BBChina

Master Program on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Wind power in China

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Chapter 1 Background

Along with high-speed economic development and tremendous energy consumption, China is facing the ever-increasing twin challenges of energy supply and demand. The total energy production between 1978 and 2014 increased from 627.7 million tons of coal equivalents (TCE) to 3.6 billion TCE in China with an annual increase rate of 4.83%[1]. The coal-based energy production and consumption energy system, faces many significant problems, such as shortages of resources, low energy efficiency, high emissions and environmental damage, and lack of effective management systems[2]. As an alternative, a suitable infrastructure for the implementation of renewable energy may serve as a long-term sustainable solution.

The wind energy potential in China is considerable, according to the 3rd national wind energy resource survey organized by the China Meteorological Administration, the exploitable wind energy potential is 600–1000 GW onshore and 400–500 GW offshore. Endowed with abundant wind energy resources, China's wind energy industry has experienced a rapid growth over the last decade (Fig. 1) [3].

The distribution of wind power in China is uneven and not matched with economic development (Fig. 2). Over 28% of the cumulative installed capacity of wind energy are concentrated in the Inner Mongolia, Gansu Province which account for only 6.78% of total electricity consumption in China, while Zhejiang, Fujian and Guangdong province in the southeast China with a more developed economy and a highly concentrated population have only 4.7% of the cumulative installed capacity of wind energy, but account for 20.5% of total electricity consumption[4]. How to solve the problem of uneven distribution of wind energy and make full use of wind energy has become one of the current hot spots.

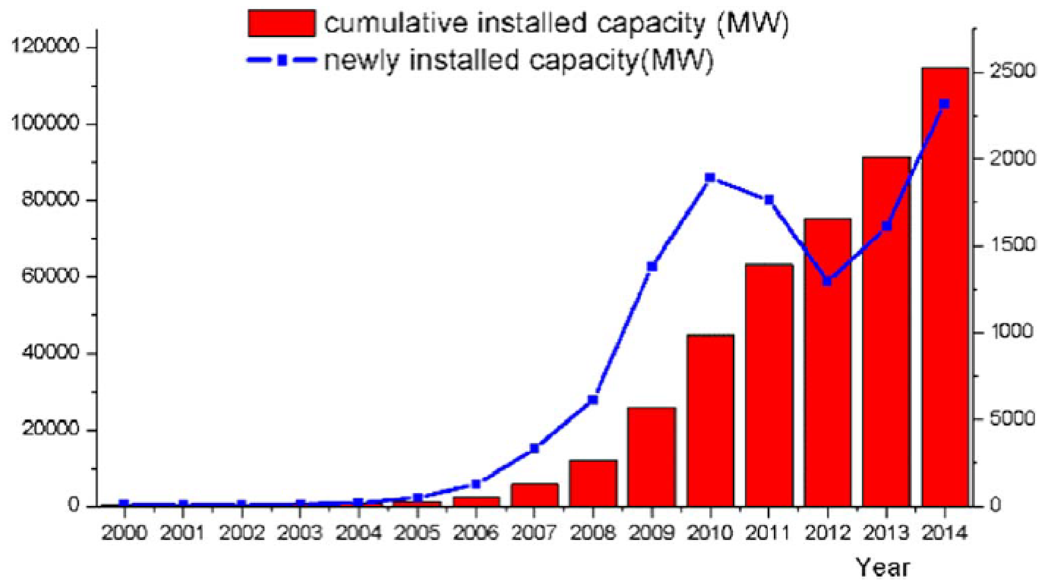

Fig. 1. Growth of wind power in China during the past decades (Source: CWEA).

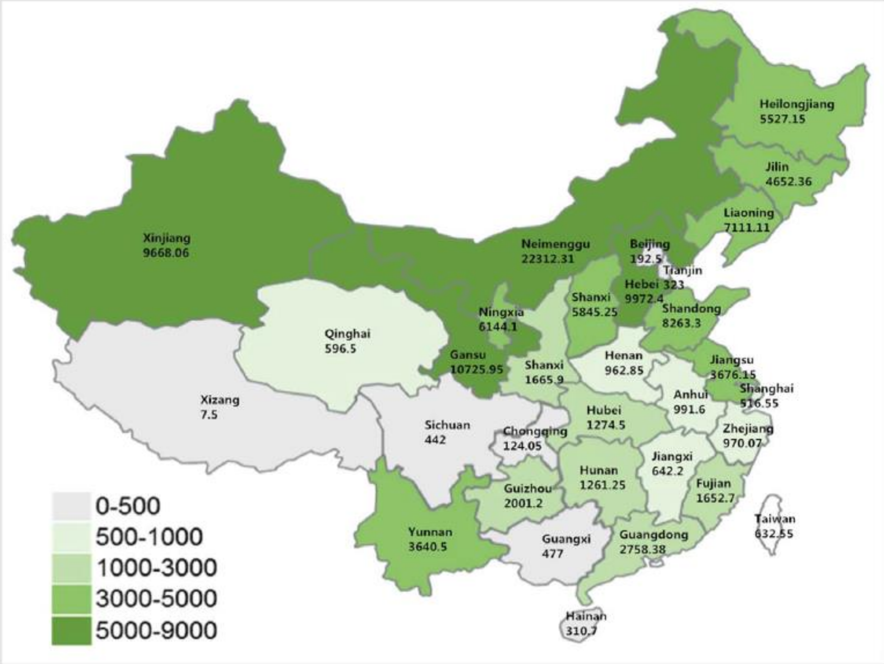

Fig. 2. Cumulative installed capacity of wind energy in different regions of China in 2014 (MW) (Source: CWEA, 2015).

Chapter 2 Technologies

Wind energy has been used for thousands of years to propel ships, drive wind mills, and pump water, with these traditional uses of mechanical energy expanded to encompass electricity production in the early 1970s[5]. In summary, the main ways of using wind energy are wind as a mechanical power and the conversion of wind energy into electrical energy.

The first form is to directly use the mechanical energy provided by the wind, and use the wind to drive the normal operation of various man-made mechanical devices, such as grain selection, sail navigation, water irrigation so on. At present, this type of utilization is still continuing, such as wind water pumps, which are currently available in many countries in the world. This is the main way for early humans to use wind energy, and it is also a general form of utilization of wind energy resources.

The second form of utilization is wind power generation, this is also the most important and effective form of utilization of modern wind energy resources. Wind power generation refers to the process of using the wind to drive the wind turbine of the power generation device to rotate, so as to convert the kinetic energy of the wind into mechanical energy and then into electrical energy. According to the different regions of wind power development and utilization, it is divided into two categories: onshore wind power and offshore wind power. The technical development of onshore wind power has been very mature. Many countries in the world that develop wind power are mainly based on the development and utilization of onshore power. Due to the limitations of technical level and development of wind power equipment, the capital cost of developing offshore wind power is much greater than that of onshore wind power. However, compared with onshore wind power, offshore wind power has the advantages of high and stable wind speed, no land occupation, no

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noise and visual pollution, so it has become a new direction of international wind power development.

Chapter 3 Current situation of wind power in China

Four stages of wind power development in China

The development history of modern wind power in China can be roughly divided into four stages as shown in Fig.3, namely early demonstration stage, industrialization exploration stage, industrialization development stage, and steady development stage. The four stages are divided according to the corresponding landmark event[6].

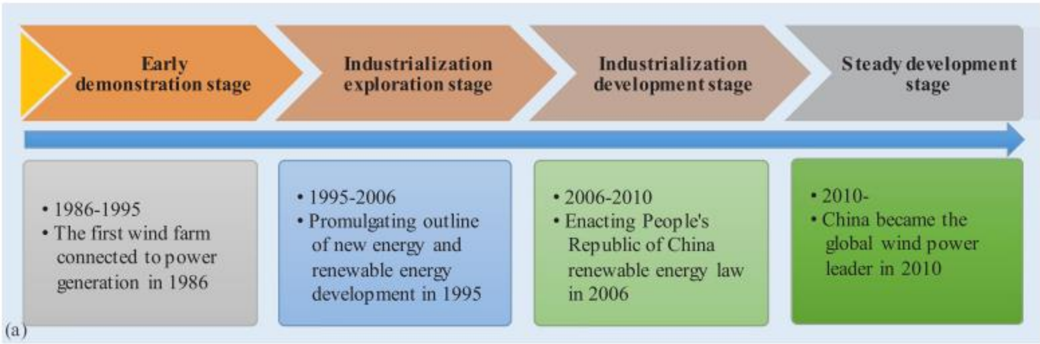

Fig.3. Four stages of wind power development in China.

