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Institutional Challenges in Resolving China's Wind Power Curtailment

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Abstract. This paper seeks to analyze the main institutional factors leading to and perpetuating the high rate of wind energy curtailment in China. It examines the current policies guiding wind industry development, identifies critical weaknesses, and offers feasible policy prescriptions within the context of China's policy making framework, market conditions and the current state of the wind power industry. The findings indicate that while policy has somewhat effectively contained curtailment, this has been primarily through closer administrative control over all the actors involved in wind energy. For the industry's sustainable growth, improvements to the underlying legal framework and enforcement mechanisms, and efforts to ameliorate curtailment by rationalizing market incentives are necessary.

Keywords: wind power, China, policy analysis.

1. Introduction

China's wind energy has grown rapidly since the government began implementing support measures in 2003, and codified a legal framework for developing renewable energy in 2006. However, due to poor coordination between grid planning and wind energy planning, as well as technical complications in harnessing wind energy, wind farm growth outstripped wind energy consumption demand and grid company's ability to bring wind energy onto the grid, resulting in substantial rates of wind power curtailment by 2010. Policy measures to address curtailment since 2012 have had some success, but substantial installed capacity remains un- or underutilized.

This paper seeks to assess the primary institutional weaknesses in promoting and regulating wind energy in China that have resulted in and perpetuated wind power curtailment, and offer reasonable policy prescriptions for correcting these weaknesses. Section 2 provides background on wind energy development and the emergence of high curtailment rates. Section 3 describes the policy making process for setting wind energy policy, and describes the current policies in place to promote wind energy and address curtailment. Section 4 analyzes the problems hindering broader resolution of wind energy curtailment. Section 5 offers policy prescriptions for addressing these problems.

2. Wind Energy Development

2.1. Growth through Government Support

Government support measures for the wind energy industry were first implemented in 2003, with the Wind Power Concession Program. The program sought to spur wind farm development by opening the previous state monopoly to competition, and cultivate a domestic turbine manufacturing industry, that could help reduce wind power equipment costs and lower costs for wind power market development [1]. This stimulated marked enthusiasm for wind farm investment and jump-started the domestic industry.

Wind power developed even more rapidly after the Renewable Energy Law came into effect in 2006. The law established a multi-part framework for promoting renewable energy nationally, most importantly by

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setting national targets for renewable energy development. It also mandated grid access for renewable sources, separate tariffs for each type of renewable energy and additional tariffs to pass costs exceeding conventional energy sources to end-users, and offering additional subsidies, preferential loan policies and tax incentives for renewable energy projects, research and domestic equipment manufacture.

As the most competitive of renewable energies in terms of cost, maturity of technology and feasibility of large-scale deployment, wind energy was well poised to benefit from the favorable market conditions created by the Renewable Energy Law, particularly government targets. Between 2000 to 2012, installed capacity of wind power of China grew by 48.4 percent annually—the fastest in the world during that period [2].

2.2. High Rate of Wind Curtailment

However, by 2010 uncoordinated planning, combined with physical and market challenges particular to China led to considerable mismatch between wind power installed capacity and generation capacity versus electric power transmission and accommodation capacity, and obvious wind power curtailment emerged. By 2012, over 200 million kW/h dispatched from wind farms was not used (see Fig. 1 and Table 1).

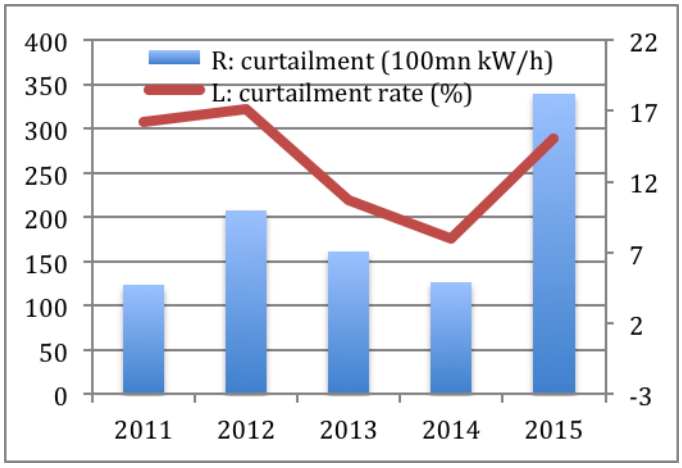

Fig. 1: Wind power curtailment 2011-2015 [3]

