentalism and difficulty of coordination. Fragmentation in electric power regulation exists at both the vertical and horizontal levels. At the vertical level, regulatory authority is assigned to the central government and 32 local governments. While the central government makes national policies, individual local government decide power generation and allocation inside their jurisdictions. At the horizontal level, regulation responsibilities are scattered among different ministries or departments of central and local governments. Decision making authority is fragmented even within individual ministries or departments. Moreover, state-owned grid companies and generation companies have strong bargaining power under this system.

The operation of the electric power regulatory framework

In this section, we outline how the fragmentation of authority between different actors plays out in the investment and allocation of wind power, and how it results in wind curtailment.

Investment in the power sector

The central government and provincial governments guide investment through wind power planning and control the size of investments by requiring projects to be approved. From 2006 to 2015, power capacity plans were formulated by governments at all levels, grid plans were formulated by grid companies, and project approvals for smaller projects (wind farms of 50 MW or less) were delegated from the central government to provincial ones at times. By 2013, the right to approving wind projects was delegated to local governments completely. Thus, the central government only sets plans.

This scattered division of roles and management inside the central and local governments from 2006 to 2015 created three mismatches: (1) between national planning and provincial planning; (2) between generation planning and grid planning; and (3) between renewable power units and other power sources. For example, while the wind power capacity targets for 2010 and 2015 in the national 11th and 12th FYP Period Renewable Energy Plans were 10 GW and 100 GW, respectively, the installed capacity were 31 GW and 129 GW, with much of the excess approved by the provincial government.

Once power projects are approved, they are developed mostly by big state-owned generation companies. Due to strong governmental endorsements, big state-owned generation companies can easily borrow money from state-owned banks. For typical wind power projects, bank loans normally account for 80% of the total investment from big SOEs (Dong, 2013).

Electric power generation and allocation

Provincial governments administer the production of power units inside their jurisdictions through the Annual Power Generation Plan, which determines the annual generation hours of power units. Provincial grid companies are responsible for carrying out the plan by disaggregating it into monthly and daily dispatch plans. Meanwhile, provincial governments manage electricity consumption through the Annual Power Allocation Plan within their jurisdictions. The plan sets the priority of electricity utilization for different consumers at different tariffs. In most provinces, these two plans are drafted by grid companies, and are later adjusted, approved, and released by provincial governments.

The current provincial Annual Power Generation Plan limits power unit dispatch inside each province, while regional dispatch is utterly inadequate. Once electricity supply surplus occurs in a province, power curtailment becomes inevitable as increasing electricity export is not an option. Intermittent wind power is usually the first to be curtailed. Beyond wind curtailment, wind farms may be required to make special arrangements with other generation units in order to gain more utilization.For example, the Yunnan provincial government in 2015 required wind power generators to compensate thermal power generators in exchange for a bigger quota in the Annual Power Generation Plan.[6]

6 Yunnan Provincial Industry and Information Committee, Notice on the Work Plan of Wind Power and Thermal Power Exchange, November 20, 2015.

For inter-provincial and inter-regional transactions, there have been three kinds of institutional arrangements: planned distribution by NDRC, negotiations by provincial governments, and market transactions. NDRC used to issue the Annual Inter-regional and Inter-provincial Power Transaction Plan, which was drafted by the two largest regional grid companies and then approved by NDRC. However, with the ongoing electricity market reform, NDRC ceased its planning role in 2017. Provincial government negotiations also play an important role in inter-provincial electricity transactions. Since 2015, Guangzhou and Beijing Electricity Power Exchange Centers began to organize inter-provincial trade; yet, transactions in wind power remained insignificant. Electricity transactions through the market accounted for only 5% of all inter-provincial transactions on the Beijing Electricity Power Exchange in 2016 (CEC, 2017).

Decelerating economic growth has revealed inter-provincial barriers. For example, local governments tend to protect local power generators for tax revenue and employment purposes. Further, a power-importing province is unwilling to import electricity from other provinces when its demand can be met by local supply. Without an improved regional market system for power and auxiliary service mechanisms, inter-regional and inter-provincial wind power trade will remain insignificant.

To summarize, the electric power regulatory system in China exhibits four distinctive features: (1) fragmented authority at both the central and local government levels; (2) provincial control of planning for electric power generation and allocation; (3) strong inter-provincial barriers; and (4) weak market mechanisms. Such a system can be very effective for rapid renewable power development, but ineffective in handling inter-provincial transmission and whole power system optimization. Next, we use two cases studies to demonstrate such inefficiencies.

Case studies: Jiuquan and Tongyu

The case of Jiuquan, Gansu province

Jiuquan in Gansu Province has abundant wind. Wind speeds in Jiuquan ranges from 4.0 to 12.0 m/s with prevailing wind at 5.0 to 6.5 m/s. Destructive wind speeds are rare. Wind power density is greater than 150 W/m2 in most areas (Northwest Electric Power Design Institute, 2008). Furthermore, the cost of wind energy development in Jiuquan is lower than in other places because of the low cost of desert land acquisition. Wind power developers consider Jiuquan the best region in China for large-scale wind power development (BTC interview, 2016). However, a key disadvantage is its distance from load centers.

Wind power development in Jiuquan

In 2005, the Jiuquan municipal government initiated a wind power development strategy and submitted its plan to build a 1 GW wind power base to the Development and Reform Commission of Gansu Province and NDRC. But NDRC did not approve this plan. However, the situation changed when China's Renewable Energy Law went into force on January 1, 2006. The law garnered enthusiasm among wind developers as well as local governments. In July 2007, the then-party secretary of the province went to Jiuquan for a field visit and expressed his support for Jiuquan's strategy and proposed making Jiuquan a provincial wind power base.