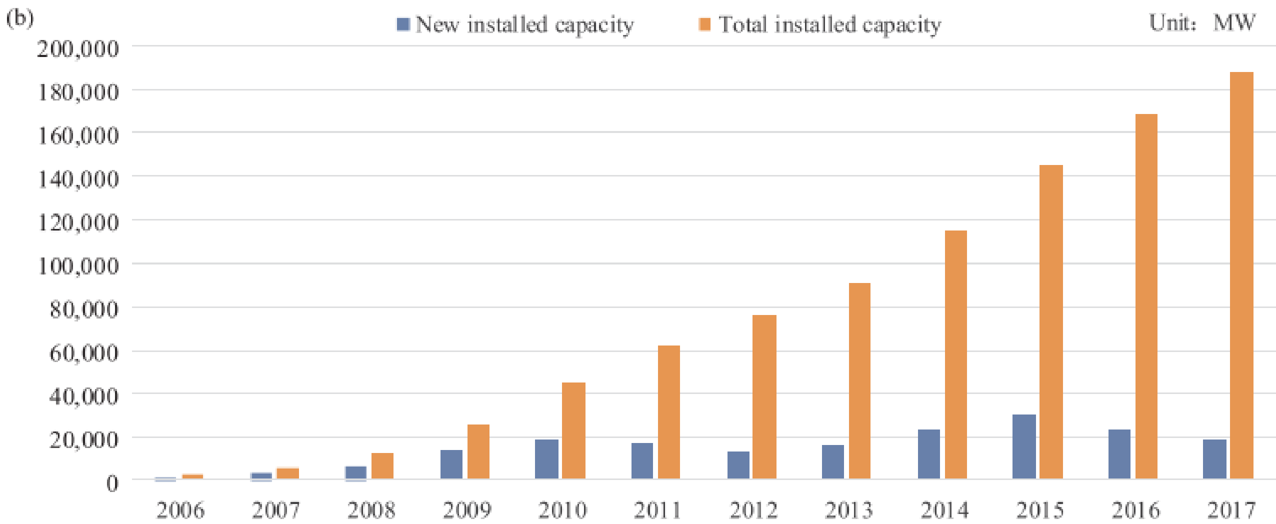

Fig. 4. Installed capacity from 2006 to 2017.

Installed capacity from 2006 to 2017

Especially after 2003, development speed has been significantly improved. According to statistical data by Chinese wind energy association (CWEA), the wind power capacity in 2003 is 546 MW, but in 2006 it has reached 2537 MW[7]. In Fig.4, from 2006 to 2010, China's wind power industry entered the period of industrialization development stage. After enacting renewable energy law in 2006, China's installed capacity of wind power has been increasing rapidly. By the year 2010, China became the global wind power leader, that is, China entered the steady development stage.

Annual average land wind power density in China (2017)

China's wind resources have the characteristics of seasonal variation. China is located in the southeastern part of the Eurasian continent. Due to the different physical properties of land and sea, the Asian continent is the source of cold air which will spread around in winter. Land in summer is quickly heated, forming a heat low pressure and causing warm air from the surrounding ocean blowing into the lowpressure center. This leads to the contrary prevailing wind in winter and summer. Daily and seasonal variations indicate that spring and winter have better wind energy resources than in summer and Autumn[7]. Also, China's wind resources have the characteristics of regional variation. Rich regions of wind resource are mainly concentrated in the southeast coast and its nearby islands, as well as the “Three North” (Northeast China, North China, Northwest China) region. There are also a number of inland wind energy-rich regions.

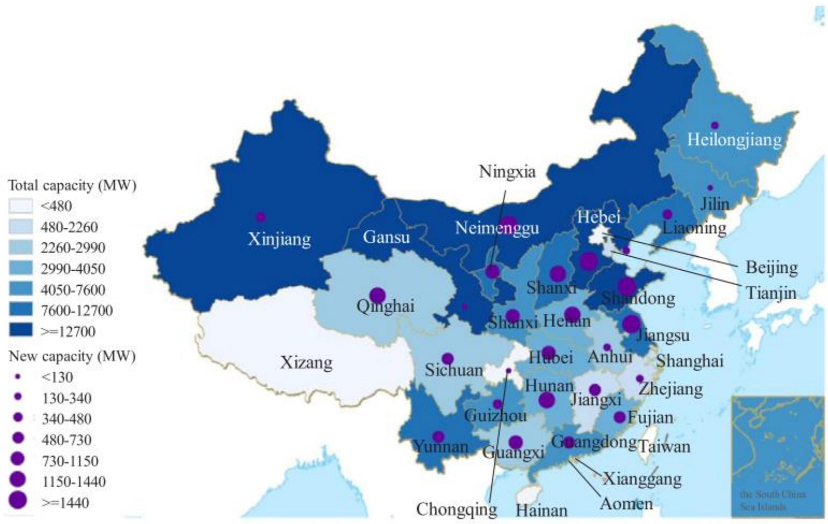

Fig.5. Annual average land wind power density in China (2017).

In Fig.5, the map of average wind power density at 70m height in 2017 is shown based on the data of China Meteorological Administration[9]. The annual average land wind power density is 233.9 W/m^2, and in 13 provincial regions, it is greater than 200 W/m^2. Especially in Neimenggu and Jilin, the annual average power density is greater than 300 W/m^2.

Total installed capacity and new capacity in provincial regions in 2017

According to the data of the Chinese Wind Energy Association(CWEA), the total installed capacity and new capacity in provincial regions in 2017 are shown in Fig.6. Neimenggu has a total wind power capacity of 29,510 MW in 2017. Xinjiang has a total wind power capacity of 19,450 MW, Hebei 14,830 MW, and Gansu 13,110 MW. The total installed capacity of these areas reaches the national total installed capacity of 41%. In Hebei, Shandong, Jiangsu, Neimenggu, Qinghai, Shanxi, Henan, and Hunan, the new installed wind power capacity is all more than 1000 MW in 2017. The new installed offshore wind power capacity is 1160 MW with 319 sets of wind turbines; the total offshore wind power capacity has reached 2790 MW. Mainstream offshore wind turbines include 4 MW units and 3 MW units.

Fig.6. Total installed capacity and new capacity in provincial regions in 2017.

In some regions especially in Northwest China, North China, Northeast China ("Three North"), part wind has been abandoned. Abandoning wind is the phenomenon that the wind turbine can operate normally, but the wind turbine is stopped because of the lack of power grid absorption capacity, the instability of wind power generation, or the mismatch of the construction period and so on. The main problem in Northeast China is the conflict between the thermal power and wind power. At present, wind power has to give way to other power supply. The main problem in Northwest China is that the electricity load is too small, and in North China is mainly the channel limit, that is, largescale wind power construction does not match with the existing power grid[10]. Abandoning wind phenomenon first appeared in 2010, and now it is still a serious challenge to the development of wind power industry. For instance, the total power output of abandoned wind has reached 33.9 billion kWh in 2015, about 18% of the total wind power (186.3 billion kWh) based on the released information by National Energy Administration of China (NEAC); total power output of abandoned wind has reached 41.9 billion kWh in 2017, about 13.7% of the total wind power (305.7 billion kWh). If wind power tariff is calculated at $0.08/kWh, the economic loss is $2.712 billion dollars in 2015 and $3.352 billion dollars in 2017.

Chapter 4 One example: Offshore wind farm

Introduction of Shanghai Donghai Bridge Wind Power Farm

The 100,000-kilowatt wind farm of Shanghai Donghai Bridge is located along the line 1000 meters on both sides of the Donghai Bridge from Lingang New City to Yangshan Deepwater Port. The northernmost end is nearly 6 kilometers away from the Nanhuizui shoreline and the southernmost end is 13 kilometers away from the shoreline. All are located in Shanghai within the city. The power plant is China's first offshore wind power project and the first large-scale offshore wind farm in Asia. It is the world's first offshore wind farm outside Europe and China's first national offshore wind power demonstration project. The total installed capacity of the wind farm is 100 MW. The annual power generation utilization hours are 2363 h, and the annual on-grid electricity is 233 million kWh. The project started hoisting on March 20, 2009, and all installation, commissioning and grid-connected power generation were completed on June 8, 2010[11].

Fig.7. The Offshore Wind Farm in Asia—Shanghai Donghai Bridge Offshore Wind Farm

Construction of Shanghai Donghai Bridge Offshore Wind Farm

1 Site Selection

Shanghai is located in the East Asian monsoon prevailing area. Affected by the winter and summer monsoons, the wind energy resources are relatively abundant, especially in the offshore area. The sea area is open and there are few obstacles. And building (structure); does not affect flood control, aviation safety, and has good value for development and utilization of wind energy resources.

According to the statistics of Shanghai Nanhui, Chongming, Fengxian and other meteorological stations, the wind speed on the surface of the offshore water can reach more than 6m/s. According to the wind measurement data of the wind tower on the Donghai Bridge test pile platform of the wind farm site area, the annual average wind speed of the wind turbine hub area of the offshore wind farm site area is about 8.6m/s, and the wind farm is 6 to 14 kilometers away from the coastline of Lingang New City Close to both sides of the Donghai Bridge, the usable sea area reaches 40 square kilometers. In one year, the effective wind time of offshore wind farms reached 8450 hours, the frequency of occurrence was 96.5%, and the frequency of effective wind energy was as high as 98.7%.

