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Analysis and recommendations for onshore wind power policies in China

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ABSTRACT

Recently China's wind power industry is challenged by many problems such as wind power integration and wind curtailment, which seriously hinders the development of onshore wind power. Since China's policy has a direct and significant influence on wind power industry, it is vital to analyze and evaluate published policies. This paper explores in detail 134 China's onshore wind power policies from 2005 to 2015 so as to provide analytical support for future formulation and implementation of wind power policy. Based on policy summary from equipment manufacturing industry, wind farms and power grid industry, this paper evaluates the policies from the perspective of overall plan, support policy and policy implementation using fitting method, game theory and empirical analysis. The results indicate that China's wind policy is gradually becoming perfected, for example, there are more reasonable objectives and improved support policies. However, many problems remain to be solved, like unreasonable planning, imperfect support policies, immature trading systems and uncoordinated actions among interest related parties. Furthermore, combined with international experiences, suggestions on improving China's wind power policy are proposed from seven aspects.

1. Introduction

With the increasing severity of global environmental and energetic problems, new energy and renewable energy development have received more and more attention [1]. Due to the advantages of abundant resources, relatively mature technologies, relatively low cost and non-pollution, the use of wind power has become a main trend of countries around the world [2]. By the end of 2016, the global cumulative installed wind capacity is 486.7 GW [3], which brings wind power to the fourth-largest source of electricity after thermal power, nuclear power, and hydropower. Meanwhile, wind power technology has been improved significantly [4,5], and the cost of wind power has been declining gradually. Such rapid development of global wind power industry is inseparable from the policy support of all countries. The United States, Denmark, Spain, Germany and other countries have issued series of policies to promote the development of wind power [6], such as fixed price, investment subsidies, tariff incentives, tax exemption, domestic rate requirements, export assistance programs, research and development (R & D) support, green electricity, renewable energy quota system, concession policy and certification policy.

China has issued numbers of wind power policies to support the development of wind power industry, which has made great progress in wind power industry. By the end of 2016, the total cumulative installed capacity of wind power in China has achieved 168.7 GW, which accounts for 34.7% of global installed capacity and ranks first around the world [3]. However, although wind policy in China has achieved installed capacity growth, technical level improvement, wind power cost reduction and development of other aspects, there are still exist other problems like wind power integration and wind curtailment [7]. Furthermore, many problems are worth studying, for example, how policies affect behaviors of subjects in wind power industry, what is the variation trend of policies, whether these policies are reasonable and which aspects still need to be improved.

Recently, many articles about Chinese wind power are published every year and many of these studies involve policy. However, most of the studies concentrate on wind power's status, only regarded policy as an aspect of reasons for wind power development and did not carry out a detailed and comprehensive analysis. In this sense, the researches about analysis and evaluation of the overall policy for the whole industry chain are still relatively few. These researches include the comparison of wind power policy at home and abroad [8–12] and the analysis and evaluation on the analysis of published wind power

Abbreviations: R & D, research and development; NDRC, National Development and Reform Commission; MIIT, Ministry of Industry and Information Technology; NEA, National Energy Administration; MOST, Ministry of Science and Technology; VAT, value-added tax; CECRE, Renewable Energy Power Control Center

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Table 1
Main literatures on the analysis and evaluation of Chinese wind power policies.

Literature	Published time	Method	Policy time	Policy scope	Policy classification
The analysis of the promotion policies in wind energy industry [13]	2009	Game theory	1986–2008	–	Classification by period
wind power development and policies in china [14]	2010	Empirical analysis	1994–2008	Incentive policies	Regulatory and mandatory policies, financial incentive policies, research and development policies
Effective policies for renewable energy-the example of China's wind power-lessons for China's photovoltaic power [15]	2010	Empirical analysis	1994–2008	Main renewable energy policies	–
Cost Analysis and Pricing Policy of Wind Power in China [16]	2011	Inflation-adapted model	1986–2008	Price policies	The initial stage, the incremental stage and the coordinated stage
Study on policy of the wind power grid in China [17]	2011	Game theory	1996–2008	Some special policies	–
China's wind power industry: Policy support, technological achievements, and emerging challenges [18]	2012	Empirical analysis	2005–2010	Some special policies	The national renewable energy law and national-level regulations
Large scale wind power integration in China: Analysis from a policy perspective [19]	2012	Empirical analysis	2005–2009	Some special policies	–
Review on wind power development and relevant policies in China during the 11th Five-Year-Plan period [20]	2012	Empirical analysis	2005–2010	Some special policies	Classification by year
Development policy for non-grid-connected wind power in China: An analysis based on institutional change [21]	2012	Empirical analysis	2005–2006	Some special policies	Mandatory institutional change and induced institutional change
Potential and policy issues for sustainable development of wind power in China [22]	2013	Empirical analysis	2005–2012	Some special policies	–
Political and institutional analysis of the successes and failures of China's wind power policy [23]	2013	Empirical analysis	2005–2011	Some special policies	–
Review of wind power tariff policies in China [24]	2013	Empirical analysis	2002–2011	Tariff policies	–
The study of Chinese wind power integration problem based on game theory [25]	2013	Game theory	–	Some special policies	–
Analysis on the policies of wind power generation industry in China-in the perspective of externality theory [26]	2014	Empirical analysis	2001–2009	Some special policies	Environment-type policy, supply-type policy and demand-type policy
A large amount of idle capacity under rapid expansion: Policy analysis on the dilemma of wind power utilization in China [27]	2014	Typical Nash strategy	2005–2010	Some special policies	–
China's policy initiatives for the development of wind energy technology [28]	2014	Empirical analysis	1986–2012	Policy initiatives for technology	Demonstration period, Early development period, Market boom phase, Plateau period
The economics of wind power in China and policy implications [29]	2015	Empirical analysis	2006–2010	Some special policies	–
System dynamics simulation of large-scale generation system for designing wind power policy in China [30]	2015	System dynamics method	–	Some special policies	–
The industrial performance of wind power industry in China [31]	2015	Empirical analysis	1994–2013	Price policies	Classification by period
Incentive policy research on the excess profit allocation in wind power projects based on DEA game [32]	2015	DEA game theory	–	Fiscal policies	–
The effectiveness of China's wind power policy: an empirical analysis [33]	2016	Regression method	1994–2012	Some special policies	Price policy and non-price policy
The evolution of wind energy policies in China (1995–2014): an analysis based on policy instruments [34]	2016	Content analysis	1995–2014	72 relevant policies	Environment-type policy, supply-type policy and demand-type policy
Wind power development in China: an assessment of provincial policies [35]	2016	Fixed-effect regression model	2001–2012	Provincial policies	–
Wind curtailment of China's wind power operation: Evolution, causes and solutions [36]	2016	Empirical analysis	2006–2013	–	Planning and management, policy incentives

policies in China (Table 1). As we all know, wind power policy is a whole and need to complement each other. Although some special policies play an important role, other support policies are also indispensable. But most studies in Table 1 mainly focus on some special policies analysis, such as "Renewable energy law", tariff policies and price policies, rather than being comprehensive and systematic. Besides, many studies do not make a classification of policies in the process of analysis and evaluation, which will be detrimental to the analysis of policy trend, vertical comparisons and horizontal comparisons. Furthermore, the methods are mainly based on empirical analysis, few studies use regression method or game theory. Empirical analysis that lack quantification and regression method are based upon the development data of wind power industry, rather than the policies itself, which could not analyze how policies influence the development of wind power industry. For most researches using game theory, their models include two players and their focuses are mainly on part of industrial chain and part of policy, which has some limitations. In addition, most previous studies ignore the analysis of policy implementation. While the formulation and implementation of policies are inseparable, it is meaningless to discuss formulation without implementation.

In order to fill these research gaps, this paper collects existing policies of onshore wind power policies from 2005 to 2015, using fitting method, game theory and empirical analysis to analyze and evaluate Chinese wind power policies. Our goal is to analyze the developing trend and evaluate the rationality of Chinese onshore wind power policies and propose appropriate recommendations for the improvement of wind power policy. The results of this paper will provide analytical support for formulation and implementation of future wind power policy.

