Wind Power in China: A cautionary tale

GSI REPORT

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Global Subsidies Initiative

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Executive Summary

Over the last 10 years, China has seen an unprecedented deployment of wind power, with capacity growing from 1.26 gigawatts (GW) in 2005 to 91.4 GW at the end of 2013 (Global Wind Energy Council, 2014).[1] Notwithstanding this impressive growth, the problems encountered have included uneven resource distribution, differing location of supply and demand of power, the need to expand domestic industry and the need to achieve a proper balance of financial supports. These issues have been addressed with some success; however, others persist, such as delay in connection of wind power to the grid and curtailment of generated power from connected farms, and need to be resolved to ensure the success of future wind power development in the country.

This report takes a closer look at the drivers behind the impressive wind power development in China in order to understand the complex connection between the policy goals, policy measures and development impact. In particular, it considers two related issues that have been encountered—curtailment of generation and delays in connection of projects—and how these are being addressed. The report aims to identify the lessons to be learned to inform future policy measures in China and elsewhere.

The analysis finds that there are technical, governance and economic factors that have given rise to these two prominent issues. With respect to delayed connection, the technical factor is that the expansion of national wind power resources has outpaced the construction of transmission. On the governance side, we see that construction plans for wind farms and grids are not aligned, grid construction was not emphasized enough, and there was insufficient state-level oversight and coordination between the national and state levels. Economically, grid operator supports are weaker than those for power development.

With respect to curtailment, there is a mismatch between supply and demand of power. The technical factor here is that curtailment has occurred in areas when growth in power demand has not matched power supply growth, leading to a "spillage" of power. Limited transmission capacity also prevents moving energy from regions of supply to where demand is greatest. Technical issues with ramping up and down conventional coal power (meaning it is slow/difficult to do) also mean that wind is often easier to curtail if curtailment is needed. A lack of integration in governance, similar to the situation in delayed connection, is a contributing factor, leading to delays in identifying and addressing this problem, including through enforcement of regulations. Additionally, at a fundamental level, the government has always targeted capacity as opposed to generation. There are also no economic incentives for grid operators to dispatch wind over other forms of generation to offset operational risks. Fixed payments provide no additional reward for thermal generators to act as reserve to wind or act in a flexible manner to support increased wind power (or at least prevent curtailment).

The government has acknowledged these issues and taken steps to address them. The 2012 White Paper on China's energy policy highlights the need to increase grid capacity. The 12th Five-Year Plan (FYP) also refers to the need to coordinate development of both grid and capacity, and there is a suggestion that the next FYP will address planning, development and integration with the goal of resolving curtailment.

From a technical standpoint, forecasting, load balancing and storage, and increased connectivity are proposed to deal with the issues of connecting energy to the grid and ensuring that areas of supply and demand are properly linked. Strengthened central planning has been implemented to address governance challenges. Reformed economic incentives have also been proposed to address the economic challenges with curtailment and delayed connection. These are all examined in detail in Section 3.

In some ways, China's current challenges with wind power can be considered in terms of the country being a victim of its own success. Capacity has expanded rapidly, and the domestic industry has grown at an impressive rate. Rather than a lack of supply, the challenges of curtailment and delayed connection are issues of getting supply to demand. This could be seen as an enviable problem by many countries looking to expand renewables, but it is a problem nonetheless.

Lessons about governance, technical limitation and economic dynamics can be learned from China's wind power challenges, including:

[1] These figures refer to the total installed capacity, of which some portion may not have been connected to the grid.

Governance

- **System design:** A system of guaranteed run hours provides little incentive for generators to scale back coal generation, while the lack of a system with full costs embedded neglects the environmental impacts of fossil fuels.
- **Incentives for dispatch:** When significant levels of renewable capacity are added to a system, the rules and incentives governing the dispatch of all sources need to be considered and adjusted to ensure that renewables are prioritized, and that these rules are enforced.
- **Target setting:** Setting targets in terms of capacity has helped to fulfill the objectives of wind turbine deployment and facilitated the growth of a turbine industry. However, from an energy and environmental perspective, energy-production targets would give an incentive to ensure that all wind farms are connected to the grid and that all power generated is dispatched.
- **Planning:** Both delayed connection and curtailment problems reflect a lack of effective planning. Development of generation capacity and transmission infrastructure was not effectively co-ordinated, so that capacity additions were not matched by grid development.

Economic

- **Pricing:** In the current system of mandated run hours and prices, thermal generators receive a fixed price for each hour of generation. There is no incentive to provide the services—such as reserve capacity or flexible operation to meet peak demand—that are required to support a high level of renewable generation. A market-based system, where prices are higher at times of peak demand, would automatically provide these incentives, and a two-part tariff, with part of the tariff dependent upon provision of capacity, would help to address this concern.
- **Subsidies:** While the feed-in tariff (FIT) system in China supported the deployment of wind energy, it also encouraged development in the three resource-rich northern regions beyond the level that could be accommodated by the grid. This experience points to a need for subsidy policy to be responsive to changing conditions, such that it does not aggravate problems encountered.

Technical

- **Capacity and infrastructure:** The development of wind power capacity needs to be matched by development of supporting infrastructure. In early stages of penetration this may not be a crucial issue, but in the later stages this matching needs to be carefully considered and planned, especially where there is a mismatch between centres of resource and demand.
- **Linking and expanding balancing areas:** Even where physical interconnections are adequate, the extent to which curtailment can be managed by export outside the balancing areas is limited by institutional structures. Relatedly, expanding balancing areas can facilitate the integration of renewable energy since this smooths the variability of generation, and thus improves the accuracy of forecasting.
- **Energy system viewpoints:** Renewable resources, in particular wind power and solar power, have been considered an add-on to the existing power system, rather than part of the system. For instance, when problems occurred, the "add-on" technologies are expected to adapt (e.g., by curtailing excess production) and not influence the operation of the "normal" power production (i.e., existing thermal power and hydropower). Clearly this is not a long-term sustainable strategy for renewable energy development. It suggests the need to update policies and develop, where not present, an understanding that renewable energy is a crucial component of energy system.

China has already taken steps to address some of these challenges, and the lessons and suggestions above could accelerate addressing the challenges of curtailment and delayed connection. Just as importantly, the issues China has faced, as one of the early global actors on wind power, provide important guidance for other countries and project developers looking to replicate their successes, and limit their challenges, in other countries.

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Acronyms and Abbreviations

CHP	combined heat and power
CNREC	China National Renewable Energy Centre
CWEA	Chinese Wine Energy Association
FIT	feed-in tariff
FYP	Five-Year Plan
GW	gigawatt
IPP	independent power producers
kWh	kilowatt hour
LCR	local content requirement
MMS	mandated market share
MW	megawatts
NDRC	National Development and Reform Commission
NEA	National Energy Administration
PRC	People's Republic of China
SERC	State Electricity Regulatory Commission
SOE	state-owned enterprise
TWh	terawatt hours
UHV	ultra-high voltage

1.0 Introduction

1.0 Introduction

China has become a world leader in the development of wind power over the past decade. A third of total global wind power is now located in China (GWEC, 2016), and the country has been an example of how to rapidly deploy renewables. This report looks into the dynamics that allowed it to occur in such a rapid way, including the policies and incentives that drove expansion and continue to do so.

The report also looks at some of the unintended side effects of this rapid expansion—notably, issues of delayed connection and curtailment. The country has found itself, it to some extent, a victim of its own success. The rapid growth that has made China a world leader in wind power has also created a situation in which this growth cannot be fully leveraged because the wind power available is either not fully connected to the grid, or it is connected but being curtailed by of a lack of demand, or inadequate transmission connection between areas of supply and demand.

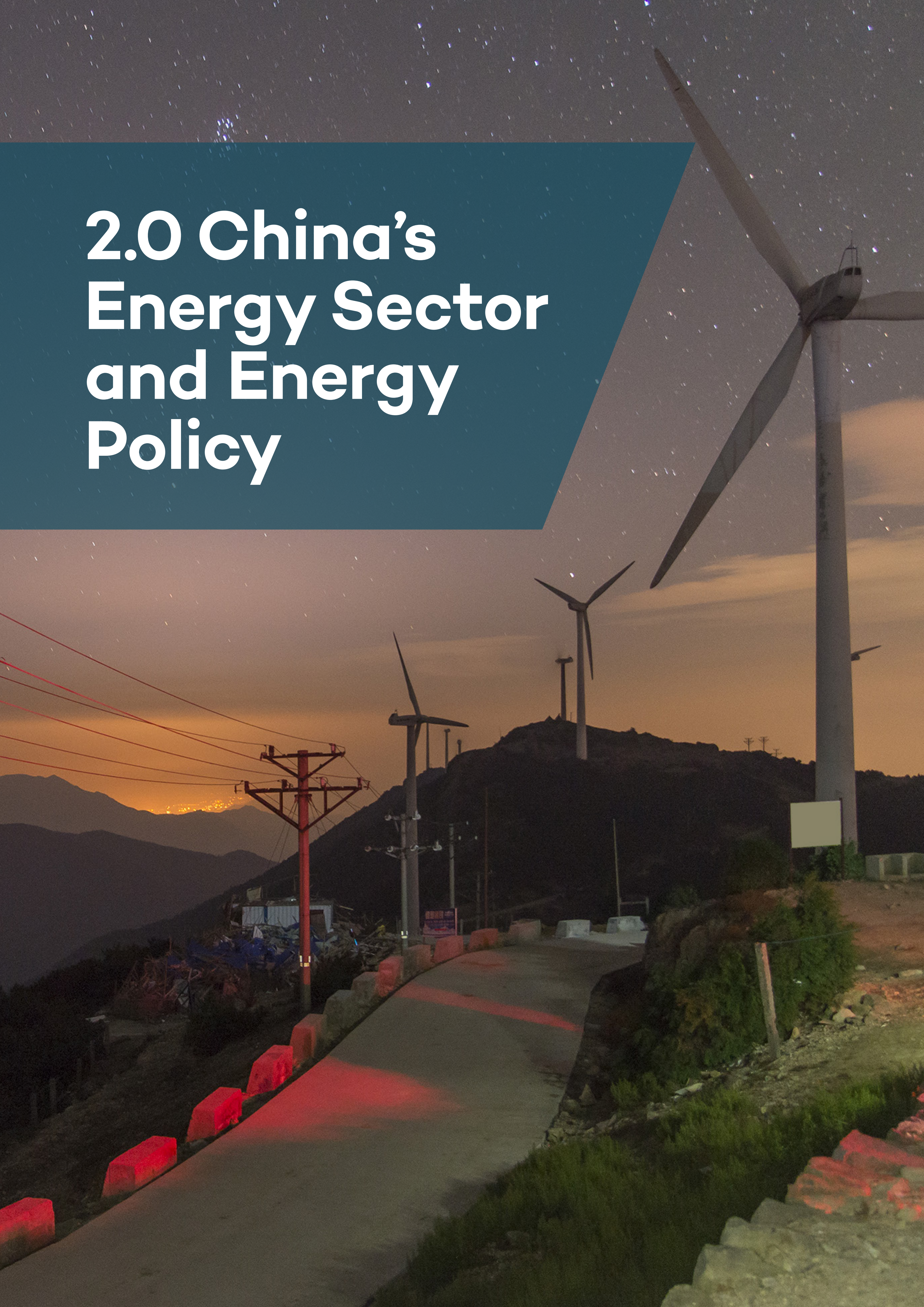
In addition to looking at the positive dynamics that allowed wind power to flourish, the paper also looks at the characteristics that led to these challenges of connection and curtailment.

Finally, the paper looks at some of the ways in which China is addressing the issues of connection and curtailment going forward. The government has taken concrete steps related to technical, economic and governance aspects of these challenges and believes that they can be resolved.

China's story is one where rapid expansion was encouraged and successful, but also shows how rapid expansion can lead to new challenges leading to a need to reform the entire energy system, not just focus on construction of new generation. China is looking at how to address these challenges, which can provide insight for other countries following their footsteps. China's experience shows that caution is needed in the expansion of renewable energy, because even the best intentions can lead to unwanted side effects.

The report is structured as follows. Section 2 gives an overview of the Chinese energy sector and relevant energy policy. Section 3 describes how the Chinese wind power sector has rapidly expanded and identifies the main policy drivers behind this expansion. Section 4 discusses the issues of curtailment and non-connection, including the causes, current status, potential solutions and, finally, lessons learned. The conclusion in Section 5 includes lessons for wind power development.

2.0 China's Energy Sector and Energy Policy



2.0 China's Energy Sector and Energy Policy

2.1 China And Energy Consumption

Since the mid-1980s, energy consumption in China has grown rapidly, and China is now the world's biggest energy consumer, accounting for 23 per cent of total global primary energy consumption in 2014 (BP, 2015). Coal accounts for the majority of China's primary energy consumption (66 per cent in 2014), followed by oil and natural gas (approximately 23 per cent in 2014), with non-fossil fuels accounting for the remainder (National Bureau of Statistics of China, 2015b).