2 Substation

In wind farms, the electricity generated by wind turbines needs to be delivered to the regional power grid in order to be used effectively. In order to reduce line loss, it should be stepped up and sent out. At present, most of the export voltage of wind turbines on the international market is 0.69 kV or 0.4 kV. Therefore, it is necessary to equip the wind turbines with a step-up transformer to raise the voltage to 10 kV or 35 kV through the field collection line and then through the power cable. Transported to the offshore booster substation or onshore booster substation supporting the wind farm, the input voltage is increased to 110 kV or 220 kV, and then transmitted to the regional power grid through the high-voltage line[12]. There are two international schemes for the construction of booster substations: one is to build offshore substations, and the other is to build onshore substations.

The booster transformers of each wind turbine at the Shanghai Donghai Bridge offshore wind farm use a high-voltage side voltage of 35 kV, which is connected to the booster substation on the coast of Pudong Lingang New City through the submarine cable and sent to the Shanghai power grid.

3 Fan Support and Installation

Considering that there is a deep water channel that crosses the Donghai Bridge wind farm, the design of the wind turbine foundation must have the ability to resist ship impact. Combined with the construction experience of China's municipal bridges and port terminals, the construction scheme using single piles, jackets, etc. It is proposed a high-pile concrete cap foundation scheme, which greatly reduces the diameter of the foundation pile, and also has similar concrete cap construction experience. If the elevation of the platform is properly controlled, the reinforced concrete platform can be used to resist the impact of the ship. No additional protective piles are required. Although this scheme has many construction procedures, it has the advantages of high structural rigidity, low total cost, and controllable construction risks.

The Donghai Bridge offshore wind farm finally chose the overall hoisting scheme, mainly using the Shenjiawan prefabricated base left over from other engineering constructions, which was transformed into a wind turbine assembly base after transformation. And on the site, the mobile platform of blades and wheels was arranged, and the crane and fan assembly tower were installed on the wharf, and the modified semi-submersible barge was used as the overall transport ship of the fan.

4 Wind Power composing into power grid

Shanghai Power Grid is a big receiving end and belongs to the strong power system. When the wind farm is connected to the Shanghai power grid, it can also obtain better power compensation of the power grid, which is very important to ensure that all power generated by the wind farm can be safely and reliably transmitted to the power grid. The Donghai Bridge offshore wind farm is equipped with an onshore control center and a 110 kV booster substation. According to the wind farm’s wind turbine layout, 8-9 wind turbines are combined into a joint unit, which is connected with a 35kV submarine power cable through a four-circuit power collection line. Connected to 220kV substation via 110 kV cable, and then merged into Shanghai power grid

Advantage

1 Geographical advantages

Research data shows that the wind speed on the sea is 20% faster than on land, and the power generation is increased by 70%. The use of sea breeze power generation is more efficient than the onshore wind farm. According to the estimates of the China Meteorological Research Center, if the onshore wind resources can be combined with potential power generation capacity, it can reach 253 million kilowatts (GW), while offshore wind resources can further provide 750 million kilowatts (GW) Electricity production.

2 Technical advantage

The Donghai Bridge offshore wind farm adopts the 3Mw offshore wind turbine independently developed by China. The height of the fan hub is 91 m and the diameter of the impeller is 91 m. It adopts the structure of three blades, horizontal axis and upwind direction. It is suitable for the

Donghai Bridge offshore wind farm site. . The main engine, hub, blade, tower and other equipment of the fan are all manufactured by domestic manufacturers, and adopt the foundation design of the high pile cap and the overall hoisting technology of the fan.

Due to the higher transportation and hoisting conditions required for offshore wind power, the unit capacity of wind turbines is larger, and the annual utilization hours are higher, that is, the service cycle is relatively long. At present, the average stand-alone capacity of offshore wind turbines is around 3 MW, and the maximum has reached 6 MW. The annual utilization hours of wind turbines are generally more than 3000 hours, and some are as high as about 4000 hours.

Disadvantage

1 Repair and cost

(1) Due to the large difference between offshore and onshore, maintenance of offshore wind turbines is subject to many restrictions. Because wind turbines are standing on the sea and the environment is complicated, it is very difficult to repair the ship and send the maintenance personnel to the wind turbine. Sending the maintenance personnel to the fan and then reconnecting them cannot be completed in a short time, so it is necessary to design a special area on the unit to facilitate the maintenance personnel to stay overnight.

(2) Compared with onshore wind power facilities, offshore wind power equipment suffers from strong corrosion. The seawater, sea mud where the offshore wind power foundation is located, the chloride ion content in the salt fog environment where the tower and the engine room are located are rich, so the corrosion activity is high, the contact area of the seawater and the air is large, the convection is sufficient, under the continuous stirring of the waves, Oxygen saturation and extreme humidity accelerate the corrosion rate of offshore wind power equipment.

(3) The total investment of the Shanghai Fengqiao Power Plant project is about 222 million yuan, and the bidding on-grid electricity price is 0.98 yuan per kWh. According to the estimated annual power generation of the power plant, it will take at least ten years to offset the construction cost of the power plant. At present, the average cost of onshore wind power is 6800 to 8000 yuan per kilowatt, while the offshore wind farm is 1.5-2.5 times that of it[13].

2 Security issues

The typhoon is a great threat to the development of offshore wind power in my country. Shanghai is located in the subtropical monsoon region, and typhoons often land in summer and autumn. The 11th typhoon "Hai Kwai" entered the sea surface of the East my country Sea on August 5th. On August 8th, it landed in Zhejiang with 14-level winds. Part of the sea surface of Shanghai and the gusts of Yangshan Port area reached 10.12. According to the monitoring data of Huarui Wind Power Donghai Bridge project. The maximum local instantaneous wind speed during the typhoon exceeds 40m/s.

Chapter 5 One example: Onshore wind farm

Wind energy in Inner Mongolia autonomous region

An abundant storage of wind energy exists in Inner Mongolia autonomous region, where the available amount of wind energy at height of 70 m is about 1.5 billion kW. The area where the wind energy density exceeds 150 W/m^2 is 1.01 million km^2, accounting for 85.63% of the total area in the autonomous region. As of the end of 2016, the total installed power capacity was 28 million kW, ranking first in China[14].

The annual wind speed distribution at 70 m height in the autonomous region is shown in Fig.8, the average wind speed at 70 m height surpassed 6.37 m/s, so it is a very ideal region to build up wind power plant.

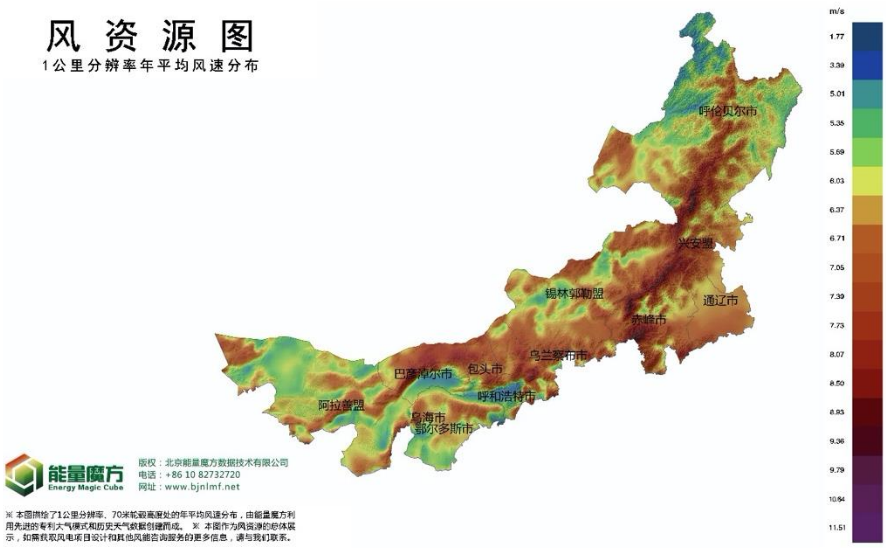

Fig.8. Annual wind speed distribution at the height of 70 m in Inner Mongolia autonomous region.

A wind power plant in Inner Mongolia autonomous region

This project is located in the middle of Inner Mongolia, where the wind power is highest with an average annual wind speed 8.0 m/s and wind power density 523.5 W/m^2. The total installed capacity is 100 MW with 50 wind power generators, table 1 shows the detailed technical parameters and economic indexes of this power plant.