Compared to other studies, this paper has four differences: 1) Policy completeness. A total of 134 wind power policies in 2005–2015 are collected, which include all relevant policies like fiscal incentives, project construction, technology R & D, supervision and management. The integrity of policies makes the analysis more comprehensive and systematic. 2) Different analysis perspectives. Wind policies are first classified and summarized according to the main subjects of industry chain (wind equipment manufacturing industry, wind farms and power grid industry) and then according to policy content. This classification facilitates the horizontal comparison of the subjects and the vertical comparison of policy content, which is conducive to the analysis of policy trends. 3) Different evaluation perspectives. Since the discussion of specific part of the policy may ignore the interaction between policies, this paper divides policy into overall plan and support policy. This division allows us to discuss the rationality of objectives while discussing other policies from an overall perspective, which is conducive to policy improvement from top-level design. In addition, because of different geographical environment, economic levels and development status of different regions, the discussion of policy implementation will contribute to the analysis and improvement of specific regional policies. 4) Different analysis and evaluation methods. The perfect information dynamic game theory of three players makes it possible to quantify the game relationship of each subject in the industrial chain, to see clearly how policy affect the behavior of subject, to provide quantitative support the evaluation of policy. Moreover, the fitting method allows us to quantitatively analyze the rationality of the overall setting of goals.

This article is organized as follows: First, methods details are described, including data collection, fitting and game theory. Second, onshore wind power policies are summarized from three subjects in the industry chain. Third, policies are analyzed and evaluated from three aspects. At last, proposals for future wind power policies are put forward.

2. Methodology

2.1. Data collections and classifications

The comprehensiveness of data collection directly affects the results of analysis. For this reason, this paper collect 134 onshore wind power policies in China from 2005 to 2015, which were issued by government agencies and researched from related government websites. The involved government agencies include the State Council, the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT), the National Energy Administration (NEA), the Ministry of Science and Technology (MOST), the Ministry of Finance, the Ministry of Environmental Protection, the State Electricity Regulatory Commission and other organization, like the State Grid Corporation.

Wind power industry chain is a system including many links, such as components and whole machine production, wind farm construction and operation, power grid consumption and other aspects. In this paper, collected policies are classified into three parts, which are the main subjects involved in wind power industry chain. When different subjects are involved in the same policy, the policy is then put into each mentioned subject (the total policies of the three categories may be greater than 134). Furthermore, for each subject, different policy parts are subdivided based on policy content. This classification is conducive to make a horizontal comparison between different subjects and longitudinal comparison of policy content, which is helpful to identify the focal point and trends of China's wind power policy during different periods from 2005 to 2015.

2.2. Fitting method

The fitting method in this paper mainly include things: 1) Analyzing the impact of data update on overall plan target, and find whether it is necessary to update data for more accurate target setting. 2) Exploring the influence of different fitting methods, and the rationality of using mathematical model for goal setting.

In order to achieve the goals mentioned above, exponential fitting and cubic spline fitting are selected. The reason of choosing exponential fitting method is that the fitting results of this method are consistent with the planning results, while the cubic spline fitting method is widely used because of its good convergence and stability.

2.3. Game theory

Game theory is usually used to understand the action of decision-makers, and find the optimal strategy [37]. In this paper, a perfect information dynamic game model is used to discuss the optimal policy choice of decision makers with the change of policy environment, and then the wind power policy is evaluated. Here, wind power policy is regarded as the external environment of the dynamic game model, and is represented by the change of time.

Concepts and parameters:

Players: Players are decision makers in a game whose purpose is to maximize the level of payoff by choosing strategies. In this paper, equipment manufacturers (A), wind farms (B) and power grid enterprises (C) are set as players.

Strategies: Strategies are the decision variables of a player at a certain point in the game. The strategies of player A, B, C are defined as i, j, k respectively. i={expand production, improve technology, unchanged, reduce production}, j={expanded scale, improve efficiency, unchanged, reduced production}, k={full purchase, partial purchase, no purchase}. For convenience and without confusion, $A_i = \{A_1, A_2, A_3, A_4\}$, $B_i = \{B_1, B_2, B_3, B_4\}$, $C_i = \{C_1, C_2, C_3\}$.

Payoff function: Payoff is the expected utility level of participants. Payoff is the most concerned factor of players, whose purpose is to choose strategies to maximize the payoff function.

As China's wind power does not participate in market competition, p^t varies only with policy changes. Suppose $R_{A_i}{}^t$, $R_{B_j}{}^t$ and $R_{C_k}{}^t$ are the payoffs of three players. $p_1{}^t$, $p_2{}^t$, $q_1{}^t$, $q_2{}^t$ are general turbine price, high-efficiency turbine price, purchase price of wind power and sale price of wind power. $C_{A1}{}^t$, $C_{A2}{}^t$, $S_A{}^t$, $N_{A1_i}{}^t$ and $N_{A2_i}{}^t$ are per general turbine cost, per high-efficiency turbine cost, subsidy, general turbine yield and high-efficiency turbine yield under i strategies. $C_B{}^t$, $S_B{}^t$, $N_{B1_j}{}^t$, $N_{B2_j}{}^t$ and $Q_{B_j}{}^t$ are per kWh cost except for turbine, per kWh subsidy, general turbine purchased, high-efficiency turbine purchase and power generation of wind farms under j strategies. $C_{C_k}{}^t$, $E_{C_k}{}^t$, $S_C{}^t$, $Q_{C_k}{}^t$ and $Q_{Max}{}^t$ are per kWh cost except for purchase wind power, per kWh income from purchase of other electrical energy, per kWh subsidy, purchased wind power generation and the maximum withdraws range of wind power grid enterprises under k strategies.

The payoff functions of player A, B and C are obtained as follow.

$$R_{A_i}{}^t = N_{A1_i}{}^t \times (p_1{}^t - C_{A1}{}^t) + N_{A2_i}{}^t \times (p_2{}^t - C_{A2}{}^t) + S_A{}^t \quad (1)$$

$$R_{B_j}{}^t = Q_{B_j}{}^t \times (q_1{}^t - C_B{}^t + S_B{}^t) - N_{B1_j}{}^t \times p_1{}^t - N_{B2_j}{}^t \times p_2{}^t \quad (2)$$

$$R_{C_k}{}^t = Q_{C_k}{}^t \times (q_2{}^t - q_1{}^t - C_{C_k}{}^t + S_C{}^t - E_{C_k}{}^t) \quad (3)$$

By definition, $0 \le N_{B1_j}{}^t \le N_{A1_i}{}^t$, $0 \le N_{B2_j}{}^t \le N_{A2_i}{}^t$, $p_1{}^t < p_2{}^t$, $0 \le Q_{B_j}{}^t \le Q_{C_k}{}^t \le Q_{Max}{}^t$. Let $Q_{C_k}{}^t = \min\{Q_{B_j}{}^t, Q_{Max}{}^t\}$. Since wind power industrial chain followed by equipment manufacturers, wind farms and power grid enterprises, power grid enterprises are in a dominant position when there are no policy impacts. Fig. 1 shows the game tree of three players. When the income of purchasing and selling wind power is greater than that of other energy power, the optimal strategy for power grid enterprises is purchasing wind power within the maximum withdrawal range. On the contrary, the optimal strategy is no purchase. Because the cost of wind power is much more expensive than that of conventional power generation, which is 117 times higher than coal power [38]. Hence, the sub game perfect Nash equilibrium without policy factors is (no purchase, reduced scale, reduce production). It means that the development of wind power industry must rely on policy support. Section 4.1.2 will discuss it again after considering the wind power policy.

3. Overview of onshore wind power policies and regulations in China

Based on data collection and classification in Section 2.1, this section summarizes 134 policies from three subjects, which are equipment manufacturing industry, wind farms and power grid industry.

3.1. Equipment manufacturing industry

To boost the development of wind power equipment manufacturing industry, “Notice of the NDRC on relevant requirements on wind power construction management” was issued in 2005. This notice required that the localization rate of wind power equipment should reach above 70%. This compulsory policy protects domestic enterprises and remarkably stimulates the development of wind power equipment manufacturing industry (This policy was canceled in 2009). In addition, China has also issued many relevant policies in some aspects like technology R & D, fiscal incentives and supervision management to support the development of wind power equipment manufacturing industry.