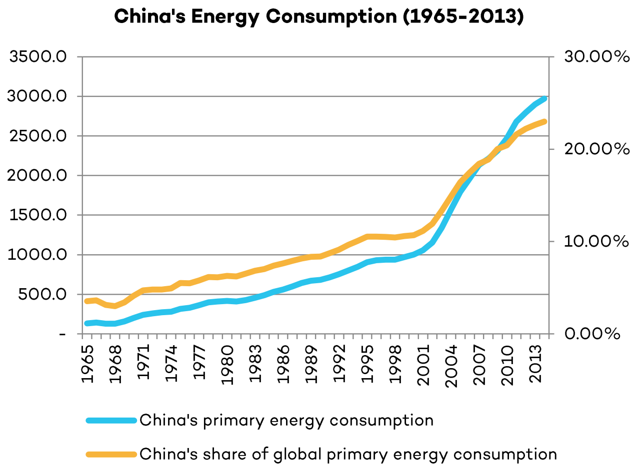


Figure 1: China's primary energy consumption as percentage of the global consumption 1965–2013

Source: BP (2014)

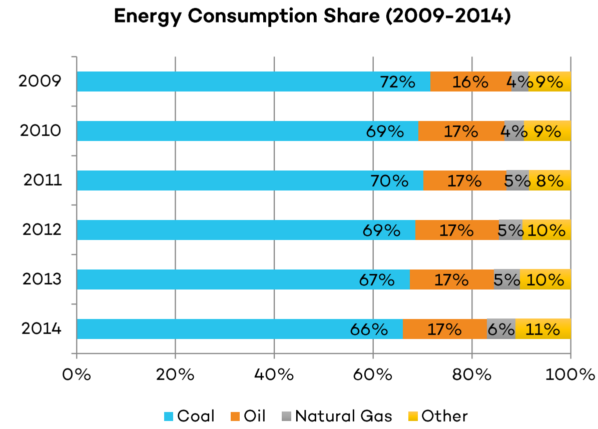


Figure 2: Energy consumption shares 2009–2014

Source: National Bureau of Statistics of China (2015b)

2.2 The Electricity Sector

Reflecting primary energy demand, electricity consumption in China has also grown rapidly, increasing four-fold between 2000 and 2013 (National Bureau of Statistics of China, 2015a). Traditionally, the generation mix has been dominated by coal and hydropower. In 2014 around 76.8 per cent of electricity was generated from fossil fuels (primarily coal), while 4 per cent was generated from sources of renewable energy, including nuclear, wind, solar and biofuel, but excluding hydropower (China National Renewable Energy Centre [CNREC], 2015).

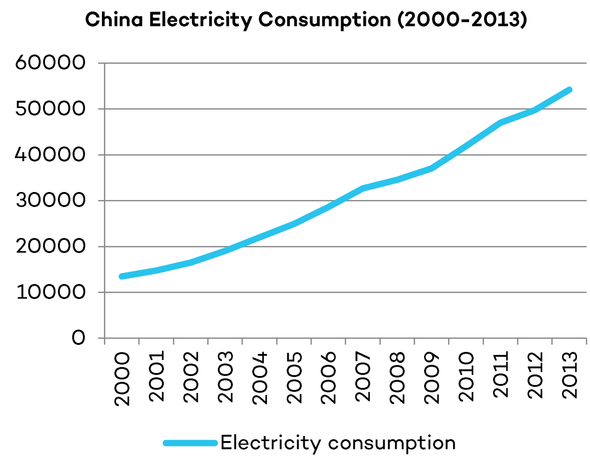


Figure 3: Electricity consumption in China

Source: National Bureau of Statistics of China (2015b)

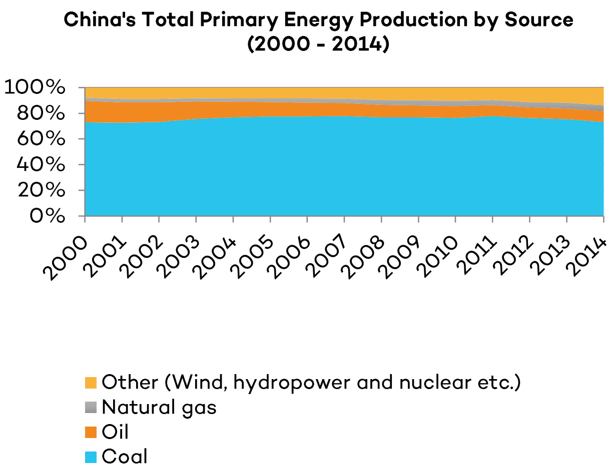


Figure 4: Energy sources in the power generation

Source: National Bureau of Statistics of China (2015b)

The Chinese power sector is dominated by large state-owned enterprises (SOEs). Prior to 2002 the Chinese State Power Corporation held a monopoly in electricity generation, transmission and distribution. Reform measures introduced in 2002 unbundled grid operations from generation assets. Today, five SOEs—China Huaneng Group, China Datang Group, China Huandian, Guodian Power and China Power Investment—account for half of generation capacity, with the remainder being generated by independent power producers (IPPs) (Dupuy, Weston, & Hove, 2015). On the grid side, three companies are each responsible for a number of regional grids (see Figure 5). Of these, the State Grid Company is the largest, operating the power transmission grids of 26 provinces and six regional grids (Northeast China grid, North China grid, Northwest China grid, Central China grid Eastern China grid and the Tibet grid). The Southern Grid Company manages the Southern China grid and handles five provinces in the south while the Inner Mongolian Electric Power Group manages the western Inner Mongolia grid.

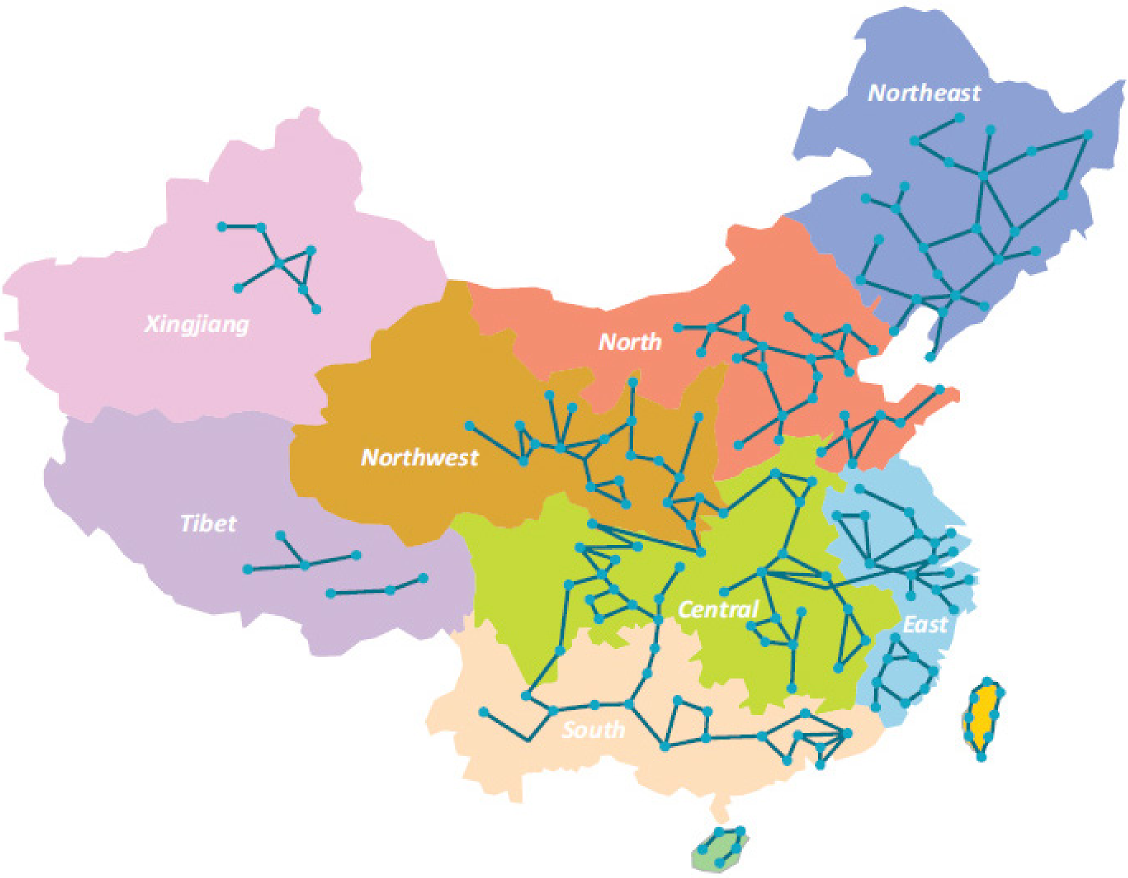


Figure 5: China's regional grids

Source: Wang et al. (2011)

Balancing of supply and demand takes place at the provincial level, with one province representing one balancing area. Trading between the provinces within one region is relatively dynamic, but trade between regions is much more limited (Cheung, 2011). However, the majority of trading (80 per cent) is conducted on the basis of long-term contracts in which prices and quantities are agreed to on a yearly basis, with only a small proportion (20 per cent) being traded on the spot market.

The 2002 policy document envisaged further reforms, including separation of secondary activities, unbundling of transmission and distribution, and creation of a market-based pricing and dispatch system, but these have not been achieved (Li, 2015). Today, the power system is operated according to a series of administrative mandates, with power pricing based on price setting by NRDC and electricity dispatch being based on an equal-share dispatch system that gives similar generators an equal number of guaranteed run hours, and thus a guaranteed return. While giving certainty, this system of mandates has reduced the incentive for generators to increase efficiency or to operate flexibly.

In March 2015 the government issued a new policy document for the power sector entitled *Deepening Reform of the Power Sector*. The document acknowledges some of the outstanding reforms from 2002, stating that power-sector design should be guided by increased use of market mechanisms. In particular, it proposes extending a pilot scheme under which the revenue of the Shenzhen grid company was capped. The new policy would extend this pilot to the entire country, thereby cutting the link between electricity supplied and revenue (Dupuy & Weston, 2015).

2.3 China Energy Policy

Since the foundation of the People's Republic of China (PRC) in 1948, energy policy has been central to economic development, with the aim of ensuring availability of energy to meet the demands of the economy. Before the 1980s the emphasis was on self-reliance, with domestic coal production being the primary source of supply, supplemented by domestic oil production from the Daqing and Shengli oil fields. By 1978 it became clear that China was struggling to meet its energy demands, and that the use of energy that was available was extremely inefficient.

After 1980, a series of Five-Year Plans (FYPs) introduced foreign participation and market forces into the energy sector, with the aim of securing both supply and efficiency in the use of this supply. During this period, coal continued to be the primary source of energy supply. In 1996 coal accounted for 76 per cent of total primary energy supply, oil for 19 per cent, hydro and natural gas for 2 per cent, and nuclear for less than half a per cent (International Energy Agency, 1998).

The 10th FYP, covering the period 2001–05, put in place measures to address this imbalance, emphasizing the development of oil and gas projects and associated infrastructure, while also proposing an increase in the proportion of hydroelectric and nuclear power sources. The plan also acknowledged the growing conflict between the patterns of energy use and sustainable development, emphasizing energy-efficiency measures, and also proposing an acceleration in the development of new energy sources and renewable energy to address environmental concerns (Arruda & Ka, 2003). Subsequently, measures to realize this ambition were introduced, notably through the wind concession program in 2003 and the Renewable Energy Law in 2005 (Information Office of the State Council, PRC, 2007; Xie, 2013).

The 11th FYP (2006–10) further emphasized the environmental (and social) problems resulting from heavy coal use and targets a decline in the share of primary energy consumption from 69 per cent in 2005 to 66 per cent in 2010, as well as a rationalization of the coal sector with smaller and less efficient coal-fired power stations being closed. The share of renewable energy in primary energy consumption was targeted to increase, albeit by just 0.3 per cent, with the focus being placed on technologies with the greatest potential for growth, such that renewable technologies could be commercialized (USC US-China Institute, 2007). Based on these strategies, a reduction in energy intensity of 19.1 per cent was achieved by the end of the plan period, against a targeted 20 per cent (Hannon, Liu, Walker, & Wu, 2011).

By the 12th FYP, economic growth had slowed and environmental damage had become a major political issue. The plan announced a fundamental shift in the economic system, away from energy-intensive and export-oriented industries towards a sustainable growth model based on domestic consumption and service-oriented industrial development (Cornot-Gandolphe, 2014). This shift was reflected in the transformation of the energy system, which prioritized a reduction in emissions from coal through deployment of clean coal technologies, increasing use of gas and renewable energy, and a focus on energy efficiency and energy saving (General Office of the State Council, PRC, 2013a). However, reflecting the dominance of coal in the energy mix and the realities of effecting a transition away from coal, it was acknowledged that coal would continue to be a major part of the energy mix for several decades.

The 12th FYP was followed by an energy White Paper issued in 2012 (Information Office of the State Council, PRC, 2012), which acknowledged the continued role of coal in the energy mix, albeit focusing on the clean and efficient development of projects. However, the White Paper overwhelmingly focused on the development of a clean and efficient energy system to support sustainable economic and social development. This includes the development of renewable energy, both at the centralized and distributed levels, supported by institutional reform.