Table 1: Wind power curtailment 2011-2015 [3]

Year	Curtailment (100 mn kW/h)	Curtailment rate (%)
2011	123	16.23
2012	208	17.12
2013	162	10.74
2014	126	8
2015	339	15

Construction was concentrated primarily in China's North, Northeast and Northwest, which have the richest wind resources, but are far from population and industrial centers with the highest electricity demand. Furthermore, these regions also have abundant thermal resources, namely coal, and thus less demand for alternative energy sources. China's wind energy consequently developed with large-scale concentration, and with long transmission distances, which require ultra-high-voltage lines. This differs considerably from the experience of other countries, where wind power development has primarily been in distributed networks, close to end users. In 2013 the North, Northeast and Northwest accounted for 83.4 percent of total installed capacity of wind power in China. Transmission distances could extend up to 1,000 km, as is the case for surplus wind power of Jiuquan Wind Power Base, in Gansu province [2]. Dominance of thermal power units in China's power supply structure also led to limited ability to regulate the power load, as the grid in areas with rich wind energy has a small scale and limited load capacity, especially in the Northeast Grid where the heat supply units have a high proportion in thermal power units.

Extensive government support for wind power development had been provided without taking these conditions into consideration. Furthermore, wind power planning was inconsistent with overall grid planning and construction, and did not adequately take into account market demand, while local and national planning were uncoordinated. From 2008, newly added installed capacity outpaced the rate at which new capacity was connected to the grid by a significant margin (see Fig. 2).

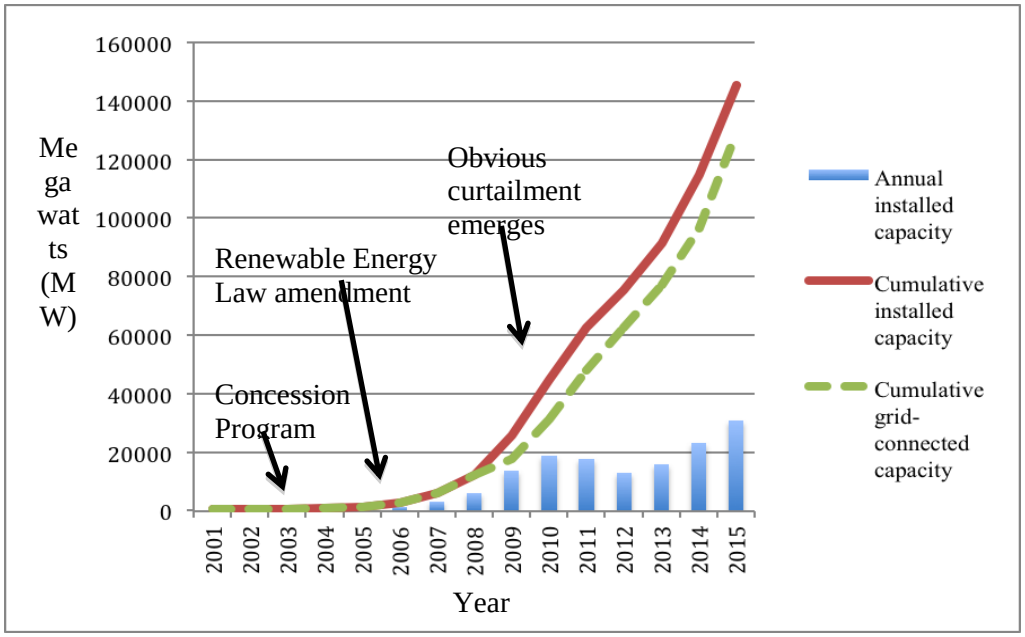

Fig. 2: Wind power annual installed capacity, cumulative installed capacity and grid-connected capacity. Source: General Wind Energy Council and National Energy Administration of China.