3.1.1. Technical research

Since 2005, the NDRC, the State Council, the MIIT, the MOST and other departments have issued many policies to support the development of wind power equipment manufacturing industry. Policies mainly include “Special notice on the organization and implementation of applying high technology to improve the production of renewable and new energy resources”, “Several opinions on guiding the healthy industrial development by restraining excess production capacity and

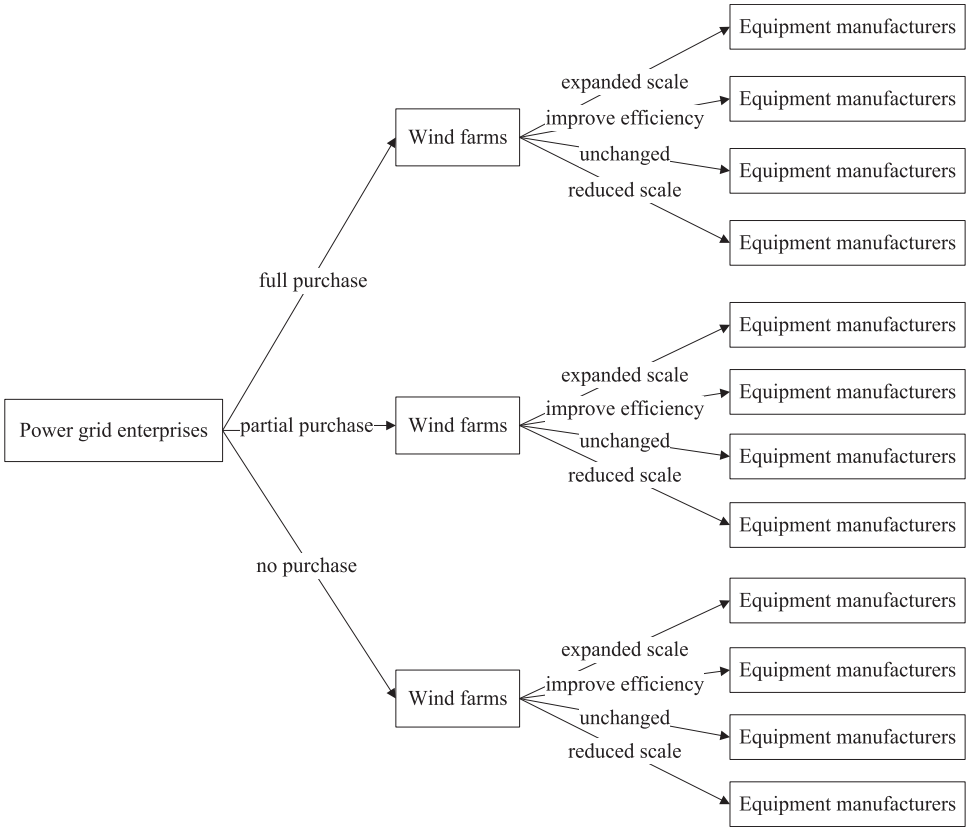

Fig. 1. Game tree of equipment manufacturers, wind farms and power grid enterprises.

repeated construction of some industries", "Implementation plan to revitalize the basic mechanical parts and components industry", "The 12th Five-Year special plan on the wind power technology development", "Notice of the 12th Five-Year development plan for national strategic emerging industries", "Catalog of encouraged industries in western China". These policies point out the direction for technology R & D of Chinese wind power equipment industry. The force of equipment technology R & D is the industrialization of 1.5 MW variable speed pitch-regulated wind turbine and 1.2 MW direct drive permanent magnet wind turbine in 2005. And in 2009, the force shift to wind turbine and key components development of 2.5 MW and above. Then focus is put on wind turbine and key components 1.5 MW and above in 2010 and shift to the development of 3–5 MW large-scale turbines in 2012. In recent years, the overall technical level of wind power is significantly improved. Manufacturing capacity of domestic blades, gearboxes, generators and other parts has been close to international advanced level [39], and individual types of wind turbines are in the leading status [40].

3.1.2. Fiscal incentives

In recent years, various national ministries have issued fiscal incentive policies to facilitate the development of wind power equipment manufacturing industry. For instance, "Notice concerning the implementation of the state council's several opinions on accelerating the revitalization of equipment manufacturers through import tax policies" adjusts the import tariff on the high-power wind turbine. "Notice on adjusting the import tax policies for high-power wind generating sets and their key components and raw materials" implements import tax rebate for key components and raw materials of wind turbine above 1.2 MW. "Interim measures on managing special funds for industrialization of wind power equipment" provides 600 Yuan/kW subsidies for the first 50 wind turbine production. These policies extremely promoted the development of equipment manufacturing industry. In recent years, China's equipment manufacturers continue to grow, which occupied the domestic market and gradually opened up international markets.

3.1.3. Supervision and management

Equipment accidents like fire disasters, collapses, abnormal outages and other major equipment accidents frequently occurred between 2010 and 2011. In view of the gradually increased wind equipment accidents, China begins to pay attention to quality supervision and standard construction. The NEA and the NDRC have successively issued several policies to put forward requirements on wind power equipment localization rate, manufacturing and operation, equipment testing and certification system, wind power equipment quality, market information disclosure and regulatory requirements. These policies mainly include "Notice on investigating into conditions about manufacturing and operation of wind power equipment nationwide", "Several opinions on promoting healthy and orderly development of industrialization of wind power equipment", "Notice on submitting information about quality of wind power equipment nationwide in 2011″, "Notice on strengthening the construction of the monitoring and evaluation system for the wind power industry" and "Notice on relevant requirements to standardize the order of the wind power equipment market".

3.2. Wind farms

China's policies for wind farms can be roughly divided into three parts, wind power projects, fiscal incentives, supervision and administration.

3.2.1. Wind farm construction

Since 2005, China has successively issued several policies to approve wind power generation projects (Fig. 2). These provinces are mainly winded energy resource-rich areas (I, II, III class) except Shandong, Liaoning and Shanxi. According to the proportion of total cumulative installed capacity of the seven wind energy resource-rich provinces from 2006 to 2016, China's wind power development shows a reversed U trend and focus begins to shift to non-rich areas. During the "12th Five-Year Plan" period, China approves and verifies five batches of wind power projects, with a total of 118.49 GW. Moreover, the structure of approved projects has a significant change since the fourth batch, which begins to incline towards IV type of resource areas. With the rapid development of wind farms, national requirements for approved projects gradually become stricter. As for the fifth batch of approved projects, wind curtailment of fast-growing regions could not arrange new project.

3.2.2. Fiscal incentives

China's fiscal incentives for wind farms mainly include power pricing policy, subsidy and preferential policy.

3.2.2.1. Power pricing policy. The gradual adjustments of wind power on-grid price keep wind farms from participating in competition, which provides a stable trading environment. Since 2005, the NDRC have successively issued a series of policies to adjust onshore on-grid price of wind power. Those policies include "Interim measures on management of on-grid price", "Provisions on management of renewable energy power generation", "Notice on improving policies concerning on-grid price of wind power", "Notice on properly adjusting the benchmark on-grid price of onshore wind power". In 2005, the on-grid price of wind power adopted the combination of government pricing and the bidding price. Then, it developed from the combination of bidding price plus approved price in 2006 to the benchmark price in 2009, and finally adjusted benchmark price in 2014.

3.2.2.2. Subsidy and preferential policy. China's major implementations of preferential policy are feed-in tariff, income tax allowance and value-added tax (VAT) rebate. In terms of feed-in tariff for renewable energy resources: "Trial measures on management of generating tariff and cost allocation of renewable energy power generation" impose renewable energy electricity for power generation subsidies. In recent years, additional charge of renewable energy electricity has been increased from 0.001 Yuan/kWh in 2006 to 0.002 Yuan/kWh in 2008, then from 0.004 Yuan/kWh in 2009 to 0.008 Yuan/kWh in 2011, and finally to 0.015 Yuan/kWh in 2013. Such adjustment plays an important role in the rapid development of wind power industry. Since 2012, China has issued six batches of "Catalog of feed-in tariff for renewable energy resources" to support wind power generation projects. Besides, construction funds subsidies and unit generation capacity subsidies for eligible distributed wind enterprises have been provided since 2013. In terms of tax policy: as stipulated by "Law of the PRC on enterprise income tax", high-tech enterprises supported by the state are charged only 15% of the total corporate income tax. "Regulations on the implementation of enterprise income tax law of the PRC" proposes that project enjoy three reduction and three halves of enterprise income tax after 2008. "Notice on comprehensive utilization of resources and VAT policies for other products" puts forward a 50% VAT refund policy for self-produced wind products. As proposed by "Notice on VAT tax policy on wind power generation", electricity products sold and produced by the taxpayers using wind power enjoy a 50% VAT refund policy since July 1, 2015.

3.2.3. Supervision and management

Since 2005, China has issued a number of policies to continually improve the mechanism to supervise wind farms. For example,

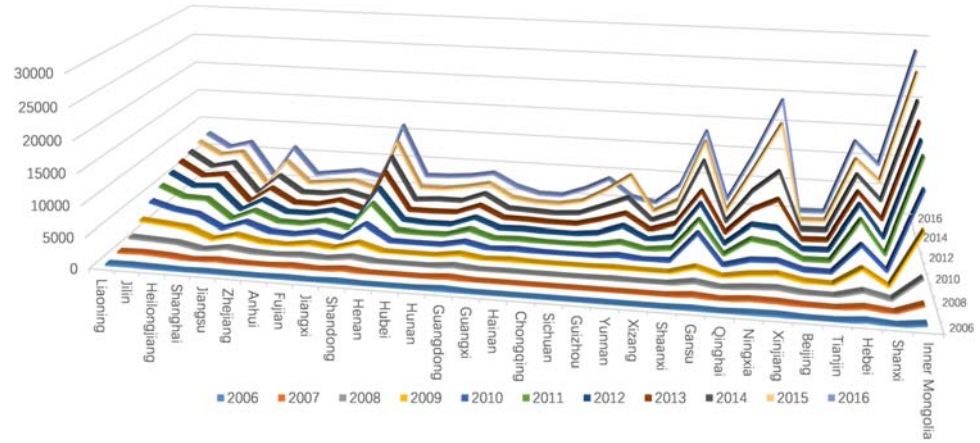

Fig. 2. The cumulative installed capacity of 31 provinces from 2006 to 2016 [41–51].