Box 1: Responsibility for Energy Policy

On the governmental level, the responsibility for the energy sector and energy policy elements are divided on a number of ministries. The National Development and Reform Commission (NDRC) with the NEA attached has the formal responsibility for planning and developing the energy sector, but a number of other ministries are involved in the policy implementation. China also established the State Electricity Regulatory Commission (SERC) in 2002, responsible for enforcing the regulations of the electricity sector and facilitating investment and competition in order to alleviate power shortages. In 2013 SERC was merged into NEA. Besides the two main authorities, the Ministry of Finance is responsible for controlling and distributing all subsidies and funds, and the Ministry of Science and Technology is responsible for promoting technology in the energy sector.

3.0 Wind Power Development in China

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3.1 Deployment of Wind Power

Reflecting the priority given by the government to renewable energy, wind power developed rapidly after 2005. The installed capacity of wind turbines rose from less than 100 megawatts (MW) in 2002 to more than 72 gigawatts (GW) by the end of 2013 (Global Wind Energy Council, 2014). Electricity generated by wind power rose from 28 terawatt hours (TWh) in 2009 to 135 TWh in 2013, resulting in wind generation accounting for 2.5 per cent of national electricity generation. Figure 6 reflects how wind-generated electricity increased between 2009 and 2013.

The emphasis given to wind power over other renewable sources reflects three factors, each of which needs to be considered when reviewing the development of wind power in the country. First, compared to other renewable energy sources, the technology is mature with greater potential to be commercialized (Li, 2012). Second, China has a good wind resource base. Finally, and reflecting both the preceding factors, there was potential for wind energy to be developed as one of the future pillar industries in China (He & Wang, 2004; Zhang, Andrews-Speed, Zhao, & He, 2013).

As a result of rapid development, the target for national deployment has been readjusted from time to time. For example, in 2003, the target was that, by 2020, national installed capacity should reach 20 GW. This target was adjusted upwards in 2005 to 30 GW, again in 2008 to 100 GW, and again in early 2010 to 150 GW. The 12th FYP then proposed that during the period of the plan, the newly installed capacity should reach 70 GW (Su, 2012). Most recently, reports suggest that the government is targeting total installed wind power capacity of 200 GW by 2020 (NEA, 2014d).

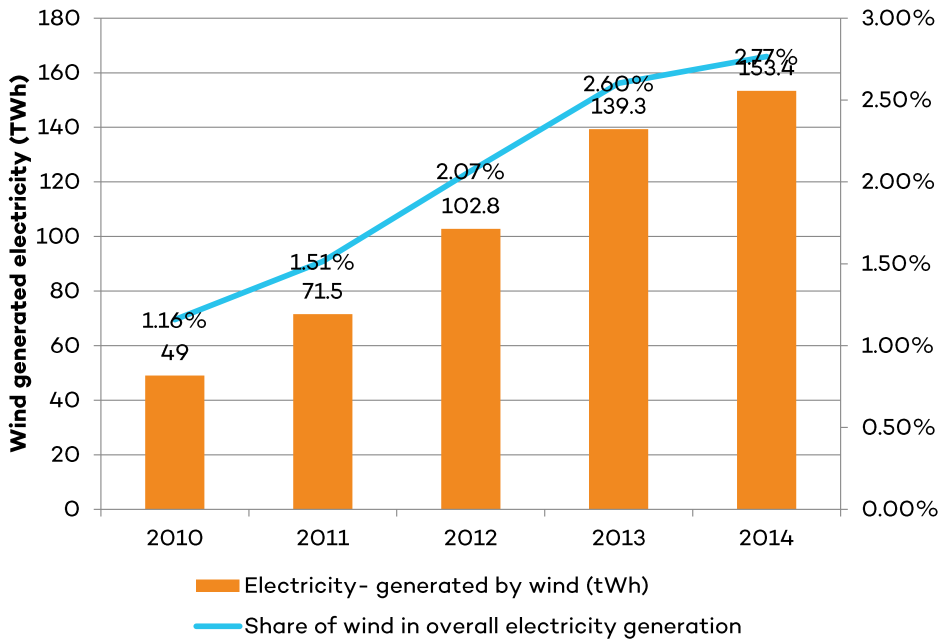


Figure 6: Growth of wind-powered electricity in China 2009–2014,

Source: CNREC (2015)

Wind resources in China are unevenly distributed, being rich in the north and northwest, and poorer in the south and southeast. It is these more resource-abundant regions—Inner Mongolia; Heilongjiang, Jilin and Liaoning in the northeast region; and Ningxia, Gansu and Xinjiang in the northwest region—that have been the focus for the wind power development efforts. By contrast, the centres of power demand are predominantly on the eastern seaboard, creating a mismatch between demand for and supply of power.

Total installed (on-grid) capacity by province is shown in Table 1. Inner Mongolia was the first province to achieve 1 GW of capacity, and today has the greatest installed capacity at almost 18 GW. After 2007 installed capacity grew in the northeast, and today these provinces still have higher levels of capacity than the rest of China. Capacity in Gansu and Hebei is each between 7 and 8 GW, and Heilongjiang, Jilin, Shandong and Xinjiang each have capacity between 4 and 5 GW. After 2009 development spread to the northwest, and then subsequently to the south of the country.

Table 1: Installed wind power capacity (end-of-year) in MW for China's provinces, 2006–2014

	2006	2007	2008	2009	2010	2011	2012	2013	2014
Anhui	0	0	0	0	148.5	297	494	591.5	991.6
Beijing	N/A	49.5	64.5	152.5	152.5	155	155	156.5	192.5
Chongqing	0	0	1.7	13.6	46.8	46.8	104.35	124.05	124.05
Fujian	88.75	237.75	283.75	567.25	833.7	1025.7	1290.7	1556.2	1652.7
Gansu	127.75	338.3	636.95	1187.95	4944	5409.2	6478.95	7095.95	10725.95
Guangdong	211.14	287.39	366.89	569.34	888.8	1302.4	1691.28	2218.88	2758.38
Guangxi	0	0	0	2.5	2.5	79	203.5	360.5	477
Guizhou	0	0	0	0	42	195.1	507.1	1190.1	2001.2
Hainan	8.7	8.7	58.2	196.2	256.7	256.7	304.7	304.7	310.7
Hebei	325.75	491.45	1110.7	2788.1	4794	7070	7978.8	8499.9	9872.4
Heilongjiang	165.75	408.25	836.3	1659.75	2370.1	3445.8	4264.35	4887.35	5527.15
Henan	N/A	3	50.25	48.75	121	300	492.55	647.15	962.85
Hubei	N/A	13.6	13.6	26.35	69.8	100.4	193.9	647.5	1274.5
Hunan	N/A	1.65	1.65	4.95	97.3	185.3	249.25	771.25	1261.25
Inner Mongolia	508.89	1563.19	3735.44	9196.16	13858	17504.4	18623.81	20270.31	22351.31
Jiangsu	108	293.75	648.25	1096.75	1595.3	1967.6	2372.05	2915.65	3676.15
Jiangxi	0	0	42	84	84	133.5	287.5	325.5	642.2
Jilin	252.71	612.26	1069.46	2063.86	2940.9	3564.4	3997.36	4379.86	4652.36
Liaoning	232.26	515.31	1249.76	2425.31	4066.9	5249.3	6118.31	6758.01	7111.11
Ningxia	159.45	355.2	393.2	682.2	1182.7	2875.7	3565.7	4450.4	6144.1
Qinghai	0	0	0	0	11	66.5	181.5	386	595.5
Shaanxi	0	0	0	0	177	497.5	709.5	1292.5	1665.9
Shandong	144.6	350.2	572.3	1219.1	2637.8	4562.3	5690.95	6980.5	7741
Shanghai	24.4	24.4	39.4	141.9	269.4	318	351.95	369.95	686.65
Shanxi	N/A	5	127.5	320.5	947.5	1881.1	2907.1	4216.05	5806.25
Sichuan	0	0	0	0	0	16	79.5	157	442
Tianjin	0	0	0	0	102.5	243.5	278	305	323
Xianggang	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	23196.8
Xinjiang	206.61	299.31	576.81	1002.56	1363.6	2316.1	3306.06	6452.06	9668.06
Xizang	0	0	0	0	0	0	0	7.5	7.5
Yunnan	0	0	78.75	120.75	430.5	932.3	1964	2484	3640.5
Zhejiang	33.25	47.35	194.63	234.17	298.2	367.2	481.67	610.27	970.07

Source: Chinese Wind Energy Association (CWEA, 2012a, 2012b, 2013, 2014, 2015)

3.2 The Chinese Wind Power Industry

Since the 1970s, the government has targeted the development of a Chinese wind turbine industry and displayed constant support (Zhi, Su, Ru, & Zhang, 2013). Realization of this goal has been based on a strategy of importing mature foreign technologies and using these technologies to gradually improve domestically produced turbines, while simultaneously striving to produce major parts and accessories domestically (Li et al., 2007). Policy measures have been implemented to ensure a market for domestically manufactured equipment, most notably local content requirements (see Box 2). As a result, Chinese manufacturers now dominate the domestic wind turbine market, with their market share climbing from 25 per cent in 2004 to 87 per cent in 2009, while the share of foreign manufacturers has fallen from 75 per cent to 13 per cent (see Figure 7).

Two major domestic manufacturers (Goldwind and Sinovel) accounted for 34 per cent of cumulative installed capacity in 2014 (CNREC, 2015). The top five manufacturers (Goldwind, Sinovel, United Power, Dongfang Electric and Mingyang Wind Power)—again, all domestic—accounted for around 60 per cent of cumulative installed capacity. Among the top 20 manufacturers, only four (Vestas, Gamesa, GE and Suzlon) are international manufacturers (see Annex 1 for a full listing). However, this picture is not replicated in the international market, where, in 2014, the largest supplier was Vestas, followed by Siemens, GE and Goldwind (U.S. Department of Energy, 2015). To date, domestic manufacturers have focused on meeting domestic demand, and have been competing on the basis of price rather than quality, reflecting the emphasis given to cost in the early stages of development. As the Chinese industry matures, the emphasis on quality has sharpened, and while turbines are not certified against international standards, domestic certification agencies have been established (International Renewable Energy Agency & Global Wind-Energy Council, 2012). As the quality of turbines improves, further entry into the international market can be expected (De Wilde, Defraigne, & Defraigne, 2012; Kuntze & Moerenhout, 2013).

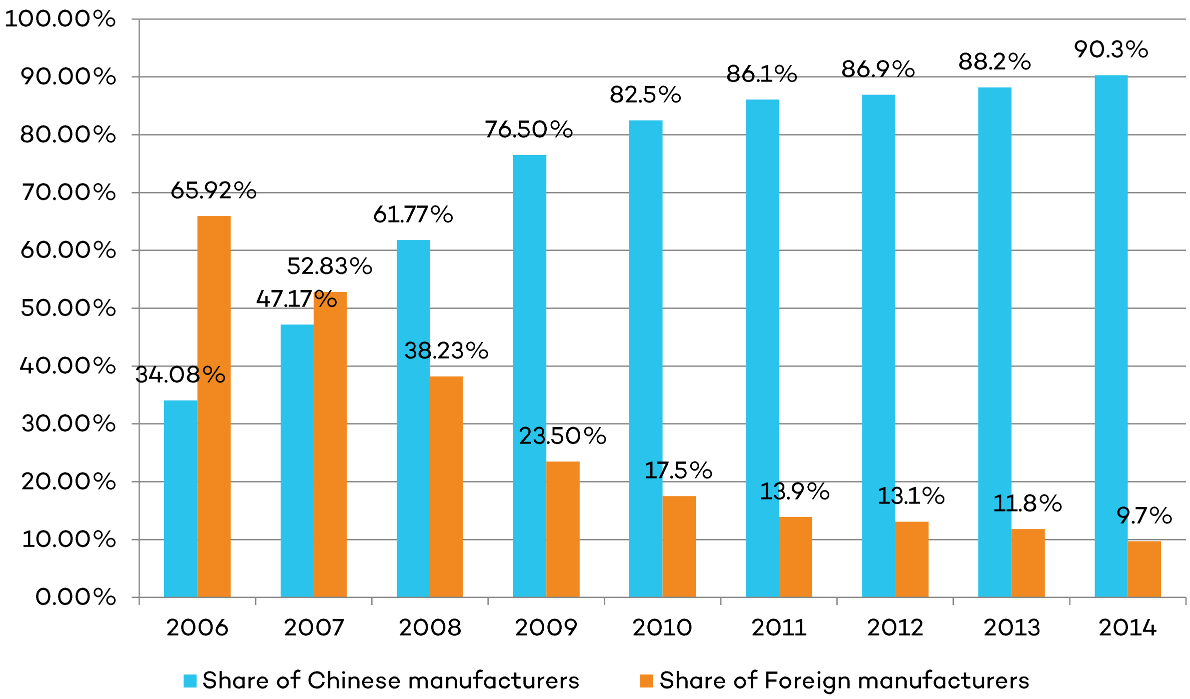


Figure 7: Market share of domestic and international wind turbines, 2006–2014

Source: CWEA (2012a, 2012b, 2013, 2014, 2015)

Box 2: Local content requirements (LCRs)

China has used different types of policies to ensure the development of the Chinese wind power industries. One of the measures requires that parts for the wind project should be manufactured domestically—the local content requirements. The Ride the Wind Program, launched in 1996, stipulated a 20 per cent local content requirement. Subsequently, the Wind Power Concession Program (2003–2009) allocated points for the use of domestically manufactured equipment. Initially, the LCR required local content of at least 50 per cent, but this was increased in 2004 to 70 per cent. The score for complying with the LCR increased from 20 per cent when the policy was introduced to 35 per cent in 2007. Although not obligatory, given that the marks for compliance with the LCR accounted for such a high proportion of total score, it was nearly impossible not to comply with them and still have a successful bid (Kuntze & Moerenhout, 2013). These same conditions applied to projects outside of the tendering system, approved by the NDRC.