3. Wind Energy Policy

3.1. How Wind Power Policy is Set

The Chinese government sets the direction of wind power development in five-year plans. On an annual basis, the National Energy Administration (NEA) releases a more detailed "National wind power development plan" [3], which typically sets annual targets for national capacity expansion, requires provinces to submit wind power development plans and gives non-binding guidance to other government agencies and other actors involved in wind power. The NEA also sets policy to guide regional development or address wind power project approval, grid uptake, clean heating and safety work.

Other key components of wind energy policy include industry policy, to encourage domestic turbine and component manufacturing, and energy infrastructure policy, including grid planning, and wind energy pricing policy. The former is set primarily by the State Council or Ministry of Industry and Information Technology (MIIT), and focuses on upgrading the industrial structure and internationalization of wind power equipment industry. Grid planning is formulated by the National Development and Reform Commission (NDRC), China's main economic planning organ, and implemented by grid companies. Wind energy prices, like all energy prices, are also set by the National Development and Reform Commission (NDRC). The pricing mechanism was changed five times since it was introduced in 1986. Since the NDRC issued "Rectifications to the wind power generation grid rate policy" in 2009, the wind power benchmark price is formulated regionally, such that areas with more abundant wind resources will have lower feed-in tariffs, while those with lower output will benefit from higher feed-in tariffs, making wind power more competitive with conventional energy sources.

3.2. Past Policy Response to Curtailment

Since 2012 wind power development policy has shifted focus from expansion to reducing curtailment. In addition to the annual development plan, NEA has released a plan on wind power absorption annually since 2012 [4]. Additionally, the approval structure for wind power projects has changed, with NEA temporarily

mandating projects be approved nationally. However, in May 2013 State Council announced "Decision on removing and delegating the power of approval of a batch of items requiring administrative approval and other issues". According to this regulation, the NEA has to delegate authority to approve wind power projects to the investment departments of local government. This change in project approval structure significantly contributed to the rapid growth of the domestic wind power market [3].

3.3. Current Policy

Current wind energy policies announced by NEA in the first quarter of 2016 focus on continuing to develop wind energy, particularly distributed wind energy and a handful of large wind power bases, while overall limiting additional capacity construction in regions with high curtailment, and encouraging wind power absorption.

"2016 national wind power development plan" limits capacity by forbidding new wind power projects in provinces with high curtailment, cancelling all plan projects from the 12th five year plan that are not already approved, and banning provincial and lower governments from granting approvals for unqualified enterprises to engage in wind power projects. The Plan also focuses on improving coordination between government agencies, grid companies and enterprises investing in wind power. It exhorts government agencies to strengthen follow up supervision, in particular to ensure newly constructed capacity is connected to the grid in a timely manner, and urges grid companies to coordinate with wind power construction and development plans, and investors to uphold environmental protection and construction quality requirements. "2016 wind power absorption work requirements" also limits capacity by strictly controlling wind power construction in areas with serious curtailment, and proposes a handful of mechanisms to increase utilization of existing wind power capacity. It encourages using wind power for residential heating systems, sharing surplus energy via idle cross-regional transmission lines, and increasing the grid's ability to accommodate wind energy in place of conventional resources. It indicates Mengxi Grid Company in Inner Mongolia is selected in 2016 to start a pilot program, to implement a clause in Document No. 9, a central document on electricity reform released in March 2015, that stipulates grid companies must purchase all energy generated from renewable sources within quotas, and bring it onto the grid.

"Notice on absorbing renewable energy in north China, northeast China, northwest China areas" reiterates more general directions to reduce wind power and photovoltaic curtailment. Like "2016 Wind power absorption requirements" it also encourages renewable use in residential heating, improving the ability of the grid to handle peak regulation from non-conventional sources, and expanding the delivery range of power generated from renewable sources.