"Provisions on management of renewable energy power generation" clearly defines the responsibility and property right of wind power integration and proposes that wind power generation projects above 50,000 kW shall be verified or approved by the NDRC (The independent approval right of local governments was taken back in 2011). During the period between 2010 and 2011, about 273 wind turbine collapse accidents occurred, imposing an enormous threat to the safe operation of the wind farms. After the occurrence of those accidents, China has issued a series of policies to enhance the supervision and management of wind farms. For instance, all wind farms should have wind power predict and forecast ability, and low voltage riding through ability. Besides, the utilization ratio of wind power shall be regarded as an important index to arrange the annual wind power development scale and project layout. Moreover, wind power projects shall be equipped with wind observation data for more than a complete year and the integrity rate of the data shall be above 90%. Furthermore, wind turbine in newly approved projects shall carry out grid connection testing. In addition, China has also strengthened the establishment of relevant standards on wind farms. By the end of 2014, China has released 161 technical standards of wind power, which includes 67 national standards and 94 industrial standards [52].

3.3. Power grid industry

China's policies for power grid industry can be roughly divided into power grid projects, fiscal incentives, supervision and administration.

3.3.1. Power grid project construction

To ensure the grid connection and consumption of wind power, China has increased investment and made great efforts in power grid project construction. According to incomplete statistics, by the end of 2010, China's total investment in wind power transmission project has reached 41.8 billion yuan; the completed route of wind power transmission project has reached a length of 23,000 km; the transformer capacity was 37.7 GV·A [53]. After 2010, China has enhanced the on-grid construction of ultrahigh voltage projects, and successively approved 17 trans-provincial ultrahigh voltage transmission and transformation projects. Among them, 8 projects have already been put into operation, 7 projects are currently being constructed and 2 projects have been approved [54]. In recent years, with the continuous expansion of wind power installed capacity, wind power generation in China has also increased. The grid-connected power generation increased from 2.84 billion kWh in 2006 to 241 billion kWh in 2016. The proportion of wind power generation accounting for the total power generation increased from 0.1% in 2006 to 4% in 2016 [55].

3.3.2. Fiscal incentives

In recent years, there are relatively few fiscal incentive policies and small subsidies for power grid enterprises. In 2006, "Trial measures on management of generating tariff and cost allocation of renewable energy power generation" proposed the charge of additional renewable energy power electricity for the relevant access network subsidies. As put forward by "Interim measure on deployment of additional revenue of renewable energy electricity price", the charging standard of grid connection shall be made according to the length of the route. Since 2012, China has issued five batches of "Catalog of feed-in tariff for renewable energy resources" to provide subsidies for grid connection projects. However, the amount of subsidies for grid connection projects is relatively small compared to that of wind farms. For example, in "Notice on the scheme of feed-in tariff and rationing transaction for renewable energy resources", the feed-in tariff for wind power projects reached 226.618293 million yuan while the subsidy for grid connection projects is only 1.156193 million yuan, which accounts for 0.51% of the wind power projects. At present, China has already started to improve policies to support and stimulate power grid construction. In July 2015, the NEA released "Action plan to construct and transform power distribution network (2015–2020)" to actively coordinate with Ministry of Finance in studying and issuing supportive policies for local budget funds and further increase investment in the construction and transformation of the power distribution network. It cooperated with the tax departments to study and implement preferential tax policies and electric charge policies for the construction, transformation and operation of the power distribution network. Compared to the increased installed capacity, relatively low grid-connected rate and high wind curtailment rate still exist. According to China's statistics yearbook of power, the grid-connected rate of wind power shows an inverted U trend from 2006 to 2016, which is 80% in 2006 and reached the minimum of 66.13% in 2010, then increased to 92.2% in 2016. This indicates that although this phenomenon has gradually been improved since 2010, nearly 22% of wind power generation per year is idled because of not connecting to the grid. In addition, under the background of power demand growth slowdown and power grid construction lags, severe wind curtailment in China has emerged since 2010. From 2010–2016, wind curtailment has showed fluctuating trends, with the average rate of 14% [56].

3.3.3. Supervision and management

Since 2005, China has successively issued a number of policies to supervise and manage power grid enterprises. As required by "Renewable energy law", power grid enterprises must purchase renewable energy power in full amount. "Administrative provisions on renewable energy power generation" stipulates that power grid enterprises are responsible for the investment of access system. "Medium

& long term development plan for renewable energy" sets a mandatory market share target for non-hydro renewable energy generation. "Amendment of renewable energy law" revises the full purchase to guarantee purchase, which legally guarantees the consumption of wind power. In addition, China has released several notices and measures to ensure wind power integration. For example, power grid enterprises shall be responsible for the investment and construction of external grid connection equipment needed in distributed generation, and the transformation of public supply system caused by the integration; electricity system operators shall be in charge of predicting the wind generation power of power system; a forecast wind power system and a corresponding power network dispatch system should be established to guarantee the priority dispatching of wind power and confirm the minimum guaranteed purchase hours in two types of resource areas; implementing guarantee purchase measurement of wind power in full amount; setting up medium & long term, short term and ultra-short term provincial wind power prediction system and dispatching mechanism of grid-connected operation; formulating and implementing management measures for the administration of renewable energy quotas and the full purchase of wind power.

4. Assessing the policies of China's onshore wind power

Based on the summary of China's wind power policies above, this section will analyze and evaluate China's onshore wind power policies from overall plan, support policy and policy implementation.

4.1. Overall plan

By comparing the planning objectives to the actual completion conditions (Table 2), we find that China's wind power policy objectives contain the following problems.

4.1.1. Targets being set is unreasonable

China takes capacity-based target as its onshore wind power planning objective, which is unreasonable. The establishment of capacity-based targets, rather than power generation-based goals, may come from the two-stage wind power development strategy of China, which is reflected in the "Opinions about the implementation of the promotion of wind power" [14]. However, the capacity target will lead policymakers to consider how to increase the installed capacity from the perspective of wind farms, without taking the whole industrial chain into consideration. This makes relevant R & D supportive policies and fiscal subsidies partial to wind farms and upstream equipment manufacturing industry. Meanwhile, grid connection links has been ignored, which leads to the unsustainable development of the whole industrial chain in China. Recently, the phenomenon of wind curtailment not only exposes the restriction of power grid but also reveals the unreasonableness of the capacity-based target.

4.1.2. Planning does not play a guiding role

Due to an inaccurate estimation of the development trend of the wind power industry, the planning index set is too low (Table 2). Since 2006, the target for wind power installed capacity has always lagged behind the practical development. Especially during the "11th Five-year" period, the actual accumulate capacity by the end of 2010 is 791.65% higher than the target set in "Notice on issuing implementation opinions on promoting development of the wind power industry" and "Medium & long term development plan for renewable energy", and 347.33% higher than the target set in "11th Five-Year planning for the development of renewable energy". Meanwhile, the newly installed capacity is 380.92% higher than the target set in the "11th Five-Year planning for the development of renewable energy". During the "12th Five-Year" period, the newly installed capacity, the accumulative grid-connected installed capacity and the accumulative installed capacity are respectively 43.17%, 27% and 45% lower than the actual values.