In September 2007, a group of central government officials visited Jiuquan, including the then-vice premier and administrator of the NEA. The local government presented the strategy for Jiuquan's wind power base development and won support from the vice premier. In the same month, NEA proposed a national strategy to "build several big wind power bases, and integrate these power bases into the regional grid" (Qin et al., 2011). In early 2008, Jiuquan was approved as the first 10 GW wind power base in China. At the same time, over 20 power generation companies signed investment contracts with the Jiuquan municipal government (Lanzhou Morning Post, 2009).

Since September 2007, the Jiuquan municipal government has put significant effort into the application and construction of the wind power base and the New Energy Industrial Park. In the summer of 2008, the first wind turbine manufacturer—Gold Wind Company—began plant construction in the New Energy Industrial Park. In 2010, investment in wind power projects and related manufacturing industries in Jiuquan reached 22.3 billion RMB ($3.3 billion), while tax revenue reached 194 million RMB ($28.7 million), and more than 8,000 jobs were created. Driven by wind power development, Jiuquan's GDP rose from the fourth among all prefectures in Gansu in 2005 to the second in 2010 (He & Feng, 2016).

The construction of Jiuquan Wind Power Base was divided into two phases (Table 4-1). The first phase was planned for 3.8 GW and construction took place from 2009 to 2012. According to the municipal government's planning, the construction of Phase I would be finished by 2010, the end of the 11th Five Year Plan (FYP) period. This was a very tight schedule given the scale of installation and construction interruption due to winter weather. However, the municipal government knew that it could compete for a higher share in national wind development planning for the 12th FYP if Phase I (under the 11th FYP) was finished by 2010. Therefore, from 2009 to 2010, the local government accelerated the wind farm construction, continuing even into the winter (Qin et al., 2011).

Wind curtailment in Jiuquan began to take place as early as in 2009 (SERC, 2012). In 2008, the wind power delivery capacity of the local grid was less than 500 MW, far below the necessary levels for future electricity export. Two additional 750 kV transmission lines were planned to transmit Jiuquan's wind power into the Northwest Grid. The first transmission project increased the delivery capacity to 2.6 GW, enough to meet the transmission needs of the planned power capacity (3.8 GW). However, the Gansu provincial government approved an additional 35 projects with a total capacity of approximately 1.3 GW. Combined with another 0.4 GW concession bidding projects, the total installed wind power capacity in the first phase reached 5.5 GW,[7] far beyond the original target (3.8 GW). As a result, the wind curtailment rate reached 30-40% in 2010. Even after the completion of the first transmission line, the curtailment remained above 20% after a temporary respite in 2011 (Table 4-2).

Transmission construction could hardly keep up with the wind farm development. In 2011, the Jiuquan government began to push the second phase of construction of wind farms even though the first phase

Table 4-1: Arrangement of Jiuquan wind power base

	Phase I	Phase II	
		Batch 1	Batch 2
Planned capacity (GW)	3.8	3	5
Installed capacity (GW)	5.5	3	0.15 (2016)
Duration of wind farms construction	2009 - 2012	2013 - 2015	Postponed
Transmission projects	1st 750 kV line	2st 750 kV line	±800 kV UHV line

Source: Jiuquan's Energy Bureau (BTC interview, 2016).

7 3.8 + 1.3 + 0.4 = 5.5

had not been completed. In response to the disorderly expansion of wind farms, NEA decided to control the scale and speed of wind development in the 12th FYP period. On August 25, 2011, NEA issued the "Provisional Measures for the Administration of Wind Power Development and Construction," and—belatedly—required that wind projects approval be consistent with national planning.

After one year of negotiation, the second phase of projects in Jiuquan were divided into two batches: the first for 3 GW, and the second for 5 GW. In September 2012, NEA approved the construction of the first batch and stipulated that subsequent projects would be approved only if the transmission problem had been solved. In 2013, another 750 kV transmission project was put into commercial operation, increasing the output capacity to 5.68 GW. However, the total wind power capacity in Jiuquan reached 6 GW, and solar photovoltaic (PV) installations reached 0.96 GW. Moreover, other cities' wind and solar installations in the regions also share transmission lines with Jiuquan, further burdening the system.

The most serious instance of wind curtailment took place following the completion of the first batch of construction in 2015. In response, NEA halted wind project approval and construction in Gansu, Xinjiang, Inner Mongolia, and other provinces beginning in March 2016. Although preliminary work for the second batch of the Jiuquan wind power project had already begun, construction of the wind farms was postponed due to serious wind curtailment. Concerned parties rested their hopes on an 800 kV UHV cross-region transmission line (from Jiuquan, Gansu, to Zhuzhou, Hunan).

In 2010, a UHV cross-region transmission line aiming to transmit electricity to central China was proposed by Gansu Province and the State Grid Corporation. The next year, provincial governments from Gansu and Hunan signed the "Framework

Table 4-2: Wind power installation and curtailment in Jiuquan, 2008-2016 (Unit: MW)

	2008	2009	2010	2011	2012	2013	2014	2015	2016
New installation	100	1700	3300	0	500	0	2000	1000	150
Total installation	500	2200	5500	5500	6000	6000	8000	9000	9150
Curtailment rate	NA	NA	30-40%	7-8%	24.3%	20.6%	11%	39%	43%

Source: (1) wind power installation: Energy Bureau of Jiuquan (BTC interview, 2016).
(2) wind curtailment rate:
a. 2011-2013 data: (Qin et al., 2011); (Wang, 2014); (Yu, 2015).
b. 2014-2016 data: (NEA, 2015); (NEA, 2016); (NEA, 2017).
Note: 2014-2016 wind curtailment rates are averages from Gansu Province data.

Agreement on Hunan's Importing Electricity from Gansu" with support from the State Grid Corporation. However, NDRC did not grant approval for the project until 2015 due to disagreements over UHV technology (Wang, 2015). Construction for the transmission line finally began in 2015 and the line became operational in 2017.