The requirements for LCRs were abolished in 2009 (effective as of 2010) when the feed-in tariff (FIT) system was introduced and when the domestic industry had been fully established, with companies covering the whole supply chain and international players coming to set up their manufacturing facilities in China.

Studies suggest that the LCRs were a significant factor in the development of the Chinese turbine industry (Organisation for Economic Co-operation and Development, 2015). However, there were also a number of unintended outcomes. Notably, LCRs acted as a disincentive to importing equipment from more experienced producers overseas, and thus reduced opportunities for continued improvement of domestic turbines, with consequent impacts on quality (Kuntze & Moerenhout, 2013).

3.3 Policy Drivers for Wind Power Development

The wind power industry in China has been marked by rapid growth and a defined shift from international to domestic supply of technology. This section lays out how the Chinese government has been supporting the wind power development through a series of policy instruments, and how these instruments have shaped the current market dynamics. China has gone through three phases of wind power development, before 2003, 2003–2007 and 2008 onwards, each with its own characteristics. A full listing of policy measures is given in Annex Two.

3.3.1 Support Before 2003

The first demonstration wind farms in China were established in 1986 (Li et al., 2007), and in the early phase of wind development small-scale wind demonstration projects were financed primarily by grants from foreign donor countries and loans. Support from the Chinese government was directed at wind turbine development and investment in small wind farm projects.

From 1994 to 2003 the former Ministry of Electric Power supported a wind power industrialization program (Li et al., 2007). During this period the ministry mandated that the grid utility should facilitate grid connection and purchase of electricity generated by wind farms. Guidelines stipulated that the grid tariff was calculated on the basis of power generation costs, loan payments and a reasonable profit. The difference between the wind electricity price and the average electricity price would be shared across the whole grid, with the power company responsible for purchase of the electricity. The State Planning Commission later stipulated revisions in the average electricity price for wind power by basing the calculation on the operational period of the turbines and the loan payment period extended over 15 years. In addition, the value-added tax was reduced by half, to 8.5 per cent, for wind power projects. In 1996 the former State Development and Planning Commission initiated the Ride the Wind program, which encouraged joint ventures for wind turbine and wind farm development and provided incentives for domestic turbine development.

3.3.2 Support Between 2003 and 2007

Between 2003 and 2007, targets and policies focused on capacity growth that simultaneously supported the development of a wind turbine industry. In 2003 the government launched a tender scheme that drove capacity increases, with further targets being set in the 2007 mid- and long-term plan for renewable energy. The legal structures for the development of renewable energy in the country were set out in the 2005 Renewable Energy Law, which prioritized the development of renewable energy and set out the mechanisms for funding this development. While the increasing emphasis given to renewable energy in this period reflects industrial policy objectives (the development of a wind turbine industry), it also correlates with increasing environmental concern in China, particularly with respect to local air pollution.

In 2003 the NDRC launched the Wind Power Concession Program (Li, Shi, & Gao, 2010). Under this program, investors and project developers submitted bids for project development to the government, and provincial grid companies subsequently purchased the electricity generated from the winning projects at the bid price. The concession program resulted in a rapid increase in grid-connected wind farms, with total capacity installed of about 3.35 GW (Li, Shi, & Gao, 2010). The structure and impacts of this program are discussed in further detail in a Global Subsidies Initiative report, which calculates the cost of this measure at EUR 0.94 billion and compares it to the cost of the program, with the average subsidy per kWh being EUR 0.007 (Moerenhout, Liebert, & Beaton, 2012).

Subsequently, the 2005 Renewable Energy Law was approved as the main instrument for renewable energy development in China, with the first implementation rules for the law issued in 2007 (Hou, 2012). The general provisions of the law included obligating utilities to buy renewable energy electricity, setting targets by the government in mid- to long-term plans, establishing FITs and provisional measures for cost sharing, and establishing a special fund for renewable energy development with provisional measures for financing the fund (See Box 3) (Lemaire, Owen, & Song, 2010).

Box 3: The Renewable Energy Fund

As part of the 2005 law, the Ministry of Finance established a Renewable Energy Development Fund to support renewable energy projects. The fund was financed by a surcharge on electricity bills, with the grid company imposing this charge directly on the consumer. Originally set at CNY 0.002/kWh (USD 0.3/MWh), it was raised to CNY 0.004/kWh (USD 0.6/MWh) in 2008.

The revision of the Renewable Energy Law in 2009 saw some changes in the guidelines for the fund. Whereas the original intent of the fund was to provide support to demonstration projects, the amended guidelines allowed grid companies to use the fund to meet the higher costs of purchasing renewable energy and connecting it to the grid (International Renewable Energy Agency & Global Wind-Energy Council, 2012). It also amended the payment mechanism such that consumers paid the surcharge directly into the fund, thus allowing the government to use the fund not only to compensate grid companies, but also to invest in various renewable energy development projects (Finamore, 2010).

However, in recent years the growth in renewable energy has led to a deficit in the fund, with the shortfall reaching CNY 10.7 billion (USD 1.75 billion) in 2011. In turn, there have been delays in payments to project developers and thus to their suppliers (Li, 2015). This surcharge was increased to CNY 0.008/kWh in 2011 and to CNY 0.015/kWh in 2013 to make up for the shortfall, and the Ministry of Finance has supplemented the fund from general revenues.

Targets for wind power development were set in the Mid- and Long-Term Development Plan for Renewable Energy (2007) issued by the National Energy Bureau (NDRC, 2007).[2] This set the national targets for renewable energy development at 10 per cent of total primary energy consumption by 2010 and 15 per cent by 2020, and the targets for wind power capacity at 5 GW by 2012 and 30 GW by 2020. It identified seven areas suitable for GW-level installed capacity: Dabancheng in Xinjiang, Yumen in Gansu, the eastern coastal area around Jiangsu and Shanghai, Huitengxile and another area in Inner Mongolia, the Zhangbei Region of Hebei, and Baicheng in Jilin. Table 2 shows the seven wind power bases with installed capacity in 2010 and the planned capacity for 2015 and 2020 (International Renewable Energy Agency & Global Wind-Energy Council, 2012).

[2] The National Energy Bureau was merged into the National Energy Administration (NEA) in 2008

Table 2: The seven GW wind power bases with installed and targeted capacity

Wind power base	Capacity (GW) 2010 (actual)	2015 (target)	2020 (target)
Hebei	4.160	8.980	14.130
East Inner Mongolia	4.211	13.211	30.811
West Inner Mongolia	3.460	17.970	38.320
Jilin	3.915	10.115	21.315
Jiangsu	1.800	5.800	10.000
Gansu Jiuquan	5.160	8.000	12.710
Xinjiang	-	5.000	10.800
Total	22.706	69.076	138.086

Source: International Renewable Energy Agency & Global Wind-Energy Council (2012)

The plan introduced a number of policies in support of these targets, including favourable price policies, mandated market share (MMS) and government investments. The MMS stated that, in areas covered by large-scale power grids, the non-hydro renewable share of total generation capacity should reach 1 per cent by 2010 and exceed 3 per cent by 2020. Power generators with a self-owned installed capacity of over 5 GW would be required to have a non-hydro renewable capacity share of 3 per cent by 2010 and more than 8 per cent of their capacity by 2020. It is worth noting that the MMS is not dealing with actual production, only the nameplate capacity. Even though the capacity targets include all non-hydro renewable energy technologies, including wind, solar and biomass, the MMS mainly was a driver for wind power development. The plan also set the clear target that the Chinese wind power industry should be developed so that in 2010 the main supply should be from domestic manufacturing.

As wind power capacity and generation increased, and as the policy environment placed increasing emphasis on renewable energy, the issue of priority dispatch came to the fore. In 2007, SERC issued their Measures on Grid Company Full Purchase of Electricity from Renewable Energy (Full Purchase Measures), implementing the provision in the 2005 Renewable Energy Law obliging grid companies to connect and purchase all renewable energy. These measures were followed by a trial efficiency dispatch policy (2007), which—in a break from international practice—aimed to dispatch units in order of level of emissions, with the least polluting plant dispatched first. These regulations were tested in five provinces—Jiangsu, Henan, Sichuan, Guangdong and Guizhou—but were not subsequently expanded to the entire country (Dupuy, Weston, & Hove, 2015).[3] The measures prioritized cleaner energy sources; however, the pilot projects have not solved the more fundamental issues regarding dispatch, particularly the system of full load hours for coal-fired power plants and the need to run CHP plants to ensure heating. Further, technical issues have proven to be a barrier, with grid companies often reluctant to turn down thermal generation in favour of wind due to concerns about the reliability of wind turbines and effects on grid stability and about limited capacity to run thermal plants in a flexible manner to match the patterns of intermittent wind supply. Thus, grid companies have frequently failed to meet the obligations with respect to dispatch, and SERC has proved reluctant to enforce penalties (Zhang & Liu, 2015).

3.3.3 Support Post-2008: Large-Scale Development

By 2008 the domestic turbine industry was mature enough to support the development of wind farms in the country, and a process of scaling up and large-scale development began. This was supported by revisions to the Renewable Energy Law and the introduction of FITs, both implemented in 2009. Official policy documents placed increasing emphasis on the role of renewable energy, with the White Paper on energy, China's Energy Policy 2012, and the 12th FYP, envisaging a central role for these technologies. On the one hand, this reflects

[3] Full ranking is: (1) wind, solar, ocean and (un-adjustable) hydro; (2) adjustable hydro, biomass, geothermal and solid waste; (3) nuclear; (4) coal-fired combined heat and power (CHP) units that supply district heating services; (5) natural gas and coal gasification-based combined cycle; (6) other coal-fired units and co-generation units that are not supplying district heating; and (7) oil-based generation units.

industrial ambitions for the country, but it also corresponds with concerns about energy security and, in particular, growing concern with respect to local air pollution (General Office of the State Council, 2013c; NDRC, 2008).

On December 26, 2009, China introduced the Amendment to the Renewable Energy Law (2009). This amendment strengthened national oversight in the development of subnational renewable energy plans (Articles 8 and 9), although there was little detail on how this provision would be implemented (Eisen, 2010). It also amended Article 14 in an attempt to address the problems encountered with the connection and dispatch of renewable energy projects. While the underlying provision remained the same, the amendment added more detail and process to the requirement of priority dispatch and full purchase by mandating the promulgation of an annual regulation governing the priority dispatch and purchases of renewable power (McElwee, 2009). Further, greater force was given to the provision by the requirement that the State Council and the national electricity regulatory bodies jointly determine and enforce the allocation of renewable energy electricity as a percentage of total electricity generated. Second, stricter penalties were applied to grid companies that failed meet their purchase obligations, with failure to comply by specified deadlines attracting a fine of up to double the amount of economic loss. Supporting measures included the requirement for grid companies to develop their capacity to connect and dispatch renewable energy through deployment of technologies such as smart grids and improved management of the power grid.

Also in 2009, the NRDC issued the Notice on Improving the Pricing Policy for On-Grid Wind Power Prices. This notice marked the end of the system of wind power concession projects, and the introduction of National FITs for wind power, a decision that has been attributed to a desire to increase the transparency of wind power pricing mechanisms and promote the development of renewable energy with economic incentives. Under the FIT, the country is divided into four regions, each with a different tariff, with areas with a strong wind resource receiving a lower tariff (see Figure 8). The grid companies pay the average coal-power price to purchase wind power, with the gap between the coal price and the wind price being reimbursed out of the renewable energy fund, which is in turn funded by a surcharge on the consumer (see Box 1).