Analysis on the reasons of low planning index: 1) leading by index determination method. Referring to the development trend of wind power industry in Germany, "Medium & long term development plan for renewable energy" put forward that the installed capacity targets of wind power in 2010 and 2020 should reach 5 GW and 30 GW respectively. However, Germany is largely different from China in many aspects like wind resource, power construction, grid construction, power load and policy environment. Therefore, it is irrational for China to make its planning based on the trend of wind power industry in Germany. As for the target that the total installed capacity should reach 5 GW by the end of the "11th Five-Year" period, this paper predicts the installed capacity of 2010 using the exponential fitting method and cubic spline interpolation method. Table 3 shows that the results of different prediction methods vary widely. 2) The basic annual data are not updated in time. The results indicate that it is necessary to update data for the more accurate target setting. The targets set in 2006 are the same as 2007, and the targets set in 2012 are the same as 2014. Although it is unreasonable to change the planning targets frequently, yet if the targets completely deviate from the practical situation and cannot play any guiding role, timely updates are needed to be carried out based on the new data. Take policies issued in 2006 and 2007 as an example, Table 3 shows that after the data in 2006 is added, the predicted value of 2010 increased by 3250.6% and 65.32% respectively. The results imply that timely updating of basic annual data has a comparatively large impact on the setting of indexes. This also indicates that the development of wind power industry is affected by many factors, and target setting cannot be completely based on the results of mathematical model. 3) The basic reason is the incomplete support policies. According to the summary of policies in Section 3, China's wind power policies are severely partial to equipment manufacturers and wind farms. Due to incentive policies like fixed power price, purchasing in full amount, fiscal and subsidy policies, and the absence of relevant standards and supervisory system, wind farms has a great enthusiasm to expand their installed capacity. As a consequence, China's installed capacity of wind power is increasing far beyond the planning targets.

In general, the gap between the planning target and the practical situation during the "12th Five-Year" period is much smaller than that of "11th Five-Year" period. This indicates that China's ability to grasp the development of the wind power industry is gradually becoming stronger and its planning targets also tend to be more reasonable.

4.2. Support policies[1]

The support policies of onshore wind power in China can be roughly divided into two stages. During 2005–2009, wind power support policies are incomplete. The main performances are: 1) Policies are seriously skewed. Policies of this stage mainly concentrated on equipment manufacturing industry and wind farms, which supported technical R & D, project approval, export tax rebate, VAT rebate, fixed price, electricity subsidies and other aspects. But there are few incentive policies for power grid enterprises, and mostly are policies that fulfill responsibilities. For example, China mandates power grid enterprise to fully purchase wind power and also responsible for the investment of wind power connection system, while there are only a few subsidies. Compared to the risk and expenditure of power grid enterprise, such small subsidy can hardly play an incentive role. 2) The deficiency of support policy in every link of wind power development, such as relevant standards and regulatory system. In this period, the support policies are also incomplete, which result in the blind expansion of equipment manufacturers and wind farms, overestimated construction and scale, underestimated quality and management and

[1] [Note]The support policy of this paper indicates other policies except the planning policy.

Table 2
Planning objectives and completion status.

Time	Policy	Planned target	Practical situation
November 2006	Notice on issuing implementation opinions on promoting development of the wind power industry	By the end of the "11th Five-Year" period, the total installed capacity should reach 5 GW. Establish the national standard and certification system for wind power equipment, and the public technical platform for the trial and test key components. Cultivate wind turbine manufacturer and key components production companies.	By the end of 2010, the total installed capacity reached 44.7325 GW. A total of 20 wind power standards have been completed or being developed, of which 5 have been issued. Three wind power testing and certification institutions are set, but the corresponding system has not been established yet. There are 80 domestic enterprises engaged in wind turbine research, 4 of which ranked among the world's top 10 enterprises and 7 among the top 15. There are also 67 blades, 10 gear boxes, 16 bear and 12 converter manufacturing enterprises.
September 2007	Medium & long-term development plan for renewable energy	By the end of 2010, the total installed capacity should reach 5 GW, and basically achieve the main equipment domestically.	By the end of 2010, the total installed capacity reached 44.7325 GW and the domestic rate of wind power equipment was 90%.
March 2008	The "11th Five-Year" planning for the development of renewable energy	During the "11th Five-Year" period, the new installed capacity should reach 9 GW and by the end of 2010, the total installed capacity should reach 10 GW. The domestic manufacturing capacity of wind power equipment and wind turbine should achieve an annual output of 5 GW, and the production of accessories should reach an annual capacity of 8 GW. The domestic wind power equipment manufacturing enterprises should realize the mass production of wind turbine above 1.5 MW.	During the "11th Five-Year" period, the new installed capacity was about 43.2829 GW. By the end of 2010, the total installed capacity reached 44.7325 GW. The production capacity of wind turbine was 18.96 GW and domestic wind power equipment manufacturing enterprises have the ability to manufacture wind turbine and main components of 1.5 MW and above. There are 22 domestic wind power equipment enterprises have a MW production ability. At this period, 1.5 MW and 2 MW become the main types of wind turbine.
March 2012	The "12th Five-Year" special plan on the wind power technology development	During the "12th Five-Year" period, China plans to achieve more than 70 GW of new installed capacity.	During the "12th Five-Year" period, the new installed capacity reached 100.23 GW.
July 2012	The "12th Five-Year" plan on wind power development	By the end of 2015, the accumulative grid-connected installed capacity should reach 100 GW. Have 3–5 wind turbine manufacturing enterprises with international competitiveness and 10–15 high-quality parts suppliers.	By the end of 2015, the accumulative grid-connected installed capacity reached 127 GW. By the end of 2014, total 8 Chinese enterprises ranked among the world's top 15 wind turbine suppliers.
July 2012	The "12th Five-Year development plan for national strategic emerging industries	By the end of 2015, the accumulative grid-connected installed capacity should reach 100 GW. Construct large-scale wind power transmission channels to solve the consumption and long-distance transmission of wind power.	By the end of 2015, the accumulative grid-connected installed capacity reached 127 GW. There are 17 trans-provincial ultra-high voltage projects.
January 2014	Guiding opinions on 2014 energy work	By the end of 2014, the newly installed capacity should reach 18 GW.	By the end 2014, the newly installed capacity reached 23.196 GW.
March 2014	Notice on issuing the work program for the energy industry to enhance the prevention and control of atmospheric pollution	By the end of 2015, the installed capacity should reach 100 GW.	By the end of 2015, the accumulative grid-connected installed capacity reached 145 GW.

Table 3
Predicted values gained by different data and methods.

	Data from 1995 to 2005		Data from 1995 to 2006	
Predicted Value of 2010 (10 MW)	Exponential Fitting 469.14	Cubic Spline Interpolation 16853	Exponential Fitting 15719	Cubic Spline Interpolation 27861

other issues. These problems planted a hidden danger for the development of wind power industry. Although there is no consumption enthusiasm for wind power enterprises during this period, wind curtailment phenomenon is not obvious. The reason is that the proportion of wind power is relatively low, which has a small impact on power grid.

Since 2010, with the emergence of frequent off-grid accidents and wind curtailment, the drawbacks of incomplete support policies begin to reveal. To solve the problems above, China has successively issued multiple measures to improve the support policies: 1) Relevant standards and supervision systems are established. For example, China proposed requirements for equipment production, quality and operation, equipment testing and certification system, market information disclosure and supervision. Moreover, China proposed requirements for wind farms' grid connected monitoring, forecast wind power ability, low voltage riding through capability, wind curtailment proportion, wind power utilization ratio, wind measurement data, construction and operation management. Furthermore, China has also put forward requirements for power grid enterprises' prediction of wind power generation output, priority dispatching of wind power, scheduling mechanism of wind power grid-connected operation and the construction of support power grid. 2) Adjusting power supply structure. Through macro-control, China restricts the new installed capacity in regions with serious wind curtailment. In addition, improve the peak-load regulation ability of conventional power units by increasing pumped storage unit, gas power generation and other flexible adjustments of power. 3) Supporting related wind power technology R & D to improve equipment technology, wind resources assessment, wind power prediction, grid connection and energy storage. 4) Exploring new approaches to utilize wind power. For instance, China has been actively promoting wind power clean heating and hydrogen technology, and provides the corresponding project supports. 5) Strengthening the power grid construction. China has increased the investment in the transformation of distribution network and fixed the preferential tax and power price policies for power grid construction, transformation and operation.

Continuing the discussion in Section 2.3, now we will analyze how policies influence the behavior of each subject in the industry chain and then evaluate policies based on the development trend of wind power industry.

According to the discussion in Section 2.3, the grid power enter-

prises have no incentive to buy wind power without policy implications as a prerequisite. During the period from 2005 to 2009, seriously skewed policies such as relatively few construction supports, high cost, low subsidy, have made grid power enterprises still reluctant to purchase wind power. But due to mandatory policies for full purchase of wind power and the small amount of wind power generation, power grid enterprises have no choice but to fully purchase. At that time, costs are gradually decreased, subsidies are gradually increased and sufficient market and price protection, the optimal strategy for wind farms is to increase wind power generation to the maximum withdraw range, while reducing equipment costs. Since the cost of expanding production is obviously smaller than improving technology, wind farms will choose to expand scale to increase wind power generation. Meanwhile, blind pursuit of profit keeps them from caring the range of maximum withdraw, which soared both number and size of power farms. Similar to wind farms, equipment manufacturers are also favored by policy. Therefore, the best approach for them is to expand production, instead of improving technology. Hence, the subgame perfect Nash equilibrium is (full purchase, expanded scale, expand production). The payoffs of power grid enterprises, wind farms and equipment manufacturers are $Q_{Max}{}^t \times (q_2{}^t - q_1{}^t - C_{C_1}{}^t + S_C{}^t - E_{C_1}{}^t)$, $Q_{Max}{}^t \times (q_1{}^t - C_B{}^t + S_B{}^t) - N_{B1_j}{}^t \times p_1{}^t$ and $N_{A1_i}{}^t \times (p_1{}^t - C_{A1}{}^t) + S_A{}^t$ respectively. This also explains that grid enterprises have no incentive to develop wind power-related infrastructure, wind farm construction and equipment manufacturer production.