However, the recipient provinces in central China no longer face a power supply shortage. Generation companies have installed 12 GW power units in Hunan Province from 2011 to 2016, an addition amounting to more than 40% of the province's total capacity in 2010. Other provinces in the region have also seen similar expansions. As such, recipient provinces which now enjoy sufficient power supply are no longer willing to accept imports of electricity. Latest reports suggest that electricity exports via the UHV line are far below Gansu's expectations. Moreover, in 2017, the rate of wind curtailment in Gansu Province was still as high as 33% (NEA, 2018).

Wind curtailment in Gansu province

Jiuquan is one of fourteen prefectures in Gansu Province. According to the current electricity regulatory system, the generation and balance of power from the Jiuquan wind power base are included in the provincial plan. Prior to September 2014, this was conducted by the regional grid company. The wind curtailment issue in Jiuquan needs to be understood within the context of Gansu Province and the northwest region.

The Gansu provincial government first proposed becoming a national energy base and providing energy to other provinces in 2009. Around the same time, four of the five provinces in the same region (i.e., the northwest) were positioned as national energy bases (e.g., Ordos Basin energy base and Xinjiang energy base) in the 12th Five Year Plan. Without sufficient trans-regional projects, overcapacity in the power sector was inevitable, especially given continued power installations for different energy sources across the northwestern provinces.

To summarize, we have identified three factors driving Gansu's wind power curtailment from 2009 to 2014: (1) transmission constraints, (2) system balances, and (3) overcapacity. Prior to 2015, the problem was primarily supply-driven. From 2015 on, the problem has largely been demand-driven. Since transmission constraints were highlighted and discussed in the Jiuquan case, we hereafter focus on the other factors behind wind power curtailment in Gansu.

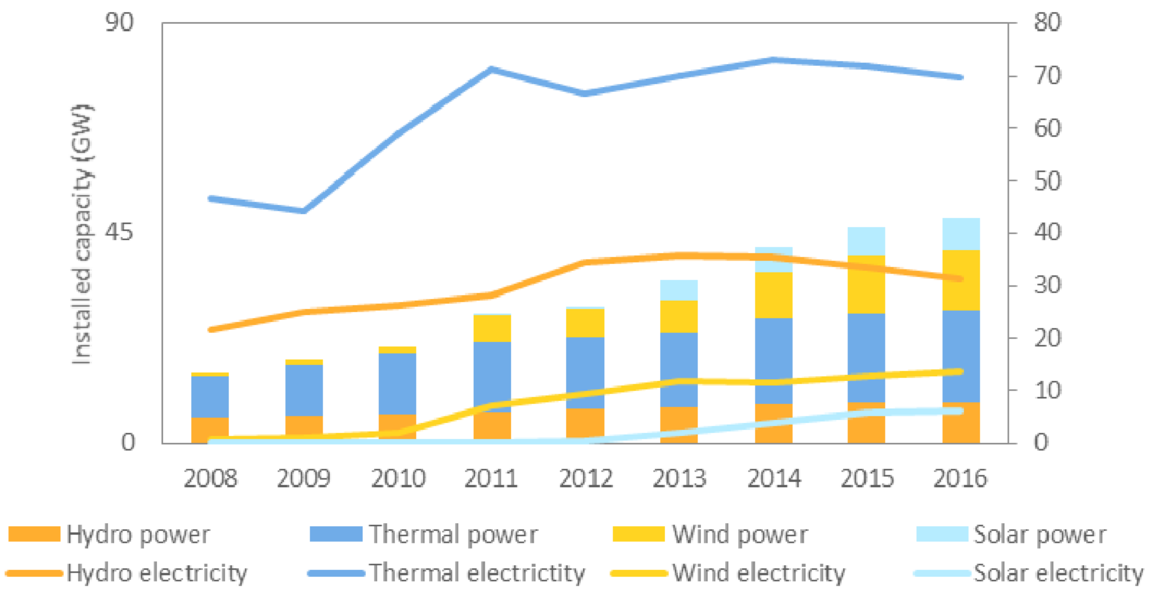
System Balance Problem

Before September 2014, the regional grid company—Northwest Grid—was responsible for operating wind power farms in the five northwestern provinces. Due to wind power's intermittency, hydro power from Qinghai Province was often used for system balance. However, wind power operating authority was transferred from regional grid company to the provincial grid company in September 2014; this in turn worsened the system balance situation in Gansu (BTC interview, 2016). The Jiuquan Wind Power Base plan failed to mention the system balance issue. Further, the 12th FYP for Energy Development in Gansu Province lacked details on the comprehensive coordination of wind power capacity growth and system balance.

Oversupply
From 2014 onwards, excessive power supply has been the biggest factor driving wind power curtailment in Gansu Province. By the end of 2016, the total installed capacity of electric power plants was 48.3 GW, with hydro, wind, and PV power units accounting for 58.5% of total capacity. Meanwhile, in July of that year, the maximum load of Gansu's grid dropped to approximately 12 GW from 13.8 GW in 2014, with the minimum load of less than 11 GW. The installed power capacity is about four times the maximum load. The power supply in Gansu is in a state of severe overcapacity. As shown in Figure 4-1, electricity generation from thermal and hydro power has been decreasing since 2014, whereas installed power capacity has increased. At the same time, wind and solar power generation showed marginal increases. In 2016, the capacity factor of wind power was only 0.12, the lowest in the country.

Slowing demand
Demand for electricity has been slowing or even decreasing both within Gansu Province and in provinces that import power from Gansu. Growth of electricity consumption in Gansu Province dropped significantly in the latter half of the 12th FYP period; the growth rate even fell to

Figure 4-1: Power capacity and generation from 2008 to 2016, Gansu province



Source: CEC.