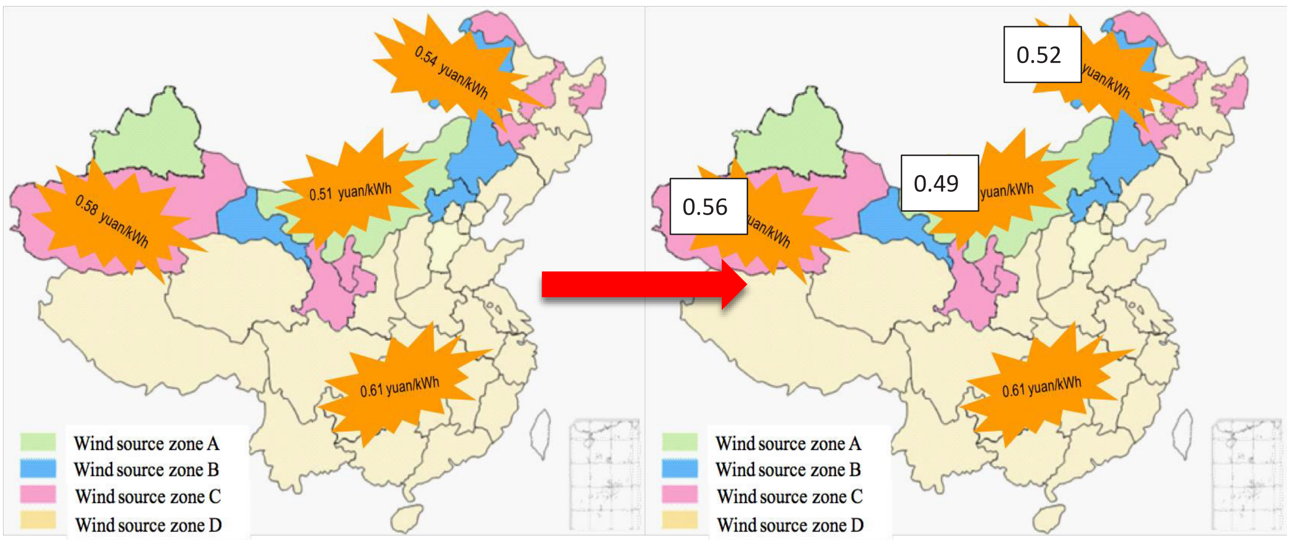


Figure 8: FIT zones in China, introduced in 2009 (Left) (Jiang, et al, 2011), FIT zones in China, 2015 (Right) (NDRC, 2014f)

The 2009 level of FIT for wind power was set to mainly reflect the production cost at that time, yet the production cost has largely decreased ever since. Meanwhile, the government faced an increasingly heavy financial burden as wind power generation also soared. As a result, by the end of 2014, NDRC announced that the level of FIT for wind power (introduced since 2009) would be lowered as of 2015 (NDRC, 2014f). Except for Zone IV, the FIT for the remaining three zones will each decrease by CNY 0.02 per kWh (Figure 8).

The importance attached to renewable energy in China was reflected in the 12th FYP (see discussion above). The plan focused on higher-quality growth that took issues of sustainability into account and envisaged a reduction in the energy and emissions intensities of economic production, supported by an increase in energy efficiency and renewable sources. Targets were set at reducing energy intensity by 16 per cent, and increasing non-fossil energy sources (including hydro, nuclear and renewable energy) to 11.4 per cent of total energy use by 2015 (KPMG China, 2011). Targets for onshore wind-energy capacity were set at 100 GW by the end of 2015 and 200 GW by 2020, with large wind power bases contributing 79 GW by the end of 2015 and 169 GW by the end of 2020 (CNREC, n.d.). The plan also emphasized supporting infrastructure, targeting the development of smart grids and investment in power infrastructure (KPMG China, 2011).

Information that has been released about the 13th FYP (covering the 2016–2020 period) suggests that green development will be fundamental. Proposals released to date refer to an energy revolution, with an increase in renewable energy sources such wind being a major pillar of this revolution (Xinhuanet, 2015). With respect to wind power, the government aims to increase capacity to 200 GW by 2020 and lower the price of wind-generated electricity to be as competitive as the price of coal-powered electricity by 2015 (NEA, 2014d). Further, in the released proposals, the government has committed to dealing with the issue of curtailment of wind power.

3.3.4 Summary of Policy Measures

Figure 9 shows the development and the timing of the different policy drivers for wind power development against total installed capacity. In general, wind power development in China has been a great success: China is now the biggest wind power country in the world: renewable energy covers more than 20 per cent of total electricity consumption and the targets for wind power deployment have been adjusted upwards several times during the last 10–15 years (National Bureau of Statistics of China, 2015b).

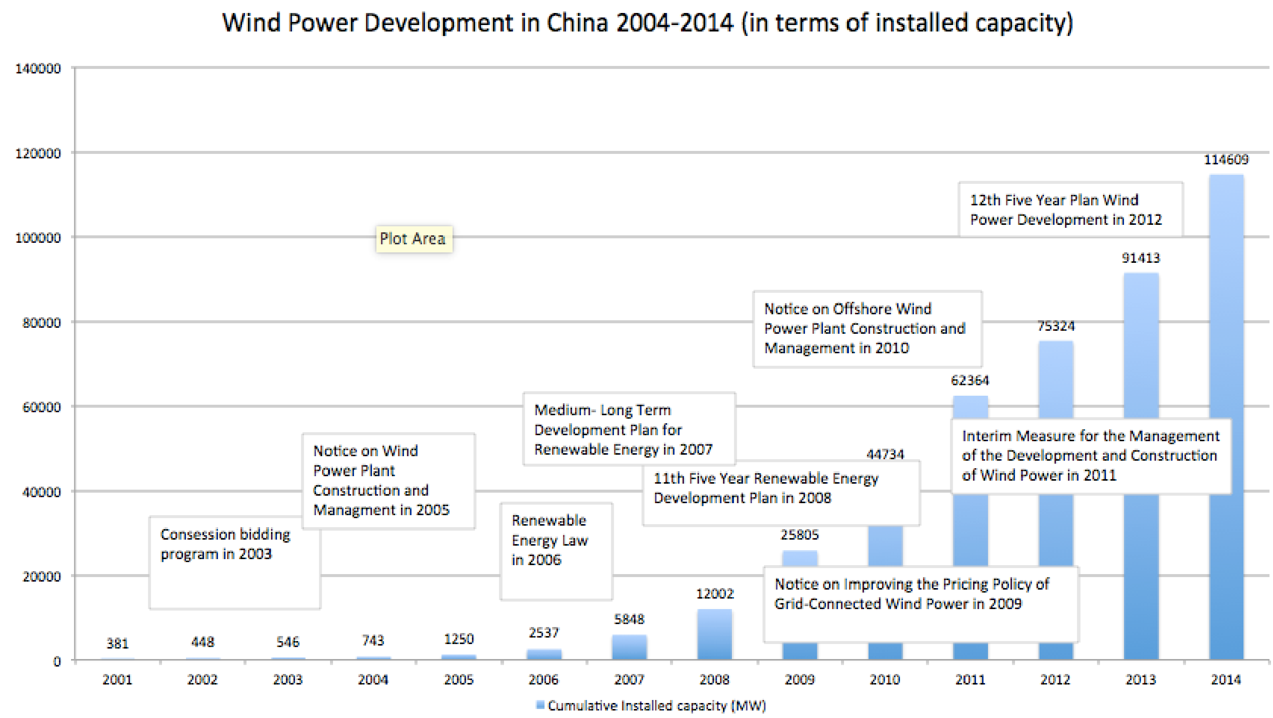


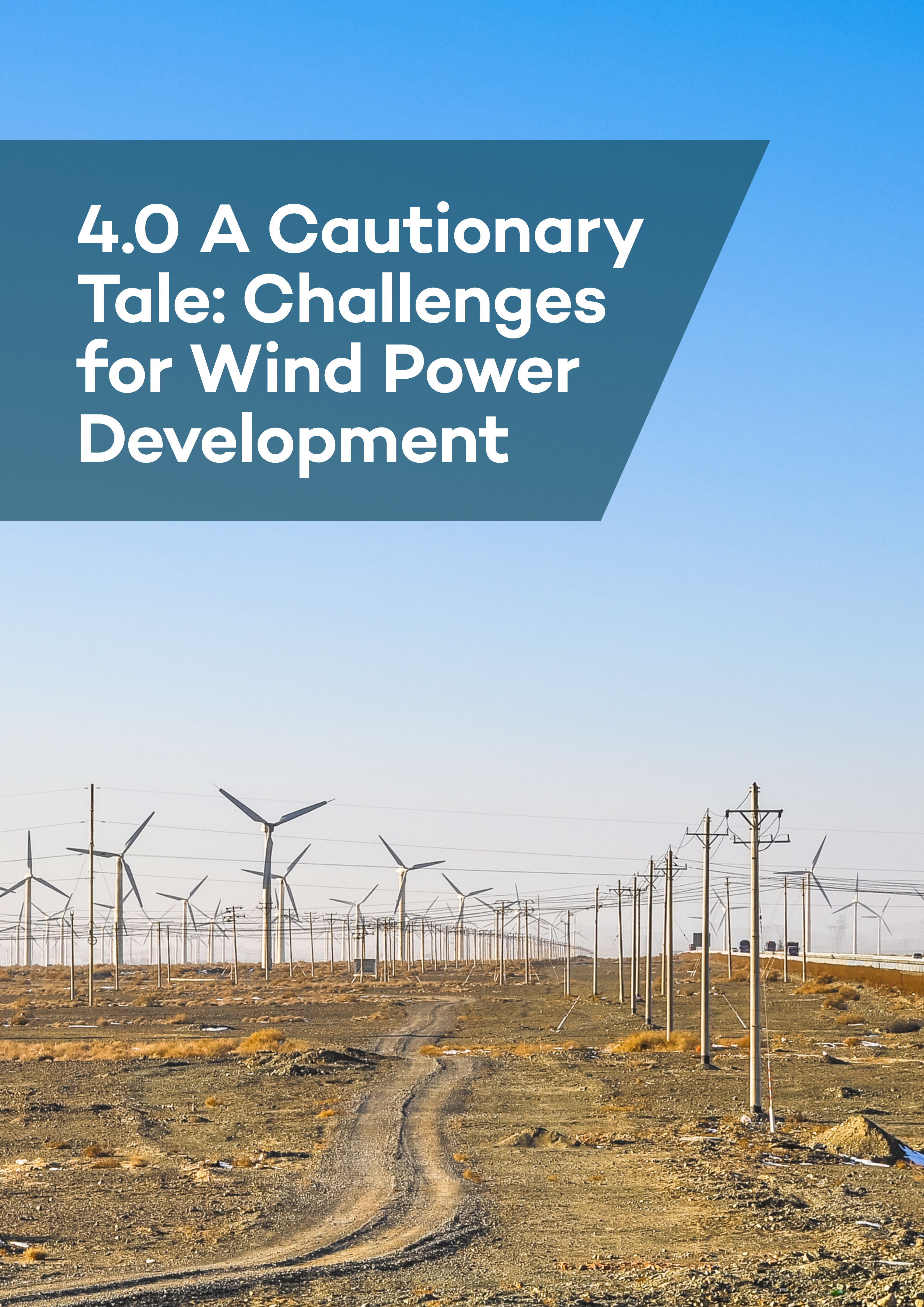
Figure 9: Support measures and wind power development, 2001–2014

Source: CWEA (2015); Li (2015)

This growth has been driven by a combination of government energy policy, environmental policy and industrial policy, with three main identifiable policy phases. Prior to 2003 deployment was limited, focusing on demonstration projects, and as such there was little impact on the broader electricity system in terms of system requirements. Even in these early stages, policy was focused on the development of a turbine industry, unconstrained by strict technical standards. Between 2003 and 2008, policy focused on capacity growth with the main measures adopted including the Renewable Energy Law and the Concession Bidding rounds, which ensured a market for the fledgling turbine industry. Despite the growth in capacity, the grid remained sufficiently robust to avoid technical problems with the connection and operation of wind turbines. From 2008 the Chinese wind industry was sufficiently developed to be able to cover the domestic market, and deployment was accelerated, supported through a system of FITs.

Despite these gains, challenges to the industry emerged. These problems are the focus of the remainder of this report. As capacity expanded dramatically, technical constraints with respect to grid operation became more acute and problems with curtailment and delays in connection of wind farms to the grid began to occur. These issues are explored in detail in Section 4.

4.0 A Cautionary Tale: Challenges for Wind Power Development



4.0 A Cautionary Tale: Challenges for Wind Power Development

While wind power development in China has been a great success, rapid development has created a number of challenges, which are not only a problem for existing wind farms, but could also adversely affect future wind power development. Here, we consider two of the most pressing challenges to have emerged in recent years: delayed connection of wind farms to the grid and curtailment of power generated from connected wind farms. We describe these related phenomena, identify underlying reasons for their occurrence, and discuss the measures taken to correct them and the likely success of these measures.

4.1 Identifying the Problem

The two issues of delayed connection and curtailment are similar in the sense that potential electricity from wind farms is not distributed, but the cause of each is different. Curtailment is generally taken to mean that the dispatch centre reduces production from the wind farms to a level below the maximum possible production at a certain time. On the other hand, delayed connection occurs when the wind farm has been constructed but not connected to the grid in a timely fashion and hence is not able to provide power, although it could if connected.

4.1.1 Delayed Connection

The process from installation of a wind farm to commercial operation includes both physical connection and an electricity generation grid compliance test. After successful testing, the wind farm can go into commercial operation. Normally the process from finished installation to commercial operation takes 3–4 months (Li, Shi, & Gao, 2010), thus some delays between finished installation and commercial operation will always occur, even with high levels of planning and coordination.

However, with the rapid development of new wind power capacity in some of the provinces in China, more significant delays between completion of construction and grid connection started occurring. Figure 10 shows an increase in non-connected projects from around 18 per cent of all installations in 2006 to 35 per cent in 2010 with a subsequent decline back to 18 per cent in 2013. Further estimates for 2014 based on NEA data place non-connection at just under 12 per cent (Koch-Weser & Meick, 2015).