Since 2010, although the construction supports and subsidy have gradually increased, grid power enterprises still have no incentive to purchase wind power, especially for the regional supply of electricity. Due to the explosive growth of wind power and imperfect supervision and management issues, it has posed a threat to the safety of power grid. Most importantly, the guarantee of purchase policy makes grid power enterprises choose partial purchase for the reasons of safety, and wind curtailment began to appear. Nonetheless, wind farms are still profitable because of high subsidies, yearly reduced equipment and other costs. The grid companies dominated once again, because that the guarantee purchase is such a vague definition that wind farm cannot determine how many wind power will be purchased and the market demand cannot be guaranteed. Therefore, wind farms choose to improve efficiency or reduce production. Correspondingly, affected by the market demand of the industrial chain, the equipment manufacturers correspondingly pay attention to improve efficiency, or reduce production like focusing on the international market or turning to offshore wind turbine research and production. In this case, there are two possible strategic profiles. The first is (partial purchase, improved efficiency, improved efficiency), with payoffs $Q_{C_2}{}^t \times (q_2{}^t - q_1{}^t - C_{C_2}{}^t + S_C{}^t - E_{C_2}{}^t)$, $Q_{B_2}{}^t \times (q_1{}^t - C_B{}^t + S_B{}^t) - N_{B2_j}{}^t \times p_2{}^t$ and $N_{A1_2}{}^t \times (p_1{}^t - C_{A1}{}^t) + N_{A2_2}{}^t \times (p_1{}^t - C_{A2}{}^t) + S_A{}^t$. The second is (partial purchase, reduce production, reduce production), with payoffs $Q_{C_3}{}^t \times (q_2{}^t - q_1{}^t - C_{C_3}{}^t + S_C{}^t - E_{C_3}{}^t)$, $Q_{B_3}{}^t \times (q_1{}^t - C_B{}^t + S_B{}^t)$ and $N_{A1_3}{}^t \times (p_1{}^t - C_{A1}{}^t) + N_{A2_3}{}^t \times (p_1{}^t - C_{A2}{}^t) + S_A{}^t$. With the adjustments of national policy in incentive policies, technical support, supervision and management, the industry chain will achieve some kind of balance, and the constraints of grid power industry will gradually disappear.

In general, the incomplete wind power support policy reflects the lack of overall consideration, which is particularly serious before 2010. After 2010, China has issued a number of policies related to standard, supervision, power supply, power grid and technology, trying to solve problems like wind curtailment. It indicates that China's wind power support policy is gradually progressed, although there still exist some places needed improving.

4.3. Policy implementation

Although China has issued numbers of wind power policies, yet part of them have become mere formalities and have not been well carried out or the implementation results failed to reach expectation. In recent years, provinces like Xinjiang, Gansu and Ningxia have successively launched local policies such as “direct-supplying electricity transaction”, “self-generation power plant substitute transaction” and “trans-regional transaction”. Consequently, even by providing a zero price can wind power enterprises gain on-grid capacity, which further aggravates the severe problems of wind curtailment. In 2015, Yunnan Province issued that wind power shall compensate thermal power. That means 40% of electric quantity in November and December, wind power enterprises have to give 0.21 yuan to thermal power enterprises for each kWh of power generation [57]. In the same year, Xinjiang Government claimed that there is no space for the consumption of new energy because of the guarantee of heating supply. The new energy power stations that had not participated in transmission or alternative transaction should suspend power generation. The above acts violate relevant rules and regulations, and indicate that there are still many problems during the implementation of wind power policies. The main reasons are as follows: 1) some policies are ambiguously defined and fail to play a guiding and restraining role. For instance, the guaranteed purchase is not clearly defined and there is no concrete standard. As a result, it is hard to supervise and evaluate power grid enterprises. 2) Part policies fairness is poor, which leads to problems in profit distribution. The compensation mechanism of support services for peak regulation do not have a diversified standard to divide basic peak regulation and deep peak regulation among all the power generation sets. It failed to take differences between peak regulation margins of different power generation sets into consideration. As a result, the standard was not fairly formulated, which leads to difficulties in collecting peak regulation compensation cost and implementing current policies. 3) Some policies lack specific operation. For example, after the issuing of mandatory market share target, no more detailed operation, reward or punishment measures were formulated later, which made quota system failed to be effectively carried out. 4) The policy has not played a synergistic effect. There is no synergy between national target planning and local target planning, wind power projects planning and other power construction planning, wind power project construction and power grid construction. As a consequence, China's planning objectives and support policies did not form a joint force, and failed to play their expected roles. 5) The development of wind power is restricted by current regulations. Current power price policy, like divisional power price, negatively affects the trans-provincial transaction of wind power. Fixed power price are disadvantageous for wind power to participate in market competition. Local governments and power grids only take thermal power into consideration while planning the quantity of electricity, which endows thermal power enterprises with the priority right and compresses the space of wind power. Meanwhile, power grid wheeling charge is not clearly clarified and transmission losses cannot be compensated, which causes problems in profit distribution and hinders wind power integration. 6) Development of environmental constraints. The space of wind power integration is restricted by relatively slow power consumption growth, overcapacity of power generation industry and wind power industry, the dominant power structure of thermal power, insufficient peak load regulation capability and other aspects. 7) Technology status constraints. Technologies related to wind energy resources assessment, wind power prediction, low voltage through capability and other technologies still need to be improved, which to a certain extent, restricted the large-scale wind power grid.

Therefore, the development of wind power in China is ultimately confronted with regulations and interests problems. Relevant stakeholders within and between regions failed to well cooperate with each other. As a result, the actions of all parties involved are not effectively coordinated and the promises cannot be well fulfilled. For instance, the power industry in Jiuquan, Gansu Province faces excess production capacity internally and limited electric transmission lines externally, yet the local government is partial to thermal power generation while

considering GDP and employment on the one hand, and trying to vigorously develop wind power generation on the other hand. Taking interests like cost and safety into consideration, power grid enterprises only regard wind power as a load instead of actually accepting it. As a consequence, Phase-I wind power projects in Jiuquan face severe wind curtailment while Phase-II projects are still being constructed. The reason for above situation is that liability subjects in wind power development are unclear and the related parties only pay attention to their own interests and shirk responsibility. Wind farms attributed wind curtailment to power grid enterprises, and maintain that as long as wind power can be integrated into the big power grid, it can be utilized throughout the country. Power grid enterprises attribute it to state grid for lack of lines to transmit power to other regions. The state grid claims that the power transmission lines have already been planned and the sluggish construction of the transmission lines is caused by complicated and slow energy project approval process. NEA denies this statement and attributes it to local governments for blindly develop wind power beyond their actual consumption ability. In addition, energy supply is divided by regions, so most regions only care about their own interests. Some regions like Hunan, Hubei and Jiangxi [58] prefer to build thermal power projects in order to solve power shortages, but they are unwilling to accept wind power from other regions. In a word, many actions need to be done to ensure the effective implementation of wind power policies issued by China. For instance, comprehensively considering the interests of all stakeholders in the entire industrial chain within a region and between different regions, making joint efforts between support policies and planning targets, and making coordination among relevant support policies. Only in this way can wind power industry gain better development.

5. Conclusions and proposals for China's wind power policy

From the above analyzes and evaluates of Chinese onshore wind power policies from 2005 to 2014, we find that policies can be classified into two stages. From 2005–2009, the target set of overall plans is unreasonable and the support policies are incomplete, which is mainly reflected in the lagged goals and heavily inclined policies. This policy environment has led to explosive development of wind farm and equipment manufacturing industry, while power enterprises are very passive in purchasing wind power. Since 2010, the actions like establishing standards, improving supervision and strengthening the support of power grid industry. The main achievements are: grid-connected rate is being gradually decreased, wind power construction has shifted to IV type of resources areas, more attention and support has been taken to wind gird. However, the phenomenon of wind curtailment caused by power grid restriction cannot be solved in a short time and the policy implements still have many problems. In general, the set of China's onshore wind power policy objectives are more reasonable, and the support policies are also being gradually improved. However, it is undeniable that there still exist technical, environmental, institutional, human factors and other issues. Therefore, combined with the international wind power policy experience, this paper gives advice for policy to support future development of wind power in China.