Tab.1. Technical parameters and economic index of wind power plant[15]

Parameter	Unit	Quantity
Rated Power	kW	2000
Blade	/	3
Rotor Diameter	m	87.3
Rotor Swept Area	m2	6066
Cut-in Speed	m/s	3.0
Rated Speed	m/s	11.5
Cut-out Speed	m/s	25.0
Survival Wind Speed	m/s	59.5

Hub Height	m	80
Installed Capacity	MW	100
Annual Power on Grid	MWh	273675
Average Feed-in Tariff (tax-out)	¥/kWh	0.4359
Average Feed-in Tariff (tax-in)	¥/kWh	0.51
Tax rate of investment profit	%	7.25
ROI	%	8.99
Payback Period	Year	8.83

Challenges and opportunities

The Inner Mongolia Autonomous Region is located in the westerly zone, and most areas has a temperate continental monsoon climate. The windy weather is mainly distributed in the spring, autumn and winter seasons, especially from the late autumn to the early spring of the next year. Cold air activities are more frequent. It is the fundamental reason for the rich wind energy resources in Inner Mongolia Autonomous Region. Of the nine modern wind power bases proposed for construction in the State Council's "Energy Development Strategy Action Plan (2014-2020)", western Inner Mongolia and eastern Inner Mongolia each occupy two seats. In addition, the “Thirteenth Five-Year Plan of Industrial Development Plan” of the Inner Mongolia Autonomous Region proposed that the installed capacity of wind power in the region will reach 45 million kW by 2020. It can be seen that wind power has broad development space in Inner Mongolia.

Although more and more policies that encouraged the wind power have been issued, challenges still exist. Wind and electricity curtailment were once a major factor affecting the development of wind power, and this situation was most severe in 2012[13] . The situation has improved in recent years, but it has not been completely eliminated. Even so, according to the 2014 statistics, the average wind curtailment rate in the autonomous region is still 9%[14].

In addition to the effect of wind turbine installation destroying topsoil, consensus has been formed on the disturbance of atmospheric circulation caused by wind power generation. In recent years, with the rapid development of wind farms on the grasslands of Inner Mongolia, its impact on the ecological environment has also attracted the attention of relevant scholars and the public. Up to now, the results of existing studies have shown that wind power generation will have a certain impact on the physical and chemical properties of the soil[17], and the soil moisture and organic matter content have been reduced compared to the areas without wind farms, which has led to a decline in the biodiversity in wind farms[18][19]. The species composition of the community has also changed. With further research in this area, the impact of wind power generation on the ecological environment of the grassland area will definitely become a factor influencing the construction of wind farms.

Chapter 6 Wind power policies in China

Policy development

Since 1986, when China established its first wind farm in Rongcheng City, Shandong Province, China's wind power development has undergone four major stages[20]: the early demonstration phase(1986-1994), the industrialization exploration phase(1994-2002), the industrialization development phase (2003-2007), and the large-scale development phase (2008-). During each phase, the Chinese government sets its policy objectives cor-responding to the status of the industry and established a series of targeted policies to guide the wind power development (Tab.2).

Tab.2. Wind power policy evolution over different periods[21]

	Early demonstration (1986–1994)	Industrialization exploration (1995–2002)	Industrialization development (2003–2007)	Large-scale development (2008–2017)
Background	(1) Technology in developed countries was mature (2) China's technological research had just begun	(1) Technology in developed countries had improved (2) China's technology still lagged	(1) Rapid development in developed countries (2) China's technology had gradually matured	(1) Wind power had expanded globally (2) China had mastered key technologies for MW-size wind turbines
Major policy objectives	Technological R&D	Technology breakthrough and industrialization applications	Localization and industrialization of wind power equipment	(1) Large-scale development of wind power industry (2) International competitiveness
Focal policies measures	(1) Direct subsidy at the R&D of wind turbine (2) Loan for constructing small-scale demonstration wind farms by importing foreign wind turbines	(1) Continuing subsidy at the R&D (2) Loan projects for construction wind farms (3) Compulsory acquisition, debt serving electrical price	(1) Concession tender programs (2) Government guide prices (3) Establishment RE fund (4) National wind power equipment standards	(1) FYP for wind power (2) The on-grid FIT in four re-gions' categories (3) National wind power industry standards and regulations (4) Export tax rebate
Development results	Accumulated wind turbine R&D techniques	600 KW wind turbine with independent intellectual property rights	(1) Increased localization rate (2) Total installations ranked the fifth in the world	(1) Leading the global wind power market (2) 95% localization rate (3) Export to 28 countries

In wind power development 13th Five-Year Plan (FYP)[7], the government formulated development goals of wind power. (1) **Total goal**: by the end of 2020, the installed capacity of wind power integrated grid shall be guaranteed more than 210 million kilowatts, including 5 million kilowatts installed capacity of offshore wind power grid connection. Wind power is guaranteed to generate 420 billion kilowatt-hours of electricity a year, about 6% of the country's total. (2) **Consumption goal**: by 2020, effectively solve the problem of wind power curtailment, and fully meet the minimum guaranteed acquisition utilization hours requirement in the "Three North" area. (3) **Industrial development goal**: the manufacturing level and research capacity of wind power equipment have been continuously improved, and 3-5 equipment manufacturing enterprises have fully reached the international advanced level, and the market share has been significantly increased.

Tab.3. Main wind power policies in the last five year

Time	Policy name	Main content
2016.11	Wind power development "13th Five-Year" plan	Overall plan of wind power development between 2016 to 2020
2017.7	Trial implementation of the renewable energy green power certificate issuance and voluntary subscription trading system	Issuing green certificates for onshore wind and photovoltaic power generation projects, and established a trading mechanism for green certificates for renewable energy power
2018.3	Renewable portfolio standard and assessment method (draft for comments)	To guide market players to give priority to renewable energy power transactions, and to carry out compulsory amortization in accordance with the quota implementation plan approved by the provincial people's governments when the market mechanism cannot guarantee the full utilization of renewable energy power
2018.4	Interim measures for the administration of the development and construction of decentralized wind power projects	Part of the electricity generated for self-use does not enjoy subsidies from the National Renewable energy Development Fund
2018.11	Notice on the implementation of renewable portfolio standard system	Quota assessment will be formally conducted from January 1, 2019
2019.1	Notice on the work of actively promoting unsubsidized and affordable access to wind power and photovoltaic power	Promoting the development of wind power and photovoltaic power generation faire/low price projects that do not require state subsidies to implement benchmark feed-in tariffs for coal
2019.5	Notice on establishing and improving the renewable energy electricity consumption guarantee mechanism	Establish mandatory market share standards of renewable energies in accordance with the law
2020.5	Guiding opinions on establishing and improving the long-term mechanism of clean energy consumption (draft for comment)	Accelerate the liberalization of priority power generation programs across provinces and regions, and constantly improve the mechanism for inter-provincial market transactions

Policy charictaristics

In recent years, the Chinese government has given more attention to the wind power, which can be seen at the amont of policies directly related to the wind power. The number increased up to 44 in 2016–2017, while the number was just 21 in 1994–2007. Polies were relatively general and single in the early, which gradually became diversified and combinatorial applications. It indicated that the Chinese government increasingly focused on guiding the market at different dimensions. Strategic positioning of wind power has changed from supplementary energy to alternative energy. In 1995, an outline for developing renewable energy was released, which defined wind power and other renewable energy sources as “short-term supplementation of energy balance” and "expectation of a long-term energy structural adjustment." In the 13th FYP for wind power development, it is proposed that China's wind power must complete the transformation from supplementary energy to alternative energy. And the government is guiding regional layout switching from resource-centered strategy to demand-centered strategy and guiding the simultaneous development of centrialized and dispersed wind power. It also make efforts to use market mechanisms to internalizethe environmental benefits of wind power.