4. Problems Impending Resolution of Wind Curtailment

4.1. Current Policies Rely on Administrative Means

The most pronounced problem in China's wind energy development, the high rate of curtailment, is a clear result of inadequate planning and coordination between energy departments, economic planners and grid companies. This was exacerbated by the unique physical and market conditions of China's wind energy development, namely large-scale centralization and long transmission distance, and competition against other subsidized power sources in a transition economy.

The current policy responses, outlined in section 3.3, can be broken down into two categories, based on how they address curtailment: 1) annual wind development plans seek to contain further curtailment through strict limits on new construction, both by outright limits on construction in certain provinces, and more rigid enforcement of approvals for additional capacity; and 2) annual wind power absorption work requirements seek to integrate existing installed capacity onto the grid.

Taken together, these two streams of policy address the curtailment problem administratively. Increased policy issuance and oversight has resulted in improved coordination, albeit by addressing symptoms more than causes. It does not directly improve overall planning and connections between different segments of the wind energy supply chain, set up a more a watertight legal framework, or rationalize market incentives.

4.2. Grid Construction and Technical Planning Weaknesses

The power system restricts the output of wind power due to weaknesses in grid construction planning and technical planning.

Electricity system reform, which in 2002 broke up a previous state monopoly that vertically integrated power generation and transmission, has weakened top-down planning of grid construction. Since the break up, NDRC has developed the grid through approving individual projects rather than overall planning (see fig. 3). At a national system level, this has led to short-sited construction of load capacity closest to population centers, but not energy (both conventional and wind) resources. Conversely, poor coordination between power stations has led to oversupply of energy in regions with lower load capacity.

Furthermore, grid planning does not take into account power source structure. The intermittency and volatility of wind power pose different demands in planning for peak load and frequency regulation than conventional energy sources. Because of the lack of peak load regulation capability, the power system began restricting the output of wind power as more was brought onto the grid [5].