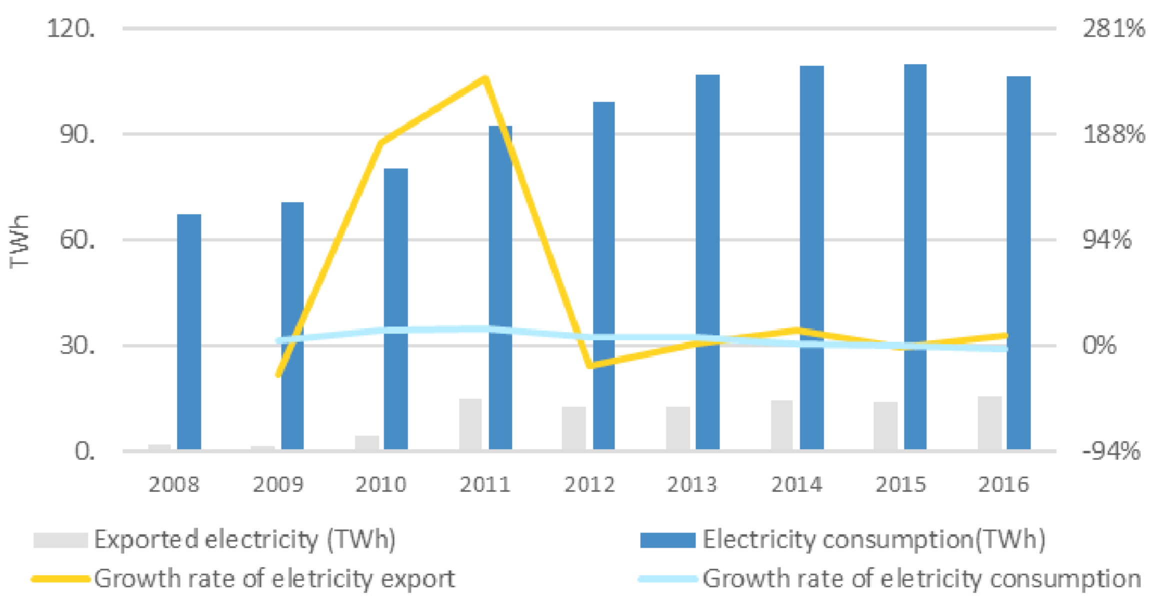
negative 3.1% in 2016 (shown in Figure 4-2). In addition, electricity demand from the Northwest Grid region has also been decreasing. In the first quarter of 2016, the maximum power load decreased by 2.0% compared to the first quarter of 2015. Furthermore, all five provinces in the region have been plagued by wind power curtailment problems (Northwest China Energy Regulatory Bureau of NEA, 2016a; 2016b).

The importing provinces have also witnessed a significant slowdown in electricity demand. As shown in Figure 4-2, electricity exports from Gansu dropped and stabilized after 2011, before further dropping in 2015. Through efforts undertaken by the provincial government, including exporting to Tibet and Qinghai (Gansu News, 2017), electricity export increased by 15.2% in 2016.

The case of Tongyu, Jilin province

Jilin Province is also rich in wind resources, with 200 GW of wind energy potential, 54 GW of which could be developed for power generation. In response to the NEA initiative to accelerate wind power development in 2007, the Jilin provincial government plans to develop five 1-GW wind power bases as well as other wind projects. The

Figure 4-2: Electricity consumption and export in Gansu province



Source: CEC.

plan calls for making Tongyu the site of Jilin Province's largest wind power generation base, as well as China's largest wind power equipment manufacturing base.

Wind power development in Tongyu

In 1999, the first wind farm in Jilin Province was built in Tongyu County. In 2004, NDRC held the second round of public bidding for wind power projects, including two big projects from Tongyu with a total capacity of 400 MW. From 2005 onwards, an increasing number of power generation enterprises came to Tongyu and built 19 wind resource measuring towers. In 2006, the municipal government announced its plan to make Tongyu a "National Green Energy Demonstration County" and develop it as the largest wind power base in China and the wind power manufacturing base of Jilin Province. By the end of 2007, the installed wind power capacity in Tongyu County was 217 MW.

In March 2009, the Jilin provincial government announced that it planned to build a 2.3 GW wind power base in Tongyu County. Through public bidding, nine developers won the development rights. In the 2009 "Planning Report for One-GW Wind Power Base in Zhanyu," which included the Tongyu wind power base, the plan designer suggested building a transmission project (including a 500 kV step-up substation and a 201-kilometer transmission project) to connect the wind power base to Jilin Grid. However, for the 2.3 GW wind power base in Tongyu County, the grid connection and wind electricity transmission were not even mentioned in the provincial grid plan.

Due to a lack of coordination around grid planning and power planning, transmission constraints became a fatal factor for local wind power development at the early stages of wind power development in Tongyu. In 2009, the municipal government submitted an application for the transmission project to NDRC. Meanwhile, the municipal government coordinated an investment of 402 million RMB ($58.8 million) across nine wind developers and began construction on the 500 KV step-up substation, which was completed in 2010. Typically, transmission lines and substations are funded by the state-owned grid company. In this case, to expedite the construction and avoid complex procedures, wind developers funded and built the step-up substation.

The municipal government also redoubled its efforts in making Tongyu a center of wind turbine manufacturing. In 2004, the Tongyu municipal government introduced the first wind equipment manufacturer with an investment of 40 million RMB ($4.8 million). In 2008, the municipal government introduced another wind power-related manufacturer with 600 million RMB ($86.4 million) worth of investment. This program was expected to bring tax revenue worth 265 million RMB ($38.2 million), or 13 times the county's tax revenue in 2008 (Hua, 2009). In 2009, Sany Wind Power Industry Park was jointly invested in by the municipal government, Jilin Province Investment Group, and Sany Group (a heavy machine manufacturer). The planned total investment for the park was 10 billion RMB ($1.5 billion) over five years, and products included wind turbines, blades, and tower tubes. The intended market included northeastern China, Mongolia, and Russia.

In May 2012, three years after the application was submitted, NDRC approved for the transmission project. Since the transmission line would pass through one county of Inner Mongolia and several other counties in Jilin, the municipal government directed efforts toward receiving permission from these counties. The Jilin provincial government and central government also needed to work with Inner Mongolia for inter-provincial transmission. After 15 months of coordination, construction of the transmission line began in 2013, and the line was put into operation at the end of 2015 (Tongyu Radio and Television Station, 2015; Ye et al., 2014; Hua, 2009). Since then, transmission constraints have no longer been the main cause of wind curtailment in Tongyu.