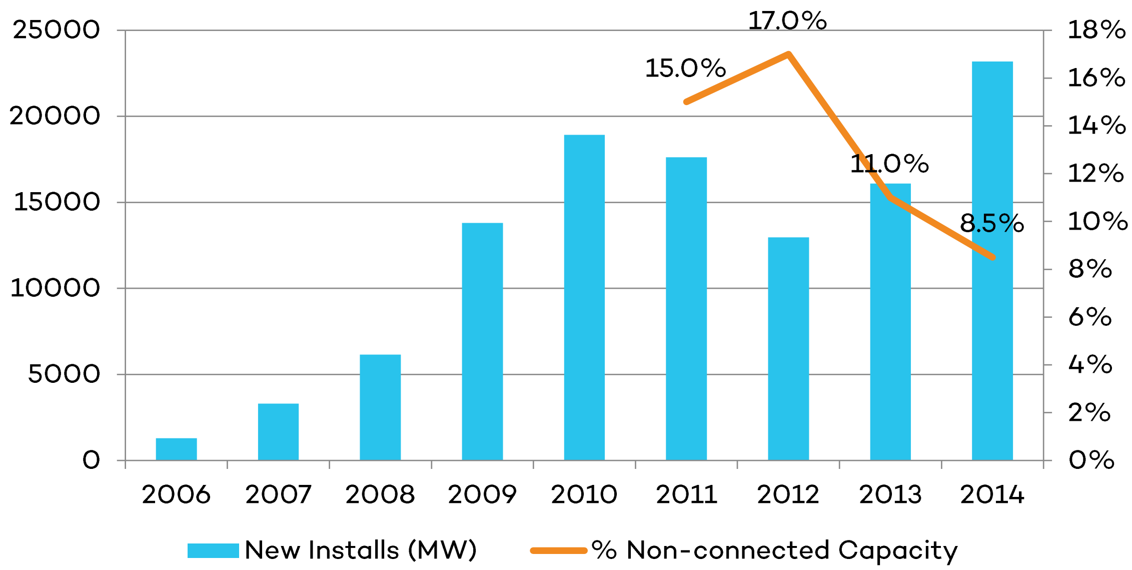


Figure 10: New installed wind power capacity and non-grid connected capacity (GW), 2006–2014.

Source: CWEA (2015); CNREC (2014)

4.1.2 Curtailment

The Renewable Energy Law (2005) stipulated that the power grid operators shall "buy all the grid connected power produced with renewable energy within the coverage of their power grid, and provide grid-connection service for the generation of power with renewable energy" (Liu, Zhang, & Xu, 2013). This provision was revisited in the 2007 Measures on Grid Company Full Purchase of Electricity from Renewable Energy (Full Purchase Measures). In the 2009 amendments to the Renewable Energy Law, full purchase and priority dispatch were given further emphasis, essentially prioritizing renewables over other forms of energy, with the promulgation of an annual regulation governing the priority dispatch and purchases of renewable power mandated, and with penalties for non-compliant grid operators strengthened.

Despite these measures, curtailment has emerged as a significant problem, with grid companies frequently curtailing wind power when local grids cannot accommodate all the incoming electricity or easily transmit the electricity surplus to adjacent grids (Zhang & Liu, 2015). Reports suggest that large-scale curtailment was first observed in Inner Mongolia in 2009, and spread nationwide in 2010. Rates subsequently increased through to 2012 before dropping off in 2013 and 2014, and then increasing again in the first half of 2015. Measuring curtailment is difficult since, once turbines are slowed or halted, it is difficult to reconstruct what the wind power production would have been otherwise (Davidson, 2014b). However, estimates suggest that losses associated with wind power climbed from 7 per cent in 2010 to 14 per cent in 2011 and 17 per cent in 2012, before falling to 10 per cent in 2013 and 8 per cent in 2014 (Song, Dong, Zhu, Zhao, & Wang, 2015). Data from the first half of 2015 suggests a rise to 15.2 per cent with eight provinces having wind curtailment rates higher than 10 per cent (NEA, 2015a).

Reflecting the concentration of wind farms within certain regions, the severity of the curtailment problem differs from region to region. As shown in Figure 11, curtailment rates are highest in the three northern regions, with rates of 18.43 per cent in Inner Mongolia (East), 15.74 per cent in Jilin and 14.8 per cent in Xinjiang reported in 2014. These regions alone were responsible for around 70 per cent of the national curtailment.

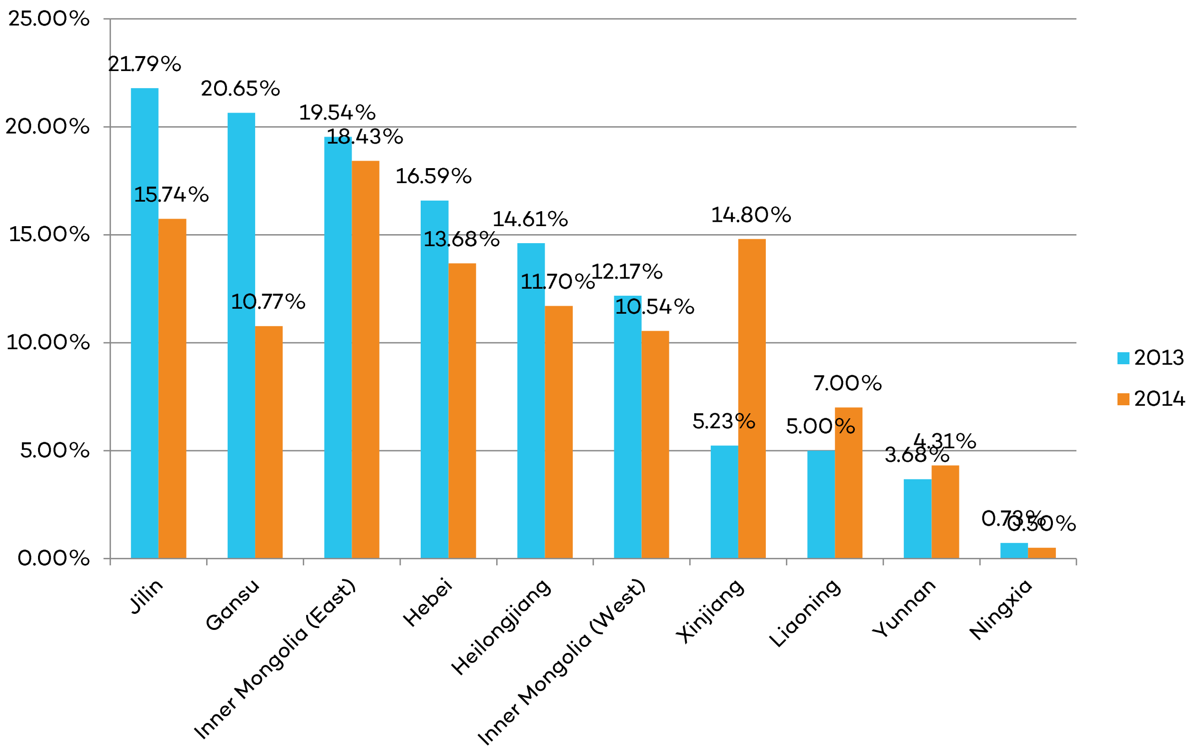


Figure 11: Curtailment by province

Source: CNREC (2015)

Because comparable data is not readily available, direct comparison of curtailment rates across countries can be difficult, but the scale of curtailment at relatively low levels of wind penetration is a problem that is rarely encountered. For example, in spite of wind power accounting for approximately 40 per cent of total power demand in Denmark, less than 0.5 per cent of wind power was curtailed in 2014 (Traehoelt Franck, 2015), as the infrastructure and market arrangements support export to neighbouring countries (Lew, et al., 2013). International experience also shows that there are solutions to the problem of curtailment. In Texas, where wind penetration rates are approximately 8 per cent, the system operator successfully reduced curtailment rates from 17 per cent in 2009 to less than 4 per cent in 2012, by implementing transmission line upgrades and reforming the design of the wholesale market (Wiser & Bolinger, 2013). Similarly, declines in curtailment have also been achieved in Italy through transmission system upgrades and investments in battery storage (Lew, et al., 2013)

4.2 Reasons for Delayed Connection and Curtailment

In both cases, the rapid pace of Chinese wind power development can be considered a proximate factor, since developing the grid in line with the growth in capacity and subsequently integrating the high levels of power generated has proved challenging. Furthermore, the disconnection between location of resources (and therefore wind farms) and demand created further problems of synchronizing grid and generation capacity.

4.2.1 Delayed Connection

The reasons for delayed connection can be categorized as related to either technical, governance or economics. On the ***technical*** side, the rapid deployment of wind power—often at rates much higher than anticipated—has meant that it has become difficult to construct the grid and make connections at the rate required. The speed of constructing grid connections is much slower than the speed of building wind farms (Zhang, 2014). While it usually only takes half a year to build a wind farm with a capacity of 200 MW, it might take more than year to build the necessary transmission infrastructure (State Grid News, 2013b).

Three factors relating to ***governance*** can be identified. First, at the state level, the construction plans for grid and wind farms are frequently not aligned. While the government has been clear about its target of speeding up wind power capacity installation in the 12th FYP, the importance of grid construction was not well addressed in the plan, nor was there any specific grid development plan (Zhang, 2014). Furthermore, there is no state-level entity overseeing both the issues of wind farm construction and associated grid development. Rather, the government has viewed the development of the industry in a fragmentary fashion, allocating different ministries to take charge of different aspects of the industry, with subsequent co-ordination problems.

In another manifestation of co-ordination problems, the permitting process for planning and constructing wind farms was, until 2011, split among different agencies, depending on the size of the wind farm. Projects with a capacity of over 50 MW were approved by NRDC, whereas smaller projects were approved by local authorities, and could therefore avoid the more stringent feasibility reviews, including those related to grid access (Davidson, 2013). Furthermore, the dual level of approval impaired the ability of the central government to plan for timely grid expansion and development, thereby compounding problems of delayed connections (Dent, 2014).

On the ***economic*** side, the developers receive subsidies for generated power; the incentives for grid operators to connect these wind farms are much weaker, despite the often significant cost of connection (Zhang, Davidson, Gunturu, Zhang, & Karplus, 2014). Further, the system of geographically based FITs has encouraged development in the resource-rich area of the north beyond the level that can be readily connected.

4.2.2 Curtailment

Curtailment is fundamentally due to a mismatch between supply of power and demand for this power. The power system in China is constrained in the extent to which it facilitates and incentivizes the dispatch of localized wind power ahead of other sources of power, with the result that excess wind generation is spilled.

Underpinning this mismatch, there is a range of factors that we consider under three headings: technical, economic and governance.

On the ***technical*** side, curtailment has occurred primarily in the less developed regions of the country—namely the northern provinces of Gansu, Inner Mongolia and Jilin. In these provinces, growth in power demand has not kept pace with growth in power supply, meaning that excess generation has to be exported or curtailed. However, export of power to the centres of demand in the south and the east of the country is restricted due to limited transmission capacity, and lack of flexibility in the processes and agreements governing the transmission of power between regions (Sandholt, 2015b). Trading is generally based on long-term contracts, which stipulate quantities and prices, and is therefore of little assistance in ensuring dispatch of renewable energy. Improving the physical and institutional capacity to dispatch power between provinces—or expanding balancing areas—could help to alleviate the level of curtailment.

With export capacity limited, and absent any feasible large-scale storage solutions, dispatchers need to curtail power.[4] In theory, they could choose whether to curtail wind generation or fossil fuel generation with legislation supporting the curtailment of the latter. However, for a range of reasons, dispatchers continue to dispatch thermal sources and curtail wind sources. On the technical side, this reflects a lack of flexibility in operation—a system with a high level of intermittent generation sources needs to be supplemented by responsive back-up sources of power, which can be turned up and down depending upon availability of renewable resource and thus renewable power. By contrast, coal-fired power stations in China are relatively slow to ramp up and ramp down, which limits their flexibility, although these problems have been overcome in other countries through minor investments and training (Sandholt, 2015b; Traehoelt Franck, 2015). Further rigidities occur since CHP units not only account for a large proportion of generation but also provide district heating and therefore—unlike wind generation—cannot be easily turned down. Replacing these CHP units with wind generation facilities will require significant levels of installation, although pilot projects aimed at this have been implemented.

Also on the technical side, reports suggest that dispatchers frequently turn down wind power out of concern that it will destabilize the grid and lead to operational disruptions. On the one hand, this may reflect limited flexibility of the power system. However, reports also suggest that concerns about the reliability of the (predominantly domestically manufactured) wind turbines also lead grid operators to curtail wind power (Koch-Weser & Meick, 2015). In turn, curtailment reduces the incentive of project developers to emphasize quality and reliability in their developments, reinforcing the cycle of curtailment. And, as described below, there is a range of other governance and economic factors that mean that wind generation, rather than other power sources, are curtailed.

On the ***governance side***, and as already discussed with respect to the issue of delayed connection, the plans for the development of the power sector in general, and wind power more specifically, are not sufficiently integrated. Further, there is a lack of strategic planning with respect to the grid infrastructure, such that the problems of curtailment have not been identified and addressed in a timely fashion (Li, 2015). In particular, the wind power section of the 12th FYP framework neither outlines a clear sequence of development nor provides feasible solutions to potential curtailment. It overwhelmingly focuses on expanding wind turbine manufacturing and augmenting installed capacity, ignoring facilitative measures, pricing issues and competition mechanisms (People's Daily Online, 2013).