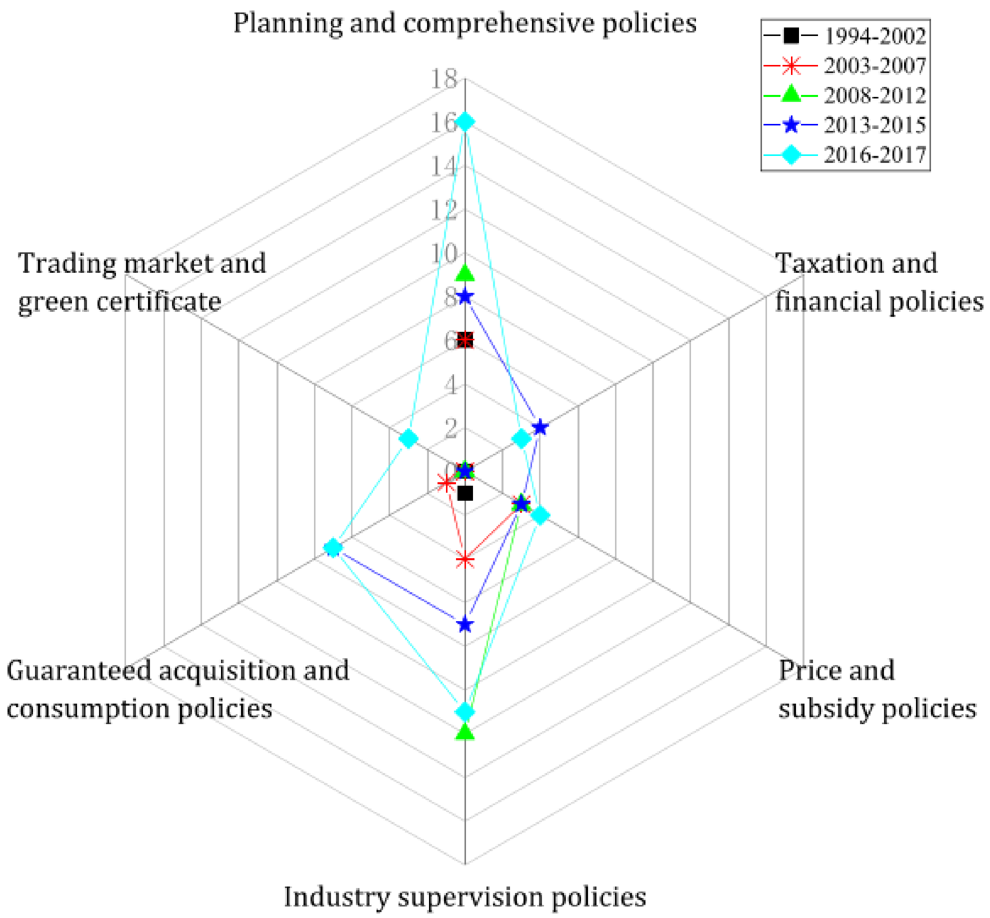

Fig.9. Status of wind power policy tools for different periods in China

Policy limitations

There is a lack of consideration on the difference of the wind power development stage between China and other developed countries. The share of wind generated electricity in China's total electricity consumption is heavily lower than that in Europe. It is evident that the wind power is less popular in China than that in Europe. In this case, a substantial reduction in subsidy will dampen the enthusiasm of market investment and affect the sustained and rapid growth of wind power.

There is an insufficient emphasis on policy stability. Meanwhile, in China, the feed-in tariff (FIT) was implemented in 2009, which has been reduced each year from 2014 to 2017, and directly replaced by the auction scheme in 2018. Thereby, a competitive bidding usually resulted in significant "cutthroat" competition by putting forward unreasonably low bid rates.

Not enough attention has been paid to the economic difference between wind power in China and other developed countries. The cost of wind power generation is 0.47-0.67 yuan/kWh in flat areas in China, which significantly higher than that in the USA (0.26 yuan/kWh) and India (0.39 yuan/kWh)[22].

China's government, wind power operators, and investors are plagued by wind power curtailment problem. Although the annual rate of curtailment wind power had fallen in the last 2 years, which was published by NEA, this problem has not been thoroughly solved. If the FIT decreases rapidly, the profits of enterprises will decline sharply, which may greatly affect market investment of wind power. So the government should solve the wind curtailment thoroughly, before dramatically cutting the price and subsidy of wind power.

Policy suggestions

In order to improve the marketcompetitiveness of wind power, we make the following suggestions[21]:

(1) The Chinese government should establish long-term development goals on wind power, especially the pro-portional goal of wind power in national electricity consumption; establish the dynamic links between green certificates, carbon emissions trading, and price subsidy policy; and guide the market to embrace the concept of green electricity consumption.

(2) New problems in the eastern and southern areas should be paid attention to, such as the economic feasibility of the decentralized wind power systems and the mitigation of environmental impacts of wind farm construction matching withthe local ecological environment.

(3) The degree of FIT and subsidy reduction should be matched to the degree of technical improvements and the corresponding cost reduction of wind power, and solving wind curtailment should be taken as the premise.

(4) More attention should be given to formulate supporting measures on land and finance to mitigate the impact of auction and free subsidy on the market as well as to strengthen support for the wind power technology.

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Master Program
on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Wind power in China

Students: Siyuan WANG, Yulong HUANG, Mingqiang LU,
Jin WANG, **Rong NIE (Leader)**

UNIVERSITÀ DEGLI STUDI FIRENZE

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MÄLARDALEN UNIVERSITY SWEDEN

c e s i e the world is only one creature

Co-funded by the Erasmus+ Programme of the European Union

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Agreement number - 2017-2984/001-001 - Project reference number - 586083-EPP-1-2017-1-IT-EPPKA2-CBHE-JP

Background

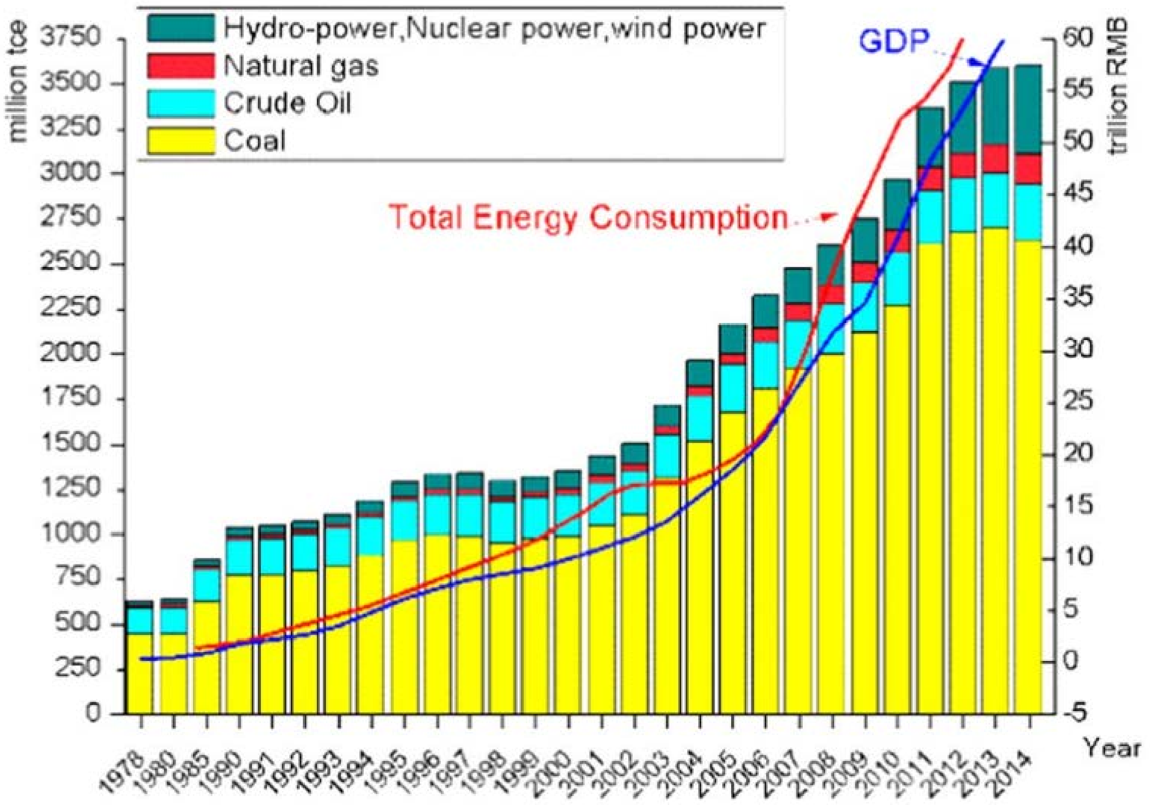

Fig. 1. Total production of energy and its composition in China[1]

coal-based energy

- shortages of resources
- low energy efficiency
- high emissions
- environmental damage
- lack of effective management systems

alternative

renewable energy

- hydropower
- wind power
- solar power
- biomass power

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1. *Zhang, Wang et al.* 2017

Background

In China, the exploitable wind energy potential is 600–1000 GW onshore and 400–500 GW offshore.

The distribution of wind power in China is uneven and not matched with economic development