Wind power installation in Tongyu County stagnated from 2009 to 2014 because of the lengthy application process and negotiations over the transmission line. As a result, the Sany Wind Power Industry Park was deserted during that period. Despite the fact that the transmission line was made operational in 2015, NEA suspended construction of wind power projects in Jilin due to the severity of wind curtailment in the province. The local government has since begun a new round of negotiation with NEA and NDRC, and has persuaded wind power developers to begin construction.

Factors driving wind power curtailment in Jilin province

The wind curtailment issue in Tongyu needs to be understood within the context of Jilin Province and the northeast region. Jilin's wind curtailment rate surged to 15% in 2011, and remained among the top three nationally from 2012 onwards. The most serious abandonment of wind electricity has occurred in Tongyu, where the average curtailment rate has been above 25%. As shown in Table 4-3, the wind curtailment rate again reached 32% in 2015, as it had in 2012.

Table 4-3: Wind development and curtailment in Jilin province, 2009-2017

	2009	2010	2011	2012	2013	2014	2015	2016	2017
Installed capacity (GW)	1.48	2.21	2.85	3.3	3.77	4.08	4.44	5.05	5.05
Electricity generation (TWh)	2.17	3.32	4	4.4	5.8	5.8	6.03	6.7	8.7
Curtailed electricity (TWh)	NA	NA	0.696	2.032	1.572	1.557	2.7	2.9	2.26
Wind curtailment rate (%)	NA	NA	15%	32%	22%	15%	32%	30%	21%

Source: China Electricity Council, 2015; Wang, 2014; NEA, 2014; 2015; 2016a; 2017; 2018.

Before 2012, the main reasons for wind curtailment in Jilin Province were transmission constraints, system balance problem, and oversupply. In 2012, electricity demand in the province began to slow down, with the electricity demand growth rate dropping from 9.2% in 2011 to 1.1% in 2012. In 2015, absolute electricity demand decreased by 2.4% from 2014.

Transmission constraints

Transmission constraints have long limited wind power development in Jilin Province. As is shown in Table 4-4, new transmission line construction in northeastern provinces (Jilin, Heilongjiang, and Liaoning) lagged behind other top wind curtailment provinces. In 2015, the 201-kilometer-long transmission project to feed electricity from Tongyu to Jilin Grid was completed. In 2016, 583 kilometers of new 550 KV transmission lines and 231 kilometers of new 220 KV transmission lines (not included in Table 4-4) were constructed. In addition, an 800 kV UHV transmission project was approved by NDRC in 2016 to transmit electricity from the northeast region to Shandong Province in the north. The project was to be completed by the end of 2017.

System balance problem

System balance was not well considered in the planning of Jilin's wind development. In addition, the power and heat supply were not integrated into Jilin's energy planning before 2016. In Jilin, the proportion of combined heat and power (CHP) units is very high. Therefore, Jilin Province has very limited units for system balance. As shown in Figure 4-3, hydro power units accounted for 14.4% of total capacity in 2015, and only 3% of these units were used for system

Table 4-4: Length of new transmission lines (330 kV and above; km) in the top wind curtailment provinces

	2010	2011	2012	2014	2015	2016	Total
Jilin	0	52	115	11	201	583	962
Heilongjiang	0	213	190	0	198	41	642
Liaoning	225	402	183	364	274	69	1517
Inner Mongolia	238	165	160	30	491	754	1838
Hebei	0	24	143	555	764	1347	2833
Shanxi	335	267	138	396	152	538	1826
Gansu	2138	653	72	1103	1354	674	5994
Ningxia	371	79	27	47	570	886	1980
Xinjiang	1133	337	0	719	673	1010	3872
Yunnan	394	885	857	136	31	1433	3736

Source: CEC.

balance. Thermal power units accounted for 68.3% of total power capacity in Jilin Province, and 74% was the CHP system.[8] Existing coal-based CHP units cannot be dispatched as peaking power plants due to their inflexibility and the mandatory nature of CHP during the winter (end of October to early April). During this period, wind power curtailment was very common, with the highest curtailment rate reaching 45% in February (shown in Figure 4-4).

Figure 4-3: Power structure of Jilin province at the end of 2015

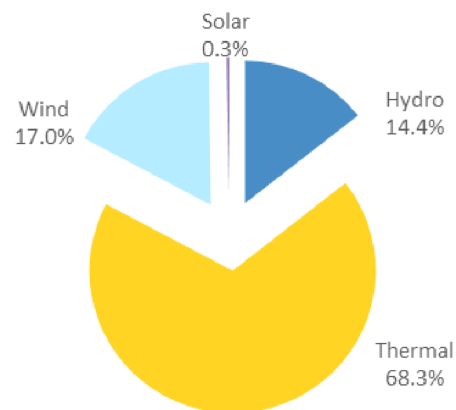
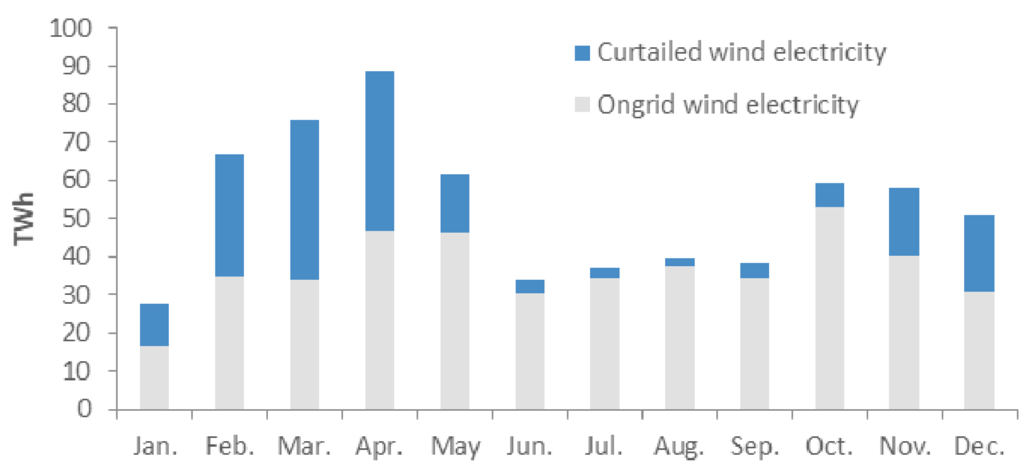


Figure 4-4: Monthly wind power generation and curtailment in Jilin province, 2012



Source: Jilin Energy Bureau, 2016; Zhang, 2014.