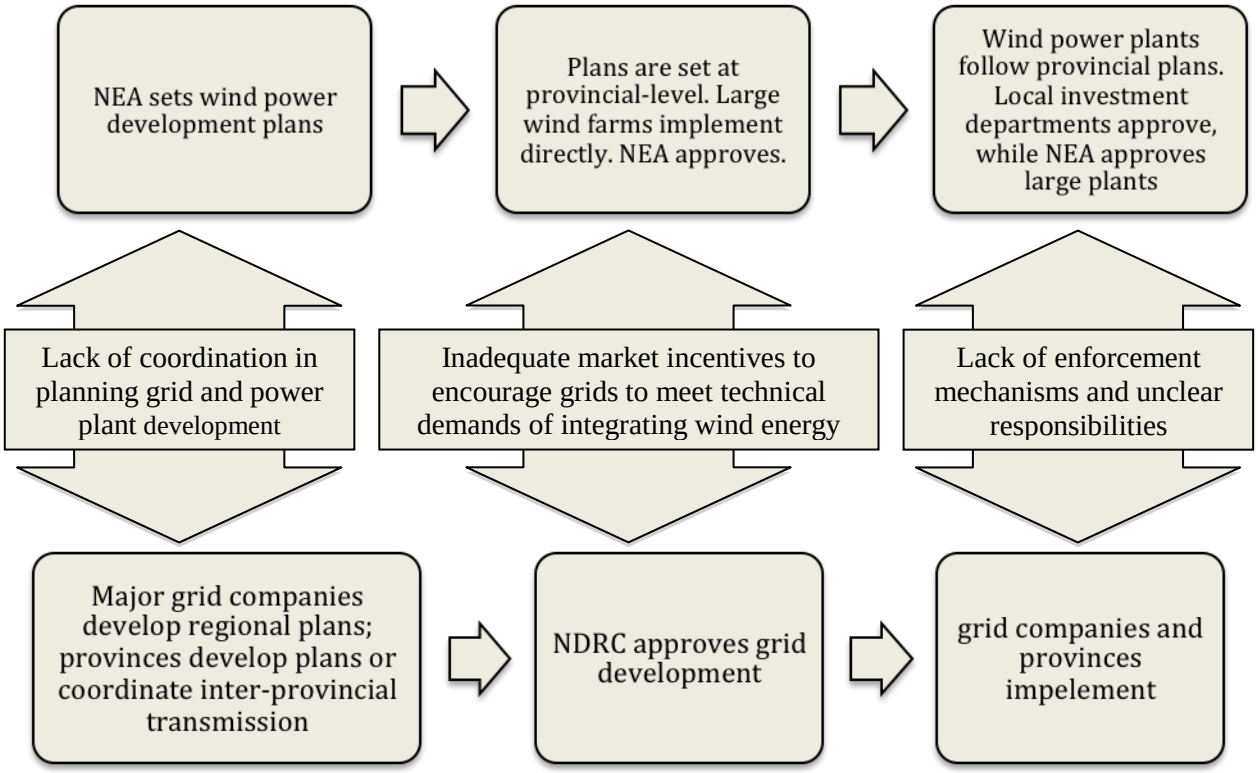

Fig. 3: Wind energy planning and development process and grid planning and development process.

4.3. Unclear Responsibilities and Enforcement Mechanisms

Some of the core articles of the Renewable Energy Law, even after its amendment in 2009, and other key documents regulating wind energy, are ambiguously worded, resulting in the responsibilities of government agencies, enterprises or other actors involved in the development of wind energy being unclearly defined. For instance, responsibility for technology upgrades that would improve the efficiency with which wind power is brought onto the grid, such as power forecasting, investment in energy storage, and standardized construction, is unclear, leading to a lack of initiative in developing technologies that could reduce costs for absorbing wind power.

Additionally, even in instances where responsibility for execution is clear, no government agency is charged with oversight or given enforcement authority. Among other consequences, this absence of enforcement mechanisms has hampered timely delivery of subsidies. Because provision of fiscal support requires complicated administrative approval procedures, subsidies for wind energy have at times not been available as needed. For instance, the Ministry of Finance delayed payments to Gansu Province exceeding 3 billion Yuan between 2011 and 2013 [6].

4.4. Inadequate Market Incentives

Ultimately, the State Council, NEA, NDRC and MIIT aim to make renewable energy sources increasingly competitive with conventional energy sources, so they require less state support and attract more non-state investment. However, uncoordinated grid planning and unclear responsibilities and enforcement mechanisms, as well as continued reliance on short-term administrative strategies to address curtailment, all threaten to deter non-state investment. These factors all signal to potential investors that wind energy is far from being competitive with conventional sources without a long-term program of government support.

5. Policy Suggestions

5.1. Improved Legal Framework to Clarify Government Agency and Enterprise Responsibility

Policy cannot be enforced if the policy itself is vague, and does not clarify which actors are responsible for executing it, and which have the authority and responsibility to ensure it is carried out. The legislation supporting wind energy developed should be revised to clarify the right and responsibilities of different actors, particularly market actors: wind farms, power grid companies, and wind turbine and component manufacturers.

Grid companies are often painted as the scapegoat for high curtailment rates, and indeed they sometimes fail to meet wind energy absorption requirements, or put off technical upgrades that would increase wind capacity utilization, on different excuses that allow them to reject external supervision [4]. Clearer provisions should be made for when grid companies may cite technical complications, or other regulation, as a reason for noncompliance with wind energy policy. Conversely, enterprises should have some recourse through the administrative law system, should government agencies fail to uphold their obligations, in particular for delivery of subsidies and support required by law.

5.2. Better Coordination and Enforcement through Inter-Agency Cooperation Mechanisms

An inter-agency cooperation mechanism, or simply more frequent multi-agency issuance of wind power policy, could increase market connectivity and optimize the industrial chain through better information sharing, while guaranteeing higher compliance with policy through stronger consensus on policy objectives between agencies, and stronger enforcement capabilities.