5.1. Improving government's performance assessment system

Performance assessment system is the prerequisite to guarantee the effective implementation of wind power policy. In 2016, “Improving the government's performance appraisal system” proposed to improve development results evaluation system so as to correct the tendency of assessing performance simply by economic growth rate. Meanwhile, this decision increased the weights of resources consumption, environmental damage and ecological benefits, overcapacity and other indicators. But at present, there is no unified policy performance evaluation standard, most areas still regard GDP as an important indicator of local government performance evaluation. For wind power, imperfect evaluation system lead by local governments did not give priority to wind power position for overall planning, which resulted in different interests starting point among local government, equipment manufacturing company, wind farms and power grid enterprise. This makes it difficult to coordinate actions among these parties. Therefore it is necessary to unify evaluation system as soon as possible, establish a third-party agency to demonstrate feasibility and rationality of local planning, policy implementation, and make the results as part of the evaluation system. And then fundamentally changing the position and attitude of the local government towards wind power and other renewable energy sources, providing ideological foundation for wind power industry development and the implementation of national policies.

5.2. Strengthening overall planning

Overall planning is the foundation to guarantee the effective implementation of wind power policy. Spain focused on the development of large-scale wind power transmission capability, and built a strong backbone, efficient and reliable distribution network and cross-border networking, which has become a strong supporter of wind power consumption. Meanwhile, wind power grid companies in Spain carried out priority scheduling for wind power. And other conventional generators cooperated with wind power output. In order to meet the increased wind power installed capacity and electricity generation, Spain has developed generator with a depth peak load capacity, like vigorously gas-fired units, oil and gas mixed fuel units, and actively promoted the construction of pumped storage units. Besides, Spain has set up Renewable Energy Power Control Center (CECRE), which is responsible for scheduling national renewable energy power generation. In addition, relative law is established to require wind farm to build real-time monitoring center, so as to strengthen the scheduling control of renewable energy generation. In China, different powers are formulated and planned separately. With the slowdown in electricity demand, power surplus begins to appear. Besides, grid infrastructure is still relatively weak, and it cannot fully meet the needs of large-scale wind power. Therefore, it is necessary to strengthen the overall planning of wind power construction, including the integration of national and local policies, the coordination of wind power and other power construction, the coordination of wind power and power grid construction. And clearing the main responsibility, implementing supervision, evaluation and punishment system to ensure that policy is implemented. Among them, the integration of national and local policy can prevent policy implementation from not matching the overall planning.

5.3. Improving the wind trading system

Trading system is the key point to guarantee the effective implementation of wind power policy. The current wind power market price mechanism of foreign countries are mainly divided into two categories: incentives policy based on electricity and incentives policy based on price, for example, the quota system represented by the United Kingdom, the United States and the Nordic countries, the fixed price, and the premium mechanism represented by Germany, Spain, Netherlands and other countries. In 2016, China's eight departments jointly issued the “Guiding opinions on promoting alternative energy”, which is proposed to encourage alternative energy companies and wind power generation enterprises to develop bilateral negotiation or direct deal of centralized auction. But our electricity market is not yet mature, the market mode is not perfect, the basic functions of market optimizing resource allocation, technological progress and the distribution of benefits and micro-equalization are also lacking [59]. This paper proposed to improve the implementation of wind power market quota system, which provides a reliable guarantee for wind curtailment

relieving and wind power industry development. And then progressively transit to a more flexible wind power price regulation. Meanwhile, it is necessary to determine trans-regional electricity trade mode, interregional trade price mechanism and trans-regional electricity trade settlement mechanism to promote marketization and standardization of wind power market trading mechanism.

5.4. Improving the financial incentives

A reasonable fiscal incentive is the focal point to guarantee the effective implementation of wind power policy. Fiscal incentives adopted by the United States, Denmark, Spain, Germany, Britain and other countries have greatly promoted the development of wind power industry, which include tax incentives, price subsidies, and investment subsidies. For example, the amendment of the “Renewable energy act” passed by Germany in 2016 stipulates that subsidies for Internet access will no longer provide in 2017. Besides, renewable energy industry has to develop power generation projects through competitive bids and obtain revenue from electricity sales [60]. China's wind power financial incentives include tax incentives and price subsidies, but the high price subsidies are unsustainable. Therefore, the subsidies of power grid companies with wind power acceptance should be increased, which will increase the enthusiasm of grid companies to accept wind power; the subsidies for wind power enterprises should be gradually declined, which will encourage enterprises to reduce costs, stabilize scale, and move towards market-oriented operation. Meanwhile, investment subsidies for wind power technology R & D, such as the wind turbine manufacturing research, wind power grid engineering and grid technology development should be strengthened.

5.5. Improving the level of wind power related technologies

Technology is one support to guarantee the effective implementation of wind power policy. Germany, Spain and other big wind power countries have attached great importance to wind power forecasting ability. In Germany, wind farm and power grid dispatching must be installed with wind power prediction system. Spanish power law formulates that wind farms must predict its generating capacity, and are subject to the penalty of inaccurate forecasts [9]. At present, the level of wind forecast in China is relatively low and the scope of application is not yet widespread. It is still far from international advanced technology in short-term wind power forecast, power generation forecast and other aspects. Therefore, this paper recommend supporting relevant companies, research institutions and establishing special funds to increase the short-term forecasting of wind resources, short-term forecasts of wind turbine output and other aspects of basic researches on the macro and micro levels.

5.6. Strengthening relevant technical standards, testing and certification system construction

Strengthening standards, testing and certification system is another support to guarantee the effective implementation of wind power policy. Currently, Germany, Spain, Britain, Denmark and other countries have established relatively complete wind power technology standards, testing and certification system. Spain has formulated strict wind power technology standards and enforced enterprises to carry out them. New installed wind turbines are required to adopt new technologies and control systems. Wind farms are required to replace old equipment for a new control system. By contrast, China's relevant wind power standards and specifications, testing and certification are relatively backward. It is recommended to improve wind turbine manufacturing, quality assurance system, and strengthen the installation operations, maintenance management and technical standards of real-time monitoring and troubleshooting [61].

5.7. Improving the supervision, evaluation and punishment system

A perfect supervision, evaluation and punishment system is the indemnification to guarantee the effective implementation of wind power policy. Germany, Spain and other countries have published relevant regulations, evaluation and punishment policies to ensure the reasonable orderliness of wind power market. For instance, the German grid company promised, if wind power is limited, power companies will pay 95% of the cost of business losses in accordance with the wind power tariff calculation. Spanish wind power business is expected to pay a fine when there is more than 20% of the differences between grid electricity and actual power generation capacity. Currently, China's regulatory system is still not perfect and lack of evaluation and punishment system. In 2016, “Guidance on the establishment of renewable energy development and utilization objective guidance system” proposed to establish monitoring and evaluation mechanisms of renewable energy development and utilization. Hence, it is essential to gradually improve the regulatory system of wind power industry, including quality system regulation of wind power manufacturing industry, wind power consumptive regulation and supervision of the payment of late subsidies, and establish the appropriate evaluation and punishment system to ensure the implementation of policy. Among them, the evaluation system is required to reflect differences in various regions, such as wind resource, grid situation, technology status and so on.