8 As heating demand kept increasing in recent years, the back-pressure type CHP units were greatly encouraged by energy-saving and environment policies. This type of CHP unit has economic and environmental advantages; however, the units are inflexible and can't be turned on and off frequently.

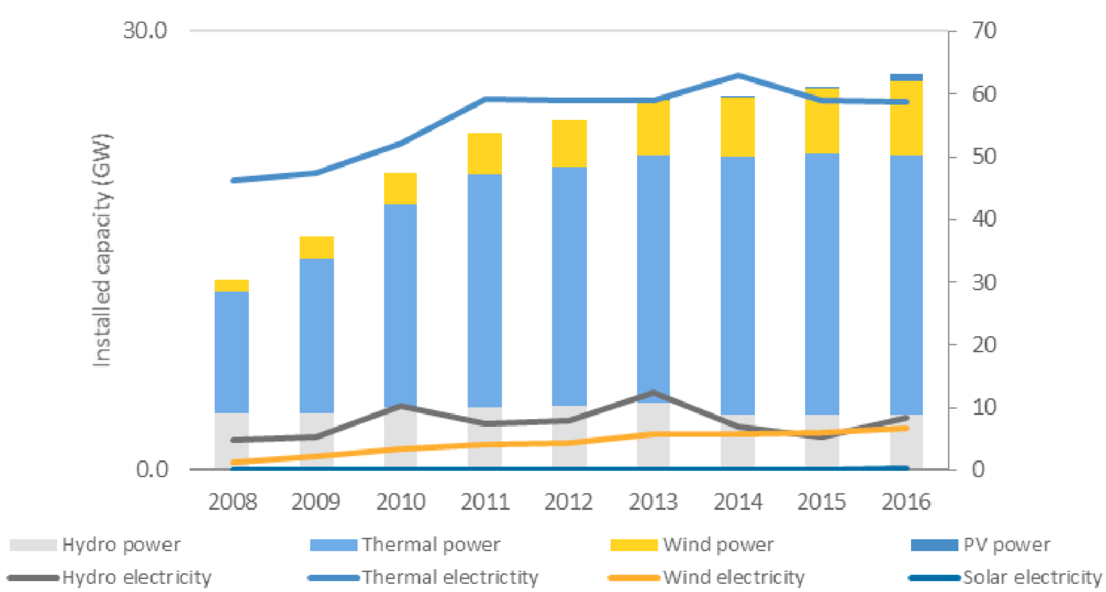
To solve the system balance problem, the Northeast Electricity System Balance Service Market was launched in October 2014. In 2015, wind power generators paid 660 million RMB ($106 million) to coal-fired and other power generators for system balance, and about 5.2 TWh of wind electricity benefited from peak regulation service. In November 2016, a special pilot of the Northeast Auxiliary Power Service Market was launched as an upgrade of the System Balance Market (Northeast Regulatory Bureau of NEA, 2016).

Oversupply

With economic deceleration in Jilin Province, the issue of oversupply in the power sector first appeared in 2010 and became serious in subsequent years. To a great extent, power supply overcapacity was the result of a mismatch between the provincial plan and the national plan. In 2011, NEA assigned a 6 GW target by 2015 to Jilin Province in the 12th FYP for Wind Power Development, while the target stated by Jilin was 14.6 GW in the Jilin Provincial 12th FYP for New Energy and Renewable Energy Plan. Due to the local government's expedited approvals, wind power projects already connected to the grid or under construction had already exceeded NEA's 6 GW target by 2012, or three years ahead of schedule. In response to this rapid development, the NEA has not approved any wind power projects in Jilin Province since 2013 (Zhang, 2014).

Jilin's overcapacity also reflects a lack of coordination in the design of heating, electricity, and system balance policies. In 2015, the installed generation capacity in Jilin Province was 26.1 GW (Figure 4-5), and the maximum generation load of Jilin Grid was only 10.7 GW. The installed CHP units

Figure 4-5: Power capacity and generation from 2008 to 2016, Jilin province



Source: China Electricity Council, 2009-2017.