The targets set in the plans for penetration of renewable energy have always been expressed in terms of installed capacity rather than generation. This has focused attention on deployment of wind turbines and ensured high levels of capacity growth, and has also supported industrial policy ambitions by ensuring a source of demand for domestically manufactured turbines. However, because generation is not rewarded, curtailment does not have a consequence related to failure to meet government-mandated targets. Further, since the performance of wind farms is not prioritized, the quality of installations and equipment is not emphasized, with the result that the Chinese turbine industry has struggled to compete on quality grounds with overseas competitors.

[4] There are various technologies available for the storage of wind energy, but few of these are mature enough for current use. Among these technologies, pumped storage is the most advanced in terms of its use, but requires significant infrastructure.

At the operational level, governance issues have also been important, with priority of dispatch for wind and other technologies. For wind power to be prioritized over coal generation, it must make economic sense for coal stations to shut down, or there must be a regulatory mandate in place. The Renewable Energy Law of 2005 and the later amendments in 2009 attempt to put this regulatory mandate in place by prioritizing renewable energy for dispatch over other sources, obliging grid operators to purchase and dispatch all power generated by renewable energy sources (Standing Committee of the National People's Congress, 2009). However, this obligation is not always fulfilled, and there have been no consequences for the grid operators, meaning that wind power continues to be curtailed, with operators bearing the associated financial cost (Li, 2015).

Institutional arrangements governing the coal sector have also incentivized curtailment of wind power. Coal-fired power stations have in the past been guaranteed a minimum number of running hours per annum, which has meant that energy sources with a low or zero fuel cost (such as wind) have been displaced by less economic and inefficient coal-fired generation (Goggin, 2015). Furthermore, under this system, there is little incentive for coal-fired generators to operate in a flexible manner since their market is secured (Sandholt, 2015a). By contrast, under a market-based system, wind power and other renewable energy sources would dispatch first, based on the zero fuel costs, therefore making mandated priority dispatch unnecessary.

The issue of dispatch order links closely to the ***economic*** reasons for curtailment. Notably, there is no economic incentive for grid operators to dispatch wind power over other forms of generation; rather, there is a cost to doing so in terms of operational effort and risk (Jiang, 2014). Nor is there any incentive for coal-fired power stations to run in a flexible manner. First, unlike a market-based system, the payment for generation is fixed at a constant level with no additional reward for meeting peak demand requirements. Furthermore, there is no financial incentive for thermal generators to act as reserve capacity or for acting in a flexible manner to meet peak demand.

On the side of the wind developers, the system of FITs has encouraged development in the resource-rich area of the three northern regions beyond the level that can be supported by local demand or exported to other areas. While lower tariffs are paid to areas of high wind resources and higher tariffs to those areas with poorer wind resources, the differential does not appear to be sufficient to encourage geographical dispersion of projects. This has not only contributed to problems of curtailment, but also may be more costly at a system-wide level once transmission needs are accounted for (Regulatory Assistance Project, 2013).

4.3 Consequences of Delayed Connection and Curtailment

At the highest level, delayed connection and curtailment represent a loss of potential and actual power supply, since the power that is lost is renewable and with minimal emissions of carbon dioxide and other pollutants, and is largely replaced by coal-fired power. This has a significant environmental impact, compromising the likelihood of China realizing its ambitions for renewable power generation, and, by extension, its ambitions for emission reductions. The current target, announced at the Conference of the Parties in Copenhagen in 2009, is to reduce carbon dioxide emissions per unit of GDP by between 40 and 45 per cent on 2005 levels by 2020 (Koch-Weser & Meick, 2015). The 12th FYP also announced that emissions per unit of GDP would be reduced by 17 per cent between 2010 and 2015.

Further, there is an economic cost to both curtailment and delayed connection. At the system level, the overall cost for the system to cover the given demand is higher than it would otherwise be, since the marginal costs of wind power are close to zero, where those of thermal plants are much higher due to fuel costs. One estimate, assuming an average variable coal-based production cost of CNY 200 per MWh, places the cost of curtailment at approximately CNY 3.5 billion for the first six months of 2015 (Riemann, 2015).

At the level of the individual plant, delayed connection pushes expected income into the future with adverse impacts on net present value and rate of return. Where power is curtailed, a compensation payment should be made, but as described above, this has not always been the case. Project developers face lower levels of revenue than expected, with the result that net present value and rate of return are adversely affected. Differences in cost structures mean that curtailment can have a greater adverse impact for renewable energy plants than thermal plants (Bird, Cochrane, & Wang, 2014). Renewable energy typically has high upfront costs; whenever there is sufficient wind to generate power and recover these costs it is dependent upon being able to dispatch this power.

These economic impacts can potentially affect the longer-term prospects for the industry. Project developers may require a higher return on their investment to compensate for the risk of delayed connection or curtailment. This may result in lower levels of project development as only the most profitable sites are developed, or alternatively in a requirement for higher levels of subsidy to encourage less profitable sites to be developed. In either case, there will be an effect on the overall development of wind power in China (Riemann, 2015).

The economic impacts are not restricted to project developers, but may span the whole value chain. On the one hand, where the profitability of developers is impaired, this may have consequences in terms of meeting payments to suppliers and to creditors. Over the longer term, any reduction in development is likely to also impair the prospects for the turbine and other supporting industries. This is particularly of concern given low levels of penetration into the international market, suggesting few alternative sources of demand. Finally, if project developers believe that curtailment will lead to reduced running hours, they will not place a premium on efficient and durable turbines (Sandholt, 2013). Consequently, the impetus for Chinese manufacturers to improve the standard of their turbines may be blunted, leading to operational weaknesses. This in turn aggravates the problem of curtailment, as dispatchers are less willing to turn down coal-fired power generation in place of wind-powered generation (Koch-Weser & Meick, 2015).

Finally, the credibility of policy initiatives is likely to be damaged as successive attempts to mandate the prioritized dispatch and full purchase of renewable energy fail to achieve the objective of reducing curtailment. As previously described, successive policy documents have emphasized these measures and curtailment has decreased, but curtailment of wind energy remains high overall.

4.4 Government Reaction and Response

This section outlines the specific actions that have been taken in response to the issues of curtailment and delayed connection, grouped under the three headings of governance, economic and technical responses. Since the responses to curtailment and non-connection are closely linked, they are considered together here.

Since 2010 a number of policy documents have emphasized the severity of the curtailment problem and the need to adopt remedial measures. The 2012 White Paper on China's energy policy points out the issue of curtailment and the need to upgrade grid capacity to alleviate the problem (Information Office of the State Council, PRC, 2012). Further, the 12th FYP refers to the need to coordinate the development of the grid with the development of capacity (General Office of the State Council, PRC, 2013a). More recently, the National Energy Administration (2014d) suggested that the 13th FYP would include commitments to addressing grid planning, smart grid development and integration, and thereby resolve the problem of curtailment. Finally, the policy document for the power sector issued in March 2015, Deepening Reform of the Power Sector, recognizes the need to improve the integration of renewable energy capacity and reduce curtailment.

However, while these documents highlight the importance of addressing curtailment, they do not always go into the details of how this will be delivered, with the implementing measures outlined in subsequent documentation.

4.4.1 Technical

A number of measures have been proposed and are being implemented to resolve the technical issues underlying delayed connection and curtailment. These include: enhancing the accuracy and timeliness of wind power forecasting, improving load balancing, developing energy storage, expanding grid coverage and upgrading the dispatching system.

Wind power forecasting: In June 2011, NEA published the *Interim Management Measures for Wind Power Forecasting*, which aimed to strengthen wind farm management and operation by requiring all grid-connected and operating wind farms to install and implement wind power forecasting systems (Li, 2012). In turn, this would facilitate dispatch centres in ensuring wind generation could be planned for and dispatched, thereby reducing curtailment. Dispatch centres are required to develop plans for generation from wind farms based on these forecasts, adhering to the principle of priority dispatch for wind generation and considering system operation requirements (CNESA, 2011). In January 2012 NEA issued a preliminary implementation rule for coordination of grid dispatching and wind forecasting for 15 minutes ahead of time and 72 hours ahead of time. However, reports suggest that the quality of wind forecasting has not been sufficiently high in the past and have been disregarded by dispatchers (Regulatory Assistance Project, 2013).

Load balancing and energy storage: Addressing the issue of curtailment and increasing the penetration of wind implies a need for a more flexible generation mix that can be balanced against the intermittent generation of wind. To this end, NEA has proposed a number of measures such as increasing the flexibility of coal-fired power plants and CHP plants (NEA, 2013c, 2014d). Further measures, which would also assist with reducing curtailment, have been proposed with respect to storage (Ministry of Science and Technology, PRC, 2012). These include increasing the capacity of pumped hydropower generation from 30 GW in 2015 to 70 GW by 2020 (NEA, 2013c) and researching other storage technologies, including batteries.

Grid coverage and connectivity: In 2006 the Chinese government began a program of investment in ultra-high voltage (UHV) transmission lines, which minimize transmission losses over long distances. At the end of 2014, nine UHV transmission lines were in operation and three under construction, connecting the north and the west to the south and the east of the country (Jianxiang & Shan, 2015). These lines are seen as one of the main means of addressing curtailment, as they facilitate the transmission of wind power from the resource-rich provinces to the centres of demand. Accordingly, the 12th FYP makes provisions for CNY 500 billion (USD 80 billion) in investment (Fulton, 2011). According to the State Grid (2015) and CPNN (2015), inter-region UHV transmission achieved an 88 per cent increase in electricity transmission in 2014, with overall transmission reaching 136.7 TWh (of which 19 TWh was renewable energy). Total transmission capacity between the west and east of the country is expected to reach 300 GW by 2020 and 400 GW by 2030 (Wang, 2014; Mao & Wang, 2014).

4.4.2 Governance

A number of changes have taken place relating to governance. First, the quality and scope of central planning has strengthened, with the government considering the issues of delayed connection and curtailment explicitly. During the 12th FYP period (2011–2015), NEA has taken actions to balance project development, reducing approval of new projects, especially in the northern provinces with high rates of curtailment. Under the first plan for wind power (issued in 2011), NEA announced that a total capacity of 28.8 GW would be installed with just 8.9 GW in the three northern regions, while in the second plan (issued in 2012), a total capacity of 16.8 GW was approved with 1.2 GW in the three northern regions (Jiang, 2014). Finally, in 2012, NEA announced that it would no longer approve new projects in regions with a curtailment rate over 20 per cent (ShangHai Securities News, 2012). Relatedly, the government is now emphasizing development of wind projects in the eastern regions and shifting away from traditional wind resource rich regions (NEA, 2013a, 2015b).

Also in a change of emphasis, NEA is optimizing its plan for wind power development by promoting distributed wind power projects, thereby facilitating an increase in capacity while avoiding curtailment problems. In February 2013 the state grid company announced that it would facilitate the development of distributed generation for wind projects, allowing individuals and companies not only to generate power for their own use, but also to sell excess generation back to the grid (Xinhuanet, 2013). This measure was further mentioned in the 2015 power sector policy document, *Deepening Reform of the Power Sector*, and it is likely that the 13th FYP will also emphasize the importance of distributed and small-scale wind farms (NEA, 2014d). However, despite being under discussion for several years, a national subsidy for distributed wind has yet to be released, thus inhibiting take up (Chu, 2015).

Another major policy shift is the authorization of governance. In 2013, the State Council announced that local governments are now authorized to approve investment in wind farms and grids, regardless of how big the projects are (General Office of the State Council, PRC, 2013b). By transferring the exclusive power from NDRC to local governments, grid companies could be able to get grid construction approved more easily and at a lower cost, with eventual reductions in rates of delayed connection.

Finally, in 2015, the government announced a system of green dispatch, discussed more fully in the following subsection on economic measures.

4.4.3 Economic

While successive amendments to the renewable energy law have emphasized that grid operators should give priority in dispatch to wind farms, and have introduced compensation measures in cases where this does not occur, compliance with these policies has been weak and curtailment has continued since their introduction (Kahrl & Wang, 2014). In 2015 China announced that it would put in place a system of "green dispatch," under which renewables would be prioritized. However, it is not yet clear how this is to be implemented, and whether it will involve dismantling the system of guaranteed run hours for coal-fired power stations. If the legislation does indeed take this step, then one of the major contributory factors to curtailment will have been removed.

In 2014 the government also announced a reduction in the level of the FIT payable to wind farms, with the exception of those located in Zone IV, the area of weakest wind resource and lowest levels of development. In doing so, the government removed one of the incentives to develop projects in areas subject to high rates of curtailment and supported a shift towards the development of projects in under-exploited areas.

Lastly, government has introduced measures to increase the demand for wind-generated electricity so as to resolve the mismatch with supply. In recent years, there has been a focus on the role of CHP in the northern regions, with projects initiated to explore the potential for replacing coal-fired CHP facilities with wind-powered facilities (Wang, 2014). The government has also encouraged increases in renewable consumption within provinces most prone to curtailment. A policy statement issued by NRDC in October 2015 encourages increasing consumption through transfer of industry to the east of the country, electrifying industries that are direct users of coal, and establishing direct contracts between renewable generators and end users—but details on implementation are limited (Dupuy, He, & Xuan, 2015).

4.5 Outcomes to Date and Further Policy Measures

Measures to address the issues of non-connection and curtailment have been put into force relatively recently, and many of the measures will only have a significant impact over the longer term as new transmission lines are constructed, new technologies are developed and integrated, and institutional changes occur.