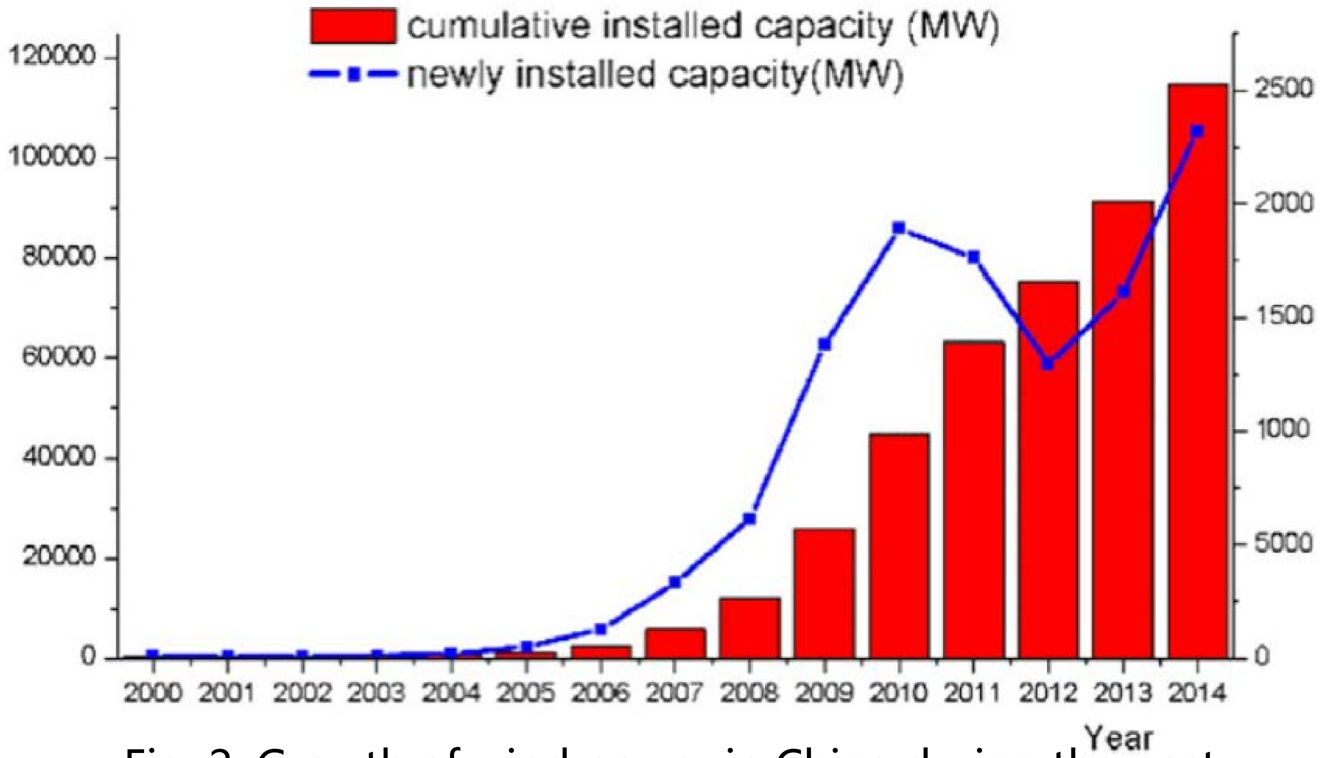

Fig. 2. Growth of wind power in China during the past decades.(Source:CWEA)

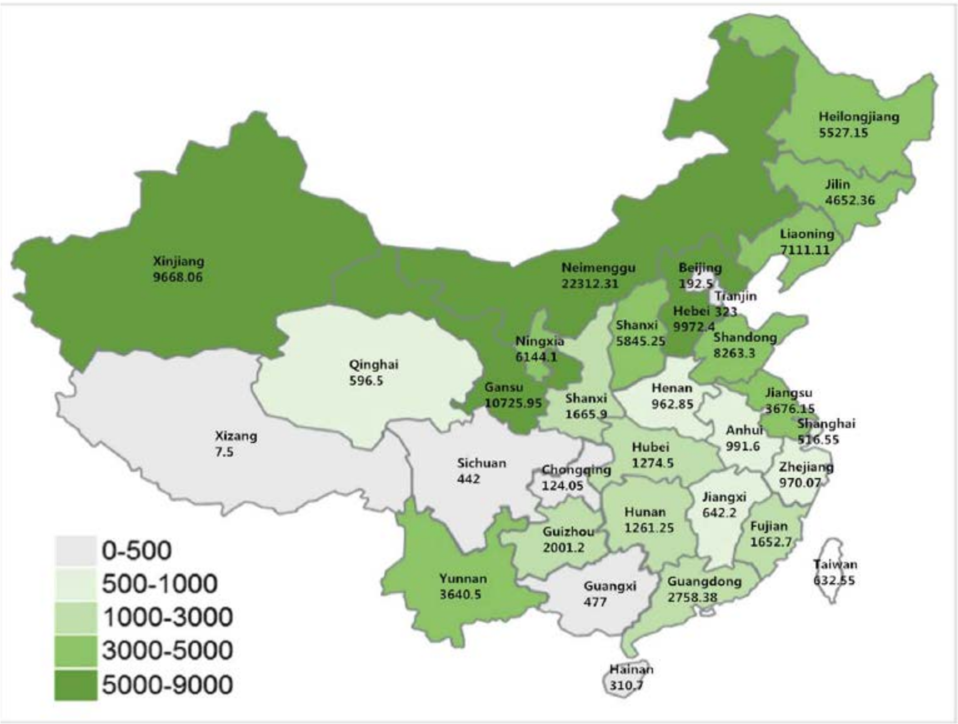

Fig. 3. Cumulative installed capacity of wind energy in different regions of China in 2014 (MW). (Source: CWEA, 2015).

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Technologies

wind energy → mechanical energy

wind energy → mechanical energy → electric energy

wind power generation

Technologies

Onshore wind power generation

1981, Danish
long history of development
very mature

Offshore wind power generation

1991, Danish
high and stable wind speed
no land occupation
no noise pollution

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Current situation

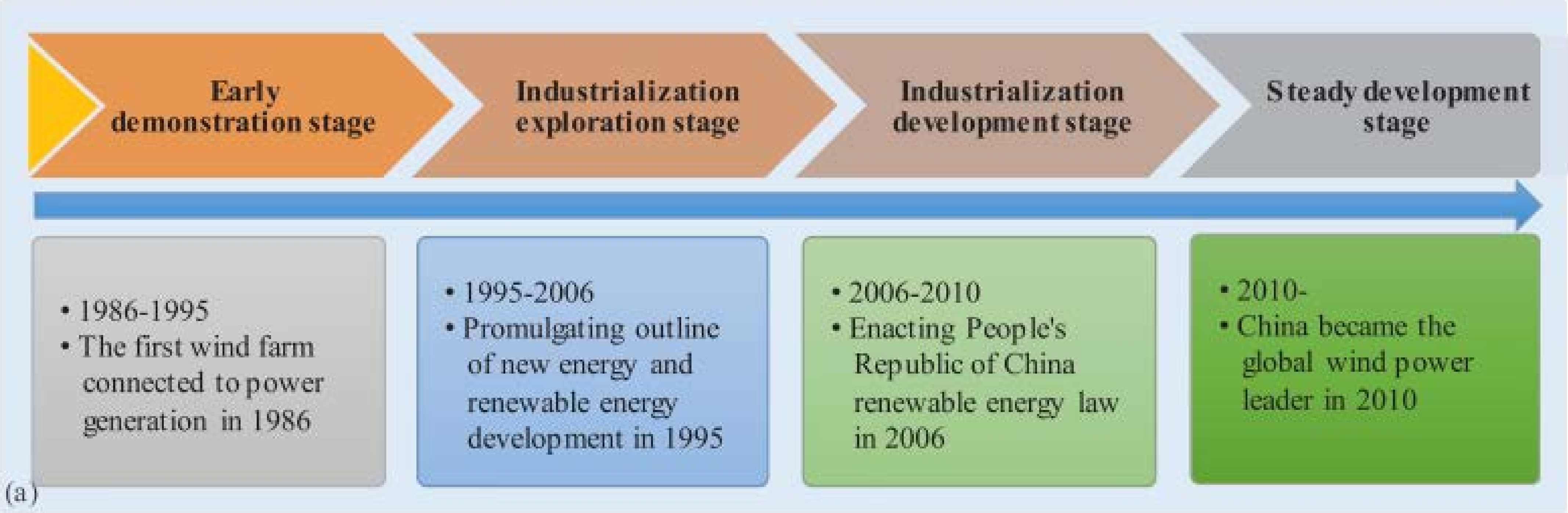

Fig. 4. Four stages of wind power development in China[1].