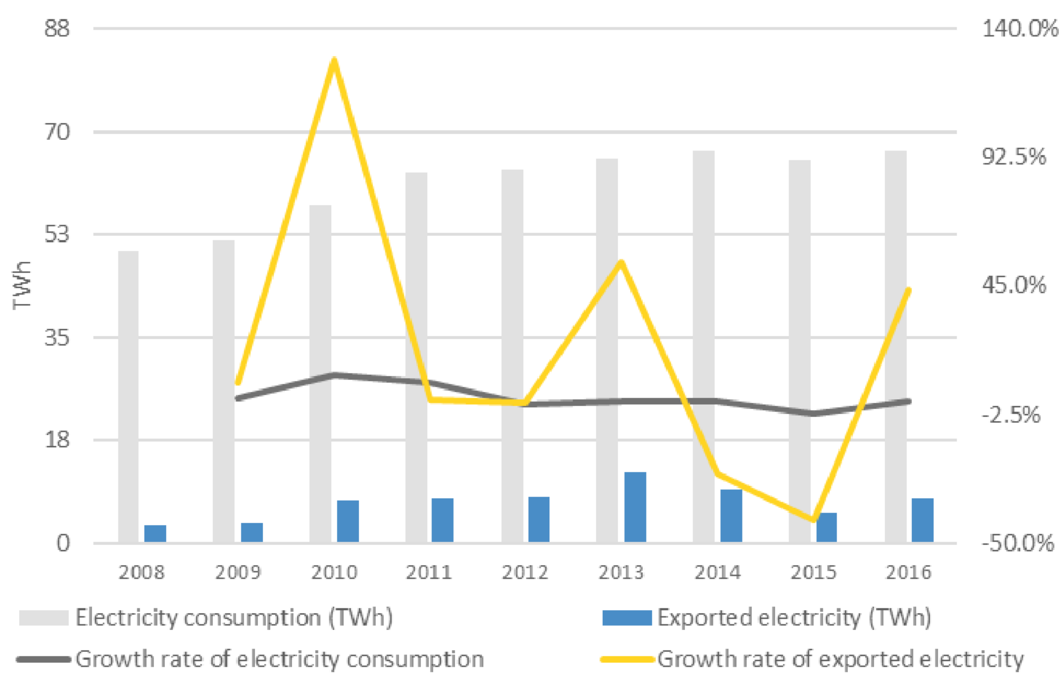
(13.2 GW) alone could fully meet electricity demand in Jilin Province. The CHP units cannot be switched on and off as needed. Thus, with such a large quantity of CHP units, the room left for wind power generation has been greatly compressed, especially during heating seasons.

Decreasing demand

The growth rate of annual electricity demand in Jilin Province was only 2.5% during the 12th FYP period, far below the provincial government's overly optimistic prediction (14.71%).[9] In 2015, the growth rate was negative 2.4% (shown in Figure 4-6). Meanwhile, the load on Jilin Grid dropped quickly: the maximum power load was only 50% of total installed capacity in 2009, and an even lower 35% in 2015.

Among the three northeastern provinces, Liaoning is the load center as well as an electricity recipient. However, the electricity demand in Liaoning Province has decelerated significantly, with a growth rate of only 3% in the 12th FYP period and a negative growth rate in 2015. Meanwhile, Liaoning itself has also had an oversupply of electricity. As a result, exported electricity from Jilin Province has dropped since 2014 (Figure 4-6).

Figure 4-6: Electricity consumption and export in Jilin province



Source: China Electricity Council, 2009-2017.

9 The growth rate can be found in "The 12th FYP for Energy Development and Energy Guarantee System Construction of Jilin Province."

Comparing the two cases

The two cases share common regulatory problems:

Fragmented authority in power project approval

Fragmented authority in wind power project approval (indicated by mismatches between provincial plans and national plans) was the major cause of local oversupply and an intermittent transmission constraint before 2011. In Jiuquan's case, the installed capacity in the first phase was one-third more than planned; in Jilin's case, the provincial target for the 12th FYP period was 2.2 times the target assigned by the national energy plan. Only after July 2011, when NEA included new wind power projects into the annual national wind power plan, were the provincial planning and national planning coordinated.

Lack of coordination between wind power and transmission

Due to the lack of coordination in grid planning during the 12th FYP period, the approval and construction of trans-regional transmission lines in the northwest and northeast lagged far behind that of power projects. For example, State Grid planned three UHV trans-regional transmission lines for Xinjiang in the 12th FYP period; however, only one transmission line was approved and constructed. State Grid also planned the UHV trans-regional transmission line for Gansu in 2010, but the line was only approved by NDRC in 2015. Further compounding the problem, cross-regional electricity export from northeast region was not sufficiently considered in the planning process. Furthermore, wind power planning did not consider generation from other sources, nor did it take into account system balancing or the heat supply needed in winter.

Province-dominated electricity regulation and decisionmaking

The inter-provincial barriers for electricity transaction is caused by province-dominated energy decisionmaking, which tends to protect local economic interests. In Gansu's case, due to delayed approval of the 800 KV transmission project, the recipient provinces built their own power plants and thus became less willing to import electricity from Gansu. In Jilin's case, the regional load center—Liaoning Province—experienced negative electricity demand growth in 2015, thus halting wind power exports from Jilin. Furthermore, inter-provincial barriers have also impeded ongoing electricity market reforms. Regional electricity markets have yet to be established.

Conclusions and policy recommendations

Fragmentation in electric power regulation exists at both the vertical and horizontal levels.

At the vertical level, power regulatory authority is assigned to the central government and the provincial governments. While the central government makes national policies, provinces determine power generation and allocation within their jurisdictions. At the horizontal level, regulation responsibilities are scattered among different ministries or departments of the central and local governments. Decisionmaking authority can be further fragmented within individual ministries or departments. Moreover, state-owned grid companies and generation companies have strong bargaining power under such a system. The scattered functions and confusion in the delegation of power and responsibilities at both central and local governments lead to departmentalism and hamper coordination.

Electric power regulatory fragmentation affects power planning and inter-provincial power transactions. The planning authority is assigned to different government departments and state-owned enterprises, which results in various mismatches of planning both at the vertical level and the horizontal level. This in turn has led to transmission constraints, system imbalances, as well as overcapacity that has resulted in wind curtailment. Furthermore, independent provincial electric power regulation and decisionmaking have created serious inter-provincial barriers to power transactions. Such an institutional arrangement limits power generation and allocation within individual provinces, resulting in sub-optimal wind integration. This is detrimental to provinces hosting national wind power bases. During economic deceleration, inter-provincial barriers also make receiving provinces less willing to take electricity from other provinces, especially when there is an oversupply of locally generated power.

Since 2011, a unified national annual plan on wind power development has helped address the problem of fragmented authority for project approval. In 2016, a unified five-year plan for the whole power sector was issued by NDRC and NEA. The plan put an end to the fragmented planning in various power sources of the previous 10 years. Nevertheless, inter-provincial barriers caused by scattered provincial electric power regulation remain unresolved.