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References

[1] Yang D, liu J, Yang J, Ding N. Carbon footprint of wind turbine by life cycle assessment. Acta Sci Circumstantiae 2015;35:927–34.
[2] Li Y. Research on the wind power generation costs and related industrial policies in China. Beijing: North China Electric Power University; 2011.
[3] Global wind statistics. 2016. ⟨http://www.gwec.net/wp-content/uploads/vip/GWEC_PRstats2016_EN_WEB.pdf⟩; 2017 [Accessed 17 June 2019].
[4] Qazi SH, Bin Mustafa MW, Soomro S, Larik RM. Comparison of reference signal extraction methods for active power filter to mitigate load harmonics from wind turbine generator. In: Proceedings of the 2015 Ieee Conference on Energy Conversion (Cencon):463-468; 2015.
[5] Fan XC, Wang WQ. Spatial patterns and influencing factors of China′s wind turbine manufacturing industry: a review. Renew Sust Energy Rev 2016;54:482–96.
[6] Zhang Q, Guo J. Major wind power using countries's experience and countermeasures in developing wind energy. Sino Glob Energy 2015;20:25–34.
[7] Zhang SF, Wang W, Wang L, Zhao XL. Review of China's wind power firms internationalization: status quo, determinants, prospects and policy implications. Renew Sust Energy Rev 2015;43:1333–42.
[8] McDowall W, Ekins P, Radošević S, Zhang L-y. The development of wind power in China, Europe and the USA: How have policies and innovation system activities co-evolved?. Tech Anal Strateg Manag 2013;25:163–85.
[9] Liu P, Tan S. Comparison of policies for wind power development in China and abroad. Procedia Eng 2011;16:163–9.
[10] Surana K, Anadon LD. Public policy and financial resource mobilization for wind energy in developing countries: a comparison of approaches and outcomes in China and India. Glob Environ Change 2015;35:340–59.
[11] Hochstetler K, Kostka G. Wind and solar power in brazil and China: interests, state–business relations, and policy outcomes. Glob Environ Polit 2015;15:74–94.
[12] Timilsina GR, van Kooten GC, Narbel PA. Global wind power development: economics and policies. Energy Policy 2013;61:642–52.
[13] Zhao ZJ. The analysis of the promotion policies in wind energy industry. Shanghai: Shanghai Jiao Tong University; 2009.
[14] Liao C, Jochem E, Zhang Y, Farid NR. Wind power development and policies in China. Renew Energy 2010;35:1879–86.
[15] Wang Q. Effective policies for renewable energy-the example of China's wind power-lessons for China's photovoltaic power. Renew Sust Energy Rev 2010;14:702–12.
[16] Wang Q, Wen FS, Yang AM, Huang JS. Cost analysis and pricing policy of wind

power in China. J Energ Eng-ASCE 2011;137:138–50.
[17] Yu LL. Study on policy of the wind power grid in China. Jiangxi: Jiangxi University of Finance and Economics; 2011.
[18] Wang ZY, Qin HY, Lewis JI. China's wind power industry: policy support, technological achievements, and emerging challenges. Energy Policy 2012;51:80–8.
[19] Zhang S, Li X. Large scale wind power integration in China: analysis from a policy perspective. Renew Sust Energy Rev 2012;16:1110–5.
[20] Kang J, Yuan J, Hu Z, Xu Y. Review on wind power development and relevant policies in China during the 11th Five-Year-Plan period. Renew Sust Energy Rev 2012;16:1907–15.
[21] Fang Y, Li J, Wang M. Development policy for non-grid-connected wind power in China: an analysis based on institutional change. Energy Policy 2012;45:350–8.
[22] Tan Z, Ngan H, Wu Y, Zhang H, Song Y, Yu C. Potential and policy issues for sustainable development of wind power in China. J Mod Power Syst Clean Energy 2013;1:204–15.
[23] Zhang S, Andrews-Speed P, Zhao X. Political and institutional analysis of the successes and failures of China's wind power policy. Energy Policy 2013;56:331–40.
[24] Hu Z, Wang J, Byrne J, Kurdgelashvili L. Review of wind power tariff policies in China. Energy Policy 2013;53:41–50.
[25] Lu Z. The study of Chinese wind power integration problem based on game theory. Lanzhou: Lanzhou University of Technology; 2013.
[26] Ren P, Zuo Y. Analysis on the policies of wind power generation industry in China-in the perspective of externality theory. Adv Mater Res-Switz 2014;860–863:375–82.
[27] Wu Z, Sun H, Du Y. A large amount of idle capacity under rapid expansion: policy analysis on the dilemma of wind power utilization in China. Renew Sust Energy Rev 2014;32:271–7.
[28] Dai Y, Xue L. China's policy initiatives for the development of wind energy technology. Clim Policy 2014;15:30–57.
[29] Liu Z, Zhang W, Zhao C, Yuan J. The economics of wind power in China and policy implications. Energies 2015;8:1529–46.
[30] Hou L. System dynamics simulation of large-scale generation system for designing wind power policy in China. Discret Dyn Nat Soc 2015;2015:1–11.
[31] Liu Y, Ren L, Li Y, Zhao X. The industrial performance of wind power industry in China. Renew Sust Energy Rev 2015;43:644–55.
[32] Peng X, Cui HR. Incentive policy research on the excess profit allocation in wind power projects based on DEA game. J Energy Eng 2016;142:04015019.
[33] Zhao XL, Li SJ, Zhang SF, Yang R, Liu SW. The effectiveness of China's wind power policy: an empirical analysis. Energy Policy 2016;95:269–79.
[34] Liao Z. The evolution of wind energy policies in China (1995–2014): an analysis based on policy instruments. Renew Sust Energy Rev 2016;56:464–72.
[35] Zhang XG, Wang D, Liu YH, Yi HT. Wind power development in China: an assessment of provincial policies. Sustainability 2016;8:734.
[36] Luo G, Li Y, Tang W, Wei X. Wind curtailment of China's wind power operation: evolution, causes and solutions. Renew Sust Energy Rev 2016;53:1190–201.
[37] Osborne MJ, Martin J, Rubinstein A. A course in game theory. Cambridge: MIT press; 1994.
[38] Research on the problems and Countermeasures of renewable energy development in China; 2016. ⟨http://www.sic.gov.cn/News/466/6619.htm⟩ [Accessed 17 June 2019].
[39] China National Renewable Energy Centre. The renewable energy industry development report in 2015. Beijing: China Economic Publishing House; 2016.
[40] Armor Construction Machinery Network. China's wind power equipment manufacturers should take advantage of one way to go out; 2016. ⟨http://www.cehome.com/news/20160310/210545.shtml⟩ [Accessed 17 June 2019].
[41] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2014, ⟨http://wenku.baidu.com/view/511072bb2cc58bd63186bdfd.html⟩.
[42] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2013, .⟨http://www.cwea.org.cn/download/display_info.asp?id=55⟩.
[43] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2012, .⟨http://wenku.baidu.com/view/6c553c5425c52cc58bd6be63.html⟩.
[44] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2011 .⟨http://www.cwea.org.cn/download/display_info.asp?id=44⟩.
[45] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2010, .⟨http://www.cwea.org.cn/download/display_info.asp?id=39⟩.
[46] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2009⟨http://www.cnwp.org.cn/fenxi/show.php?itemid=316⟩.
[47] Shi PF. Statistics of China's wind power installed capacity in 2008.⟨http://wenku.baidu.com/view/61967a3e0912a216147929f7.html⟩.
[48] Shi PF. Statistics of China's wind power installed capacity in 2007, .⟨http://wenku.baidu.com/view/5ce010a0284ac850ad02422d.html⟩.
[49] Shi PF. Statistics of China's wind power installed capacity in 2006, .⟨http://wenku.baidu.com/view/15eb7f2d2af90242a895e5e3.html⟩.
[50] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2015,.⟨https://wenku.baidu.com/view/7dbed80a77c66137ee06eff9aef8941ea76e4b03.html⟩.
[51] Chinese Wind Energy Association. Statistics of China's wind power installed capacity in 2016.⟨http://cpfd.cnki.com.cn/Article/CPFDTOTAL-FLJX201702001015.htm⟩.
[52] Chinese Institute of Engineering Development Strategies. The development report on China's strategic emerging industries (2016). Beijing: Sciencep 2016.
[53] National Power Grid Corp . Promoting white paper on wind power development. Beijing: National Power Grid Corp; 2011.
[54] State Grid Energy Research Institution . Analysis report of China's new energy power generation. Beijing: China electric power press; 2015.
[55] National Energy Administration. Wind power grid operation in 2016, .⟨http://www.nea.gov.cn/2017-01/26/c_136014615.htm⟩, 2017 [Accessed 17 June 19].
[56] Wang ZB. China's wind curtailment report. Energy 2014;07:42–8.
[57] Energy Ring. This should be the trend of energy development wind power, why became the local government "abandoned son", ⟨http://www.360doc.com/content/16/0628/14/4802652_571378383.shtml⟩.2016 [accessed 17 June 19].
[58] China Central Television News. 100 billion wind power project Phase I is discarded, Phase is still under construction, who is to blame; 2016. ⟨http://news.cctv.com/2016/04/08/ARTIA4KSi9D8tP1dldxUNAf4160408.shtml⟩ [accessed 17 June 2019].
[59] Li JF, Shi PF, Gao H. China wind power outlook 2010. Haikou. Hainan: Publishing House; 2010.
[60] China Electric Power News. Germany will no Longer provide subsidies for renewable energy online,⟨http://newenergy.in-en.com/html/newenergy-2273858.shtml⟩.2016 [Accessed 17 June 19].
[61] China Power News Network. Wind power 24 new standards to help break through the development bottleneck,.⟨http://www.cec.org.cn/xinwenpingxi/2016-06-06/153883.html⟩.2016 [Accessed 17June 19].