1. *Dai, J, et al.,*2018, *Renewable and Sustainable Energy Reviews*

Current situation

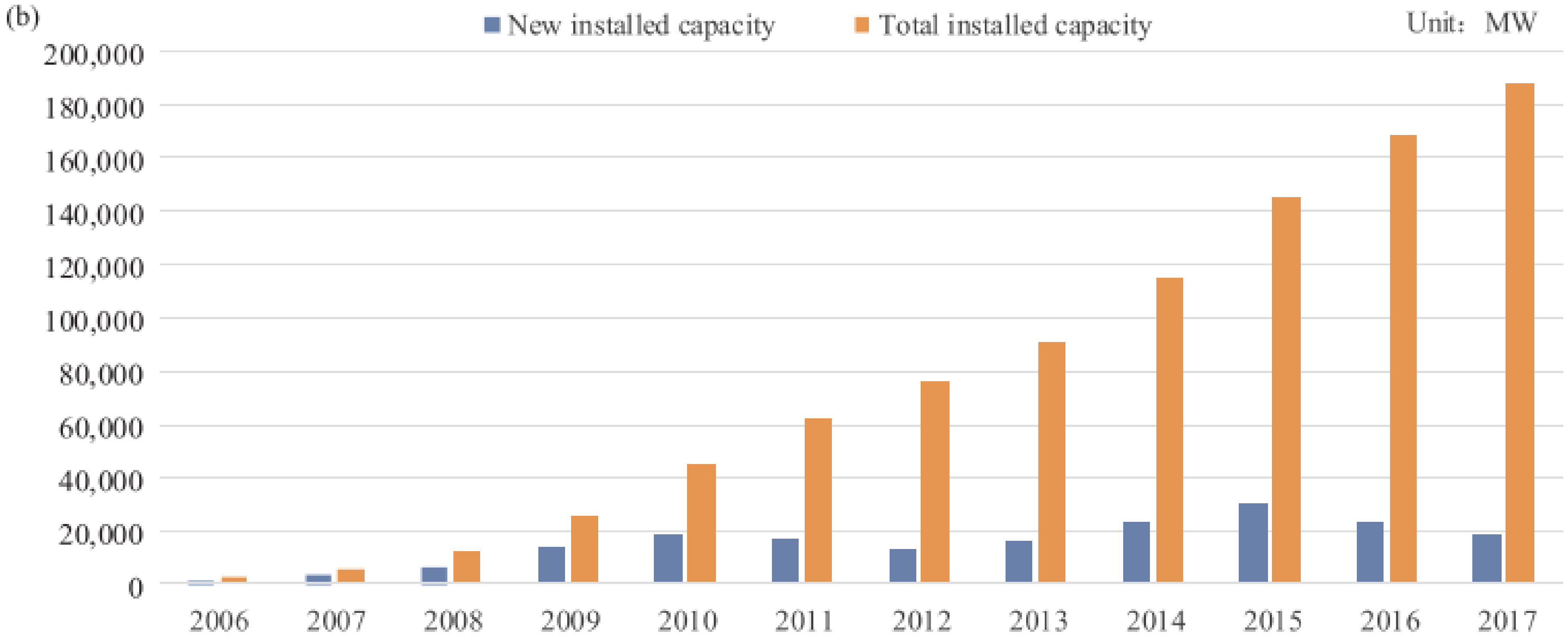

Fig. 5. Installed capacity from 2006 to 2017.

Current situation

Fig.6. Annual average land wind power density in China (2017).

Current situation

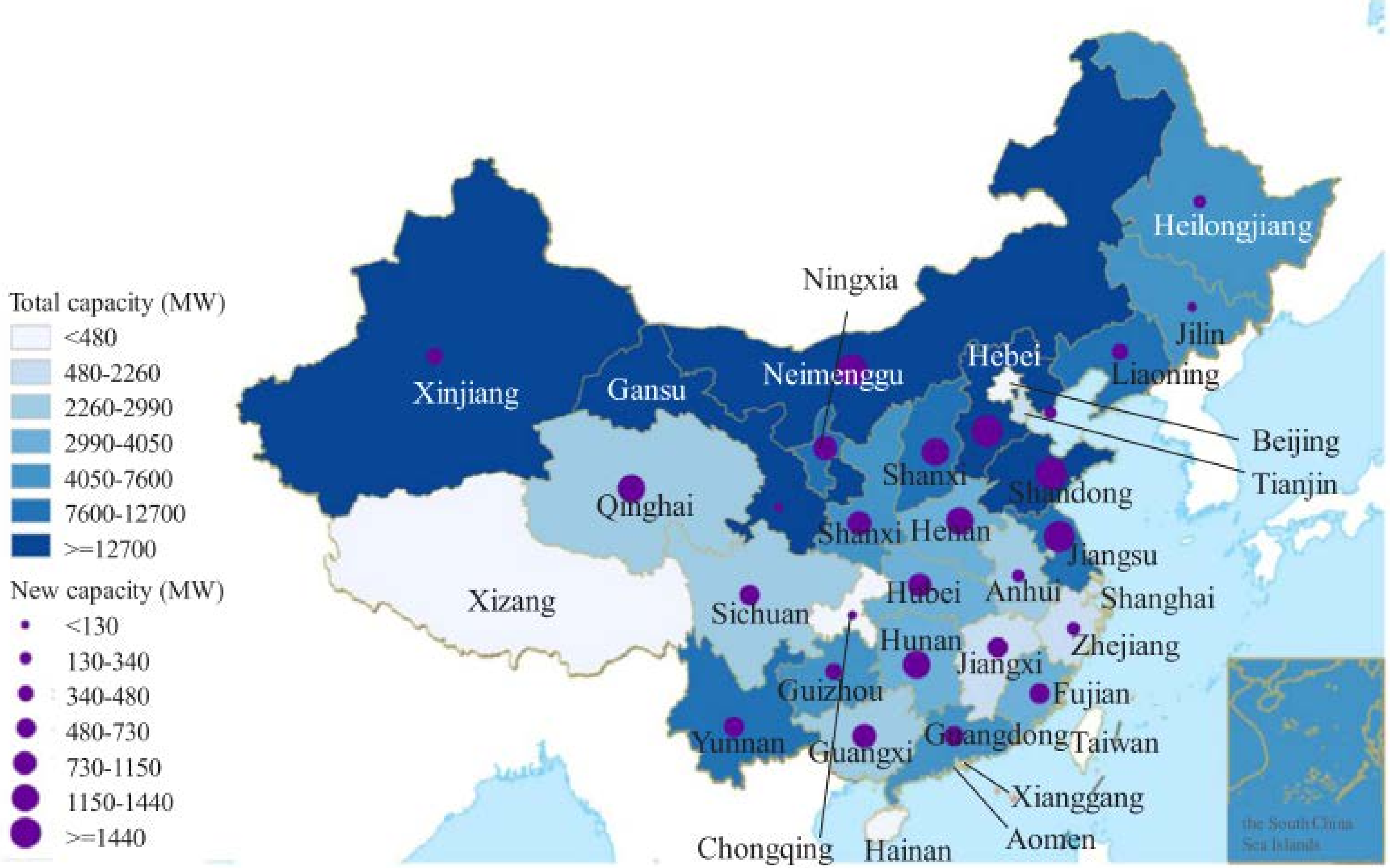

Fig. 7. Total installed capacity and new capacity in provincial regions in 2017.

Case study - Offshore Wind Farm

Shanghai Donghai Bridge Wind Power Farm

Fig.8. The Offshore Wind Farm in Asia—Shanghai Donghai Bridge Offshore Wind Farm[1].

150MW 233 million kWh

222 million RMB (31.3 million USD)

8.6 m/s

8450h

Introduction of the offshore wind farm

1. *Yang T et al.* 2012, *Resear Project Refere .*

Case study - Offshore Wind Farm

Advantages[1]

More rich resource

Better technology

→

8.6 m/s 8450 h

3 MW 4000 h

1. *Zhang Y et al.* 2010,*Design and analysis foundations.*

Case study - Offshore Wind Farm

Disadvantage[1]

Cost

Maintenance

222 million RMB
31.3 million USD

13600～16000 RMB/kW
1922～2261 USD/kW

more corrosion and maintain manually

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1. *Zhang Y et al.* 2010,*Design and analysis foundations.*

Case study - Onshore Wind Farm

Wind energy in Inner Mongolia Autonomous Region

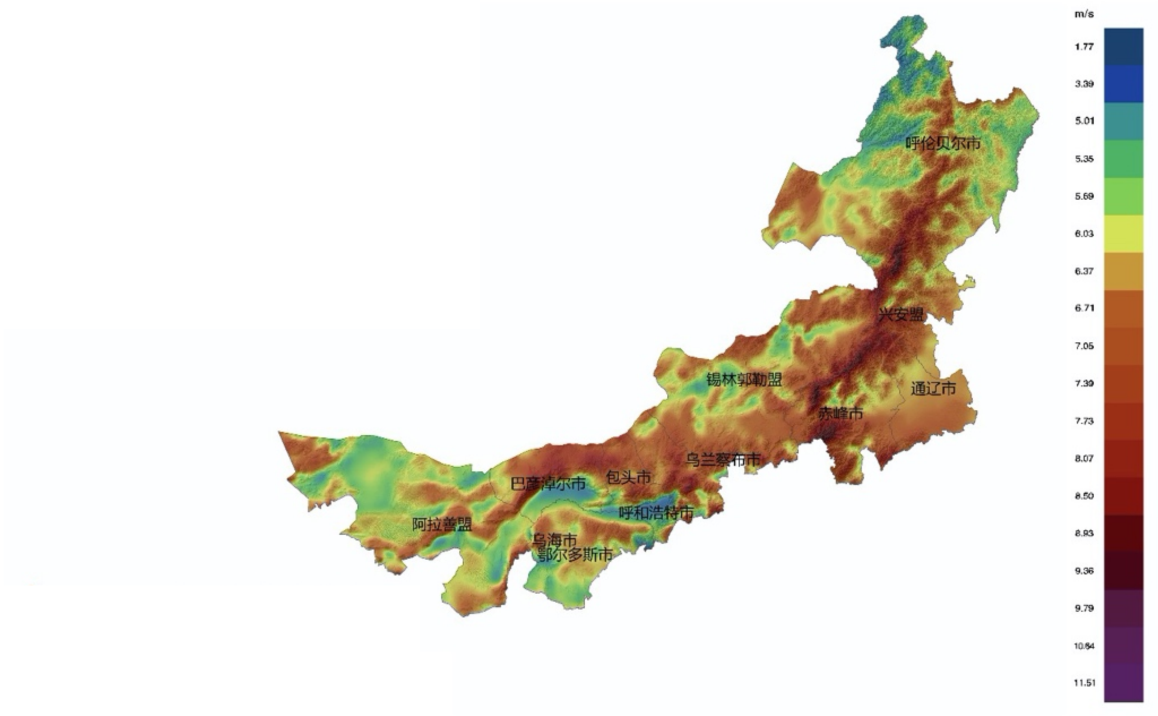

Fig.9. Annual wind speed distribution at the height of 70 m in Inner Mongolia autonomous region[1].