The strongest policy recommendation from this report is to establish regional spot power markets. These markets aim to break the inter-provincial barriers and to achieve broader power system optimization. A regional spot power market is a regional power market only for spot products. Depending on the market, spot products can be daily products (day-ahead), weekend products, half-hour products, or hourly products. To gain the support of local governments, we suggest establishing regional markets for spot products and leaving provincial markets to local governments for medium- and long-term trade.

First, establish six regional spot power markets based on current regional grid divisions. The six regional spot markets follow as: South China, East China, Central China, North China, Northeast China, and Northwest China. NEA and NDRC should take the lead in this mission. To gain support from local governments, provincial electricity markets should retain the role of balancing provincial power units. Regional grid enterprises should be responsible for building power trade platforms, trade organizations, and dispatch centers.

Second, introduce spot products and facilitate the participation of renewable energy in market competition. Regional trade organizations should provide flexible mechanisms on trade declaration, forecasting, and updating for renewable energy. Meanwhile, NEA and NDRC should require renewable energy to provide basic system balance service just as other power units do now. At the early stage, regional spot markets should be responsible for the trade of incremental wind power and other power.

Third, construct a unified regional spot trading system. The regional trade organization should establish interface standards to connect regional and provincial trade platforms. Both intra-provincial and inter-provincial spot transaction service should be provided simultaneously. NEA and NDRC should incentivize market players to increase transaction volumes in the regional market. Moreover, a clear timetable for the gradual exit of planned electricity generation and allocation administration should be formulated by NEA and NDRC. Ultimately, all spot transactions should be conducted in regional markets, and medium- to long-term forward markets can be maintained in provincial markets.

In the long term, China should further proceed with power market reform and build a power market that is friendly to renewable energy, focusing on the construction of auxiliary service trading mechanisms. In accordance with China's resource-based wind power strategy, trans-regional auxiliary service mechanisms should be designed to meet the requirements of large-scale power exports. In this way, the wind curtailment problem can be solved through a mature and complete power market.

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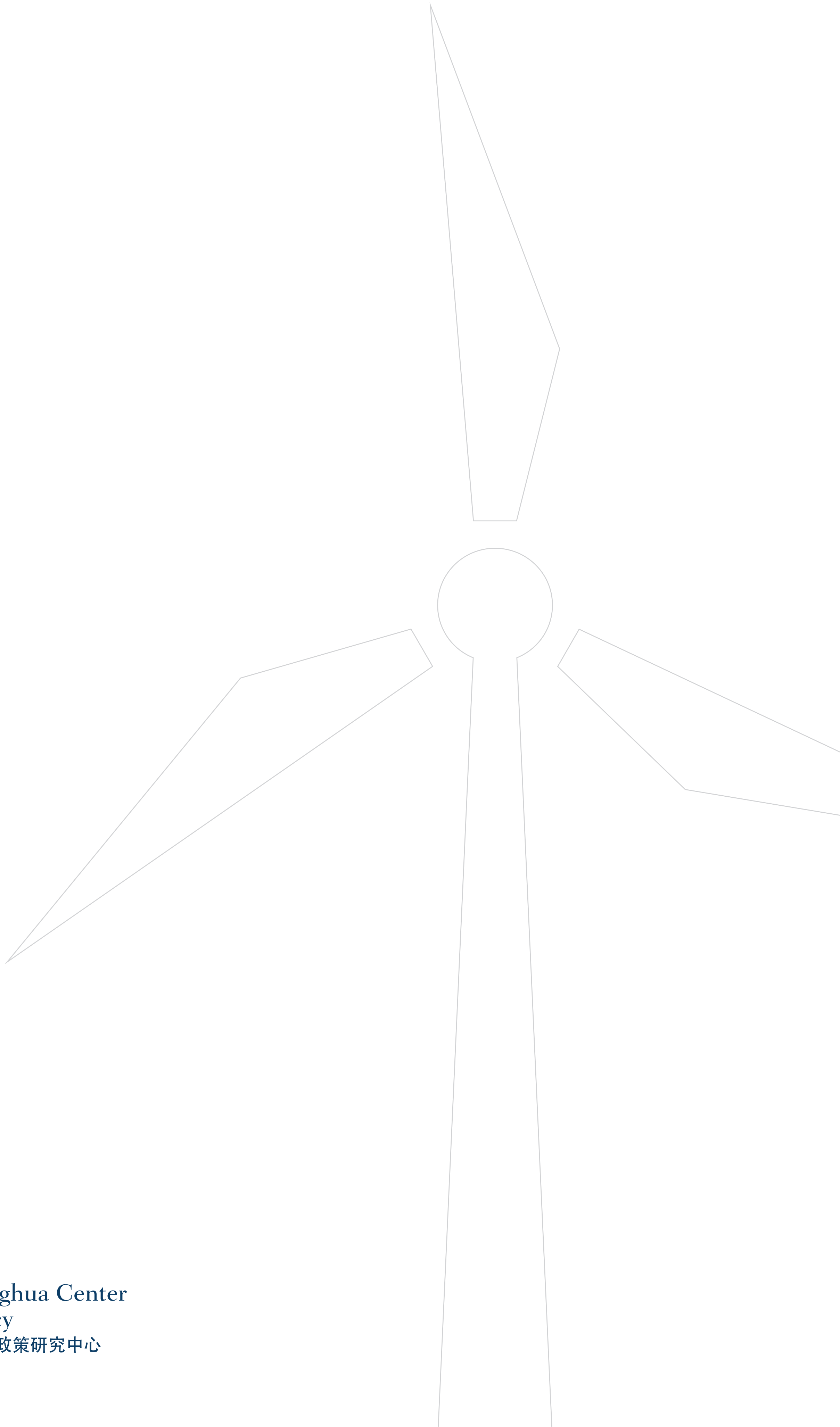

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