While the domestic turbine and component manufacturing industries have shifted from competing on price to competing on quality, enabling a burgeoning export market to take shape, there is still substantial room for innovation to address technical challenges in grid connection [7]. Better coordination and information sharing between government organs responsible for funding research and development, and wind farms and grid companies confronting technical challenges that limit the output of wind power, could better guide technological innovation to address these challenges.

Furthermore, much of the difficulty in enforcing renewable energy policy lies in that fact that, in addition to the underlying laws being vague, specific policies or provisions therein are not always binding, and the agencies issuing them may not have power to enforce the actors they address. For instance, the NEA issues policies to guide grid companies, but the NEA may not have power to enforce them, or initiate punitive action against grid companies in case of noncompliance. Issuing and implementing policy through a multi-agency coalition would increase the power behind individual policies, as issuing agencies would all be in consensus on actions to be taken or regulations to be upheld, and agencies with authority to regulate a wider range of wind energy capacity installation and utilization would be involved. In the case of annual “Wind power development work” plans for instance, participation by the NDRC, which ultimately has authority to approve grid construction, would ensure better compliance by grid companies, while cooperation with the MIIT and Ministry of Environmental Protection could improve compliance with quality standards and environmental protection protocol, respectively.

5.3. Pricing un- and Underutilized Wind Energy Hours

Currently, there is no mechanism by which wasted wind energy is priced, and only wind farms and investors bear the costs of constructing capacity that goes unused, even though other market actors, namely

grid companies, may be responsible for wind energy being underutilized. Requiring grid companies to pay a penalty in cases where they do not utilize wind energy that they clearly had an option to dispatch would be an effective method to put a price on wasted wind energy. Grid companies may then be incentivized to take measures to increase wind energy absorption, for instance by expediting construction of cross-regional transmission lines that would open new markets to wind energy, increase energy storage, or research technologies to ease grid integration of wind energy, if it were obvious these measures would ultimately be cheaper than paying for neglected wind resources.

6. Conclusion

China became the world leader in installed wind power capacity within a decade of initiating government support for wind energy development. Yet, capacity construction focused on regions with the richest wind resources, where grids had lower load capacities and in areas that already benefit from extensive thermal resources. Inadequate coordination between wind energy development planning and grid planning resulted in high rates of curtailment.

While the policy to address this curtailment has been successful, close examination reveals that it has not established a legal framework or market incentives for the industry to continue moving in the right direction without continued government intervention. The paper prescribes policy mechanisms that could improve the underlying legal framework, by clarifying responsibilities and enforcement channels, and establishing stronger incentives for grid companies to utilize available wind power. These adjustments could in turn make the industry more viable in the eyes of private investors, and thus promote growth and long-term sustainability while reducing state support.

7. References

[1] S. Zhang, X. Zhao, P. Andrews-Speed, Y. He. The development trajectories of wind power and solar PV power in China: A comparison and policy recommendations. Renewable and Sustainable Energy Reviews. 2013, 26: 322-331.

[2] Y. Ling, X. Cai. Exploitation and utilization of the wind power and its perspective in China. Renew Sustain Energy Rev. 2012, **16**(4): 2111–2117.

[3] J. Li, F. Cai, L. Qiao. Report on China's wind power development. Beijing: The Chinese Renewable Energy Industries Association (CREIA). 2014.

[4] G. Luo, Y. Li, W. Tang, X. Wei. Wind curtailment of China's wind power operation: Evolution, causes and solutions. Renewable and Sustainable Energy Reviews. 2016, 53: 1190–1201.

[5] X. Zhao, F. Wang, M. Wang. Large-scale utilization of wind power in China: Obstacles of conflict between market and planning. Energy Policy. 2012, 48: 222-232.

[6] Z. Zhao, J. Zuo, L. Fan, G. Zillante. Impacts of renewable energy regulations on the structure of power generation in China - A critical analysis. Renewable energy. 2011, 36: 24-30.

[7] P. Ru, Q. Zhi, F. Zhang F. Behind the development of technology: the transition of innovation modes in China's wind turbine manufacturing industry. *Energy Policy*. 2012, 43:58–69