150 W/m², 1.01 million km²

28 million kW

6.37 m/s

An ideal location to build up wind farm

1. *ZHOU Dandan, et al.*, 2018, *Arid area resources and environment.* (In Chinese)

Case study - Onshore Wind Farm

Wind farm in Inner Mongolia Autonomous Region

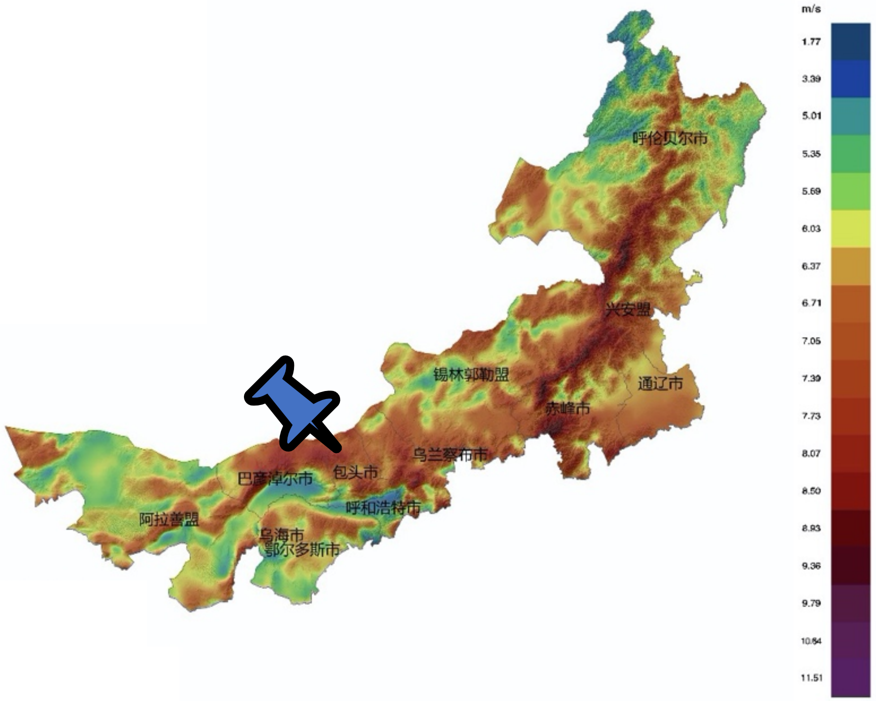

Fig.9. Annual wind speed distribution at the height of 70 m in Inner Mongolia autonomous region[1].

Installed Capacity 100 MW

50 Wind Turbines

Rotor Diameter 87.3 m

Net Power 273,675 MWh/a

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1. *ZHOU Dandan, et al.*, 2018, *Arid area resources and environment.* (In Chinese)

Case study - Onshore Wind Farm

Challenges and opportunities

Wind curtailment
Limited load capacity
& lack of energy transport

Negative effect on local ecosystem
Reduction of
Soil moisture, organic matter
content & biodiversity

V.S.

Policy encouragement

Energy Development Strategy Action Plan (2014-2020)
Thirteenth Five-Year Plan of Industrial Development Plan

Wind power policies in China

Policy development

Tab.1. Wind power policy evolution over different periods[1]

	Early demonstration (1986-1994)	Industrialization exploration (1995-2002)	Industrialization development(2003-2007)	Large-scale development (2008-2017)
Backgroud	(1)Technology in developed countries was mature (2)China's technological research had just begun	(1)Technology in developed countries had improved (2)China's technology still lagged	(1)Rapid development in developed countries (2)China's technology had gradually matured	(1)Wind power had expanded globally (2)China had mastered key technologies for MW-size wind turbines
Major policy objectives	Technological R&D	Technology breakthrough and industrialization applications	Localization and industrialization of wind power equipment	(1)Large-scale development of wind power industry (2)International competitiveness
Focal policies	(1)Direct subsidy at the R&D measures of wind turbine (2)Loan for constructing small-scale demonstration wind farms by importing foreign wind	(1)Continuing subsidy at the R&D (2)Loan projects for construction wind farms (3)Compulsory acquisition, debt serving electrical price600 KW wind turbine within dependent intellectual property rights	(1)Concession tender programs (2)Government guide prices (3)Establishment RE fund (4)National wind power equipment standards	(1)FYP for wind power (2)The on-grid FIT in four regions ‘ categories (3)National wind power industry standards and regulations (4)Export tax rebate
Development results	Accumulated wind R&D techniques	600 KW wind turbine with independent intellectual property rights	(1)Increased localization rate (2)Total installations ranked the fifth in the world	(1)Leading the global wind power market (2)95% localization rate (3)Export to 28 countries

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1. *Yuan L, et al.*, 2019, *Environ Sci Pollut Res Int*

Wind power policies in China

Policy charictaristics

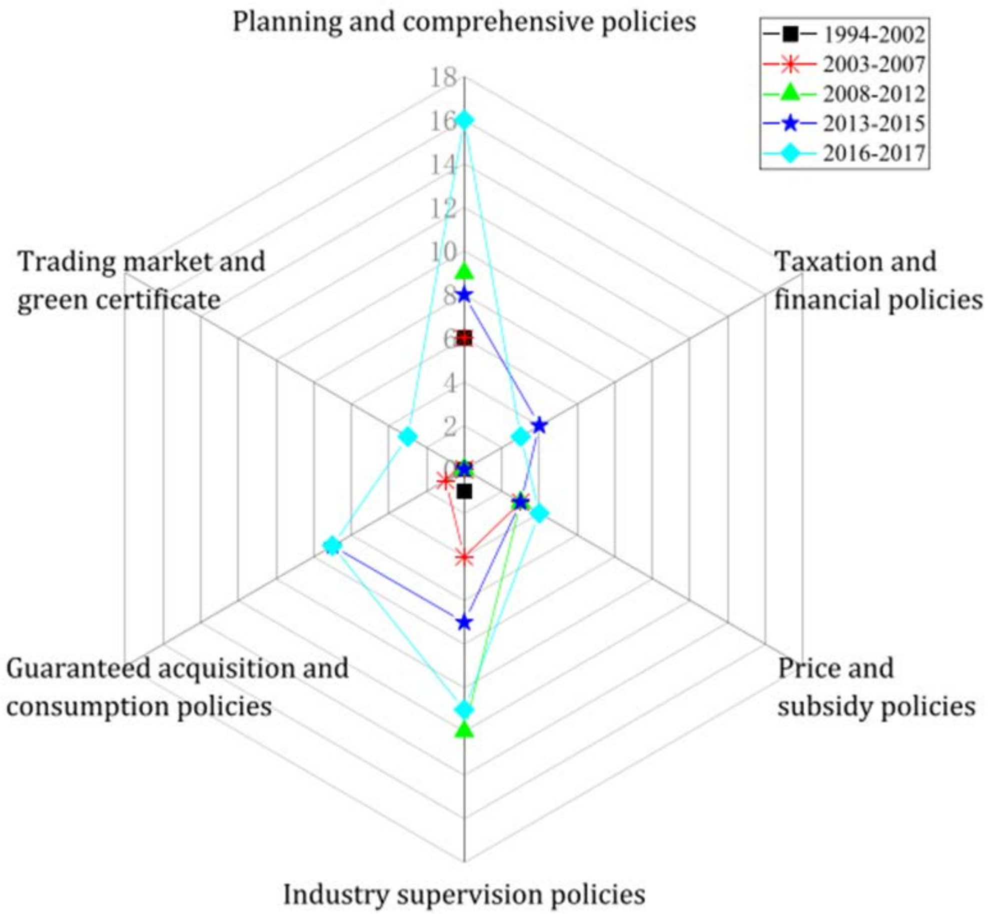

Fig.10. Status of wind power policy tools for different periods in China[1]

- More attention given to the wind power
- Gradually became diversified and combinatorial applications
- From supplementary energy to alternative energy
- Switching from resource-centered strategy to demand-centered strategy
- Simultaneous development of centralized and dispersed wind power

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1. *Yuan L, et al.*, 2019, *Environ Sci Pollut Res Int*

Wind power policies in China

Policy limitations & suggestions[1]

Limitations

- ☹ A lack of consideration on the difference of the wind power development stage
- ☹ An insufficient emphasis on policy stability
- ☹ Not enough attention paid to the economic difference
- ☹ Plagued by wind power curtailment problem

Suggestions

- ☺ Establish long-term development goals on wind power
- ☺ New problems in the eastern and southern areas
- ☺ FIT and subsidy reduction matched to the degree of technical improvements
- ☺ Formulate supporting measures on land and finance to mitigate the impact of auction and free subsidy

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1. *Yuan L, et al.*, 2019, *Environ Sci Pollut Res Int*

Thank you!

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