In terms of delayed connection, statistics suggest that much progress has been made. Davidson (2014b) notes that, since 2010, the percentage of non-connection capacity of installed capacity has declined from over 30 per cent to less than 20 per cent (also see Figure 10). This is partly the outcome of government-guided reform, but might also be the outcome of changes in investor behaviour. According to Jiang (2014), investors are now prioritizing the connectivity issue when building wind farms, and they now place more gravity in guaranteeing access to grids and minimizing curtailment when planning new wind power projects.

On the curtailment side, however, the picture is more mixed. Rates of curtailment decreased in 2013 and 2014. While this has been attributed to policy measures that have limited the rate of new construction in areas where curtailment rates are high, it is also likely that lower wind speeds—particularly in 2014—have resulted in lower levels of generation and, thus, fewer difficulties with integrating the power generated. In 2015, with higher wind speeds, levels of curtailment did indeed rebound, suggesting that policy measures have, to date, not been fully successful in addressing this issue.

Many of the measures that have been introduced can only be expected to be effective over the longer term, as they require development and implementation of new technologies, or construction of new facilities and infrastructure. For example, construction of UHV transmission lines to facilitate the export of power can be expected to take several years, while development of storage solutions to store excess power is dependent upon commercializing technologies. However, it is possible to identify some gaps in the policies that have been developed to date.

In particular, the measures that have been introduced to date have not fully addressed the barriers imposed by coal-fired power generation in the country and, in particular, the system of guaranteed run hours. Dismantling this system would remove one of the non-market incentives that currently exist to dispatch coal over renewable energy sources. However, ensuring priority dispatch for renewable energy relies on enforcement of regulation mandating renewable dispatch, or upon development of a market-based system under which renewable energy sources have a cost advantage due to low marginal costs.

Additionally, grid companies can be incentivized to limit curtailment by requiring them to meet at least part of the costs of curtailment (Regulatory Assistance Project, 2013). To the extent that grid companies are well placed to design and implement solutions to curtailment, they should be responsible for the costs of curtailment. However, if generators remain responsible for meeting at least part of the cost, they will be incentivized to locate projects in areas with adequate transmission capacity. There is a range of international examples that can be drawn upon in design of these compensation policies, variously requiring reimbursement of a certain part of the costs or under certain circumstances (Dupuy, Weston, & Hove, 2015).

There are economic measures that could help improve the flexibility of the generation system and the ease with which wind is integrated into this system. For example, reforms in the pricing mechanism for power generation could mean that coal plants receive compensation for providing back-up capacity to support intermittent renewable energy sources, rather than just for power generation, as is currently the case. These proposals will need to be supported by measures that improve the capacity of coal-fired power stations to adjust generation in response to wind generation and to overall demand, and the capacity of dispatch centres to manage this variation. While these measures are largely technical in nature, there is also a significant component relating to training and capacity building among personnel.

5.0 Conclusion: Development Lessons

5.0 Conclusion: Development Lessons

In many ways, the development of wind power in China has been a considerable success: capacity has been deployed at a phenomenal rate and the turbine industry has developed rapidly. Today, wind power is becoming more and more competitive with coal-fired production, especially taking into account the severe environment costs, which are currently only partly internalized in the electricity price from coal-fired power plants. For good reasons, China continues to have ambitious targets for development of wind power as an efficient means to fulfill policy goals regarding energy, environment and industry development.

However, as levels of wind penetration have increased, problems related to the connection and dispatch of wind power facilities have become evident. Examination of these issues reveals valuable lessons not only for their resolution in China, but also for the design of renewable energy policy more generally. This concluding section summarizes the lessons learned from wind power development in China, focusing on the issues of curtailment and delayed connection. The reflections are categorized by themes of governance, economic and technical concerns.

Governance

- **System design:** The power system in China is based upon a series of administrative mandates, which dictate run hours and prices received. Notably, the revenue of thermal generators is based upon a number of guaranteed run hours and the price that is mandated for this generation. Grid companies, required to meet these mandated hours, prioritize the dispatch of thermal generators rather than renewable generation. This is in spite of the financial and environmental costs associated with thermal generation and the absence of these costs in relation to renewable generation. A system that that takes account of the full cost of fuels and seeks to limit environmental impact (e.g., an emissions cap) could incentivize the dispatch of renewable sources.
- **Incentives for dispatch:** To limit curtailment, the government tried to institute a system whereby renewable generation was prioritized in the dispatch order, issuing regulations and introducing penalties for non-compliance. However, this system has proved largely ineffective. This inefficacy can be attributed to a number of factors—including limited capacity of grid companies to deal with intermittent sources and weak implementation—but fundamentally it conflicted with the system of guaranteed run hours for thermal plants. This experience suggests that, when significant levels of renewable capacity are added to a system, the rules and incentives governing the dispatch of all sources need to be considered and adjusted.
- **Target setting:** Setting targets in terms of capacity has helped to fulfill the objectives of wind turbine deployment and facilitated the growth of a turbine industry. It has also provided certainty, in that meeting targets is not dependent on the variable wind resource. However, from energy and environmental perspectives, targets in terms of energy production would have been more appropriate. This would give an incentive to ensure that all wind farms are connected to the grid and that all power generated is dispatched. It would also give an incentive for development and deployment of efficient and high-quality turbines, and may thus have alleviated some of the problems encountered with the reliability of domestic turbines.
- **Planning:** Both delayed connection and curtailment problems reflect a lack of effective planning. Development of generation capacity and transmission infrastructure was not effectively coordinated, so that capacity additions were not matched by grid development. This problem was compounded by a lack of consideration given to local electricity demand or the ability to export power. Effective utilization and integration of renewable energy requires an integrated approach to planning—and approving—both generation and transmission projects.

Economic

- Pricing: In the current system of mandated run hours and prices, thermal generators receive a fixed price for each hour of generation. There is no incentive to provide the services—such as reserve capacity or flexible operation to meet peak demand—that are required to support a high level of renewable generation. Incentives to provide these services could be introduced through a number of possible structures, among them a market-based system, where prices are higher at times of peak demand, or a two-part tariff with part of the tariff dependent upon provision of capacity.
- Subsidies: While the FIT system in China supported the deployment of wind energy, it also encouraged development in the resource-rich northern region beyond the level that could be accommodated by the grid. Relatedly, as deployment increased, the associated cost of the subsidy scheme rose above the levels envisaged, thereby creating a significant financial liability. This experience points to a need for subsidy policy to be responsive to changing conditions, such that it does not aggravate problems encountered.

Technical

- **Capacity and infrastructure:** The development of wind power capacity needs to be matched by development of supporting infrastructure. In early stages of penetration, this may not be a crucial issue, but in later stages it needs to be carefully considered and planned, especially where there is a mismatch between centres of resource and demand. It is necessary to promote research to address future problems, such as power storage, transformation and long-distance transmission. There is also need to develop human capacity by providing training programs and encouraging knowledge transfer.
- **Linking and expanding balancing areas:** Even where physical interconnections are adequate, the extent to which curtailment can be managed by export outside the balancing areas is limited by institutional structures. Trading primarily occurs based on long-term, inflexible contracts, which are of limited value in managing renewable generation. Further, the mechanisms for payment and distribution of revenues do not incentivize trading between balancing areas. Relatedly, expanding balancing areas can facilitate the integration of renewable energy since this smooths the variability of generation, and thus improves the accuracy of forecasting.
- **Energy system viewpoints:** Renewable resources, in particular wind power and solar power, have been regarded as an add-on to the existing power system, rather than part of the system. For instance, when problems occur, the add-on technologies should adapt (e.g., by curtailing excess production) and not influence the operation of the "normal" power production (i.e., existing thermal power and hydropower). Such a strategy might be applicable when the share of wind and solar power is low—the "connect and forget" thinking has been used in many countries in the start-up phase—but clearly this is not a long-term sustainable strategy for renewable energy development. It suggests the need to update policies and develop, where not present, an understanding that renewable energy is a crucial component of the energy system.

In China, efforts have been made to incorporate many of these lessons into policies for the design and operation of the sector. For example, efforts have been made to expand transmission capacity and develop legislation for priority dispatch of renewable generation. However, there remain fundamental issues that need to be addressed, notably the system of guaranteed run hours for thermal generation and the lack of incentives for thermal facilities to run in a flexible fashion. Thus, while some improvements to curtailment and grid connection have been made recently, addressing the current institutional structures that favour thermal power generation is crucial if China is to realize its full potential with respect to wind generation.

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Annex 1: Turbine Manufacturers in China

Cumulative MW installed capacity of the 20 largest wind turbine manufacturers on the Chinese market 2014.

No.	Manufacturer	Cumulative Installed Capacity (MW)	Market Share (%)
1	Goldwind	23,384.6	20.4
2	Sinovel	1,5805	13.79
3	Guodian United Power	1,1381	9.93
4	DFSTW	9,272.5	8.09
5	Mingyang	7,600.5	6.63
6	XEMC	5,527.5	4.82
7	Shanghai Electric	5,353.1	4.67
8	Vestas	4,749.6	4.14
9	Envision	4,383.2	3.82
10	Gamesa	3,597.6	3.14
11	CSIC Haizhuang	3,205.5	2.8
12	Windey	2,899.3	2.53
13	China Creative Wind Energy	2,750.1	2.4
14	CSR Zhuzhou Institute	2,255.8	1.97
15	GE	1,869.1	1.63
16	HEAG	1,340.2	1.17
17	Sany	1312	1.14
18	China Energine	1,245.2	1.09
19	Suzlon	901.3	0.79
20	XJ Wind	754	0.66
	Other	5,022.1	4.38
	Total	114,608.9	1

Source: CNREC (2015)

Annex 2: Policy Milestones For Wind Power Development

1986–1993	Small-scale demonstration wind farms built using grants from foreign donor countries and loans. Support from the government was mainly in terms of financial backing, such as investment in wind farm demonstrations, commercial projects and research.
1994–2003	Support for Wind Power Industrialization Program: The former Ministry of Electric Power initiated support for utility-scale, grid-connected wind farm development and set guidelines for wind electricity price calculations.
1996	Brightness Program is introduced, bringing off-grid solar electricity to rural areas of China; Riding the Wind program is introduced by the former State Development and Planning Commission (SDPC).
2002	National Township Electrification Program provides support for off-grid solar and wind development.
2003	Wind Concession Bidding: The NRDC oversees annual concession tendering of on-shore wind projects >100 MW from 2003–2009. This gives the government experience needed to later set a feed-in tariff (FIT) price for wind.
2005	Renewable Energy Law of 2005 is issued as an umbrella framework, followed by specific regulations and measures supporting the development of wind, solar and biomass resources through a national surcharge on electricity, FITs, mandatory grid connection and power purchasing and the setting of national targets.
2006	*Suggestions for Promoting Wind Electricity Industry* is released by the NDRC, targeting resource assessment, capacity building, grid planning, standards, domestic equipment production, and project construction and management. The NDRC announces a package of policies to encourage development of bioenergy, including risk reserves, subsidies and tax relief.
2007	*Mid and Long-Term Development Plan* for the Renewable Energy Law is released by the National Energy Bureau (merged into the National Energy Administration in 2008).
2007	The Interim Measures on Revenue Allocation from Renewable Surcharges are issued to ensure that the surcharges paid to grid companies are fairly distributed according to the amount of renewable energy generated in their service area.
2009	Photovoltaic (PV) Concession Bidding: First concession tender is offered for a 10 MW centralized PV project in the Gansu Desert; the Golden Sun and Solar Rooftops programs provide investment subsidies for distributed PV projects.
2009	Renewable Energy Law Amendments provide clarifications on grid integration and purchase of generation.
2010	Onshore Wind FIT is set; Biopower FIT is set; first Off-Shore Wind Concession tender; second round of PV Concession Bidding; First Concession Bidding for Solar Thermal project is issued.
2010	Amendments to the National Renewable Energy Law come into effect.
2011	Renewable Energy Fund; PV FIT
2012	Second round of Off-Shore Wind Concession Bidding
2013	The 12th Five Year Plan's chapter on energy development; relevant policy documents on specific issues, such as curtailment, overcapacity and non-connection
2014	The announcement about moderate modification of onshore wind power FIT policy

Annex 3: Curtailment Rates By Province

The table below shows the development of curtailment (percentage of the total wind production, which has been curtailed) from 2012 to 2014. Before 2011 the calculations of the curtailment are too unsecure to allow for comparison.

Curtailment in Key Provinces (2012–2014)

Province	Loss of curtailment (GWh)			Rate of Curtailment		
Year	2012	2013	2014	2012	2013	2014
Gansu	3024	3102	1386	24.30%	20.65%	10.77%
Hebei	1765	2800	2322	12.50%	16.59%	13.68%
Heilongjiang	1050	1151	925	17.40%	14.61%	11.70%
Inner Mongolia (East)	5236	3399	3012	34.30%	19.54%	18.43%
Inner Mongolia (West)	6099	2990	2680	26%	12.17%	10.54%
Jilin	2032	1572	1091	32.20%	21.79%	15.74%
Liaoning	1129	5280	780	12.50%	5.00%	7.00%
Ningxia	47	43	34	1.20%	0.73%	0.50%
Xinjiang	2150	431	2372	4.30%	5.23%	14.80%
Yunnan	170	169	281	6.00%	3.68%	4.31%

Source: CNREC (2013, 2014, 2015)

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