An Overview on the Status Quo of Onshore and Offshore Wind Power Development and Wind Power Enterprise Localization in China

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Abstract:

A series of main supporting policies implemented by the government from 2009 to 2016 is summarized in this paper. Due to the lack of studies on wind energy development in China up to the 13th Five Year Plan, this paper aims to provide a systematic overview on the evolution and implementation of onshore and offshore wind power development, as well as analyse the localization and competitiveness of wind power enterprises. This paper introduces how the Chinese government efficiently promote the drastic wind power development by means of fiscal and non-fiscal policies, which includes stimulating the wind power investment, addressing the wind power curtailment problem, localizing the Chinese-owned manufacturers in domestic markets and internationalizing the exposure of Chinese-owned enterprises. This paper concludes that the effectiveness of wind power policies enacted is high, and they play a vital role in Chinese wind power market.

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KEYWORDS: Wind power; Curtailment rate; Capacity factor; Industry localization; Policies; Competitiveness.

Abbreviations[1]:

FYP	Five Year Plan
UNFCCC	United Nations Framework Convention on Climate Change
CDM	Clean Development Mechanism
REL	Renewable Energy Law
NDRC	National Development and Reform Commission
MF	Ministry of Finance
SC	State Council
FIT	Feed-in-Tariff
CWEA	Chinese Wind Energy Association
NEA	National Energy Administration
SGCC	State Grid Corporation of China
CSG	China Southern Power Grid Corporation
SOEs	State-owned enterprises
NEB	National Energy Bureau

[1] The explanation of all the abbreviations are attached in Appendix A

1. Introduction

Climate change and global warming cause negative impacts on the ecology. The most influential factor to aggravate global warming is the industrialization in the past 150 years, which has raised the average temperature of the earth's surface by 0.85^{o} C (Handbook of Environmental and Sustainable Finance 2016). Realising that tackling the climate change problem requires the cooperation and supervision among different countries, in June of 1992, 189 countries reached the consensus to form an international treaty known as United Nations Framework Convention on Climate Change (UNFCCC). Thereafter, in 1997, Kyoto Protocol was adopted by UNFCCC and proposed the Clean Development Mechanism (CDM) that assigned duties to developed and industrialized countries, with the obligation to implement greenhouse gas mitigation projects in developing countries to achieve their specific targets in the Protocol. As a developing country, China was not required to set limits on the greenhouse gas emissions. However, the dramatically fast development of China's economy after millennium makes China the largest consumer of traditional energy and the largest emitter of greenhouse gas, which is due to China's energy dependency on coal (68.5%, in 2016) and oil (18.9%, in 2016) (BP Statistical Review of World Energy 2017). The rapid development of China's GDP highly depends on sufficient and reliable power supply (Shen and Luo 2015). Meanwhile, renewable energy technology becomes mature in developed countries. To reduce the emission of greenhouse gas and other pollutants, the Chinese government decided to develop renewable energy to replace the air-polluting traditional energy by enacting Renewable Energy Law (REL) in 2005, and then implemented an amended version of REL in 2009. Thereafter, the National Development and Reform Commission (NDRC) has subsequently enacted a series of legislation and regulations to expand the dissemination of renewable energy, of which the subsidy and incentive policies by the Ministry of Finance (MF) are the majority.

Table 1. Summarizes the core policies that the government has implemented to boost the development of onshore and offshore wind power and the localization of wind power enterprises. The main issuers also include the State Council (SC), NEA (National Energy Association) and NEB (National Energy Bureau) besides NDRC and MF. The SC is the highest administrative organization of China. It directly supervises the various subordinate bodies in the renewable energy decision-making system, including the State Electricity Regulatory Commission (SERC), the NDRC, the MF and the Ministry of Science and Technology (MOST). The SERC supervises the electricity system of the state. The National Energy Leading Group and the NDRC are two major institutes under SC to formulate renewable energy price measures. The MF is the national executive agency which administers macroeconomic policies and the national annual budget and at the same time handles fiscal policy, economic regulations and government expenditure for the state (State Council 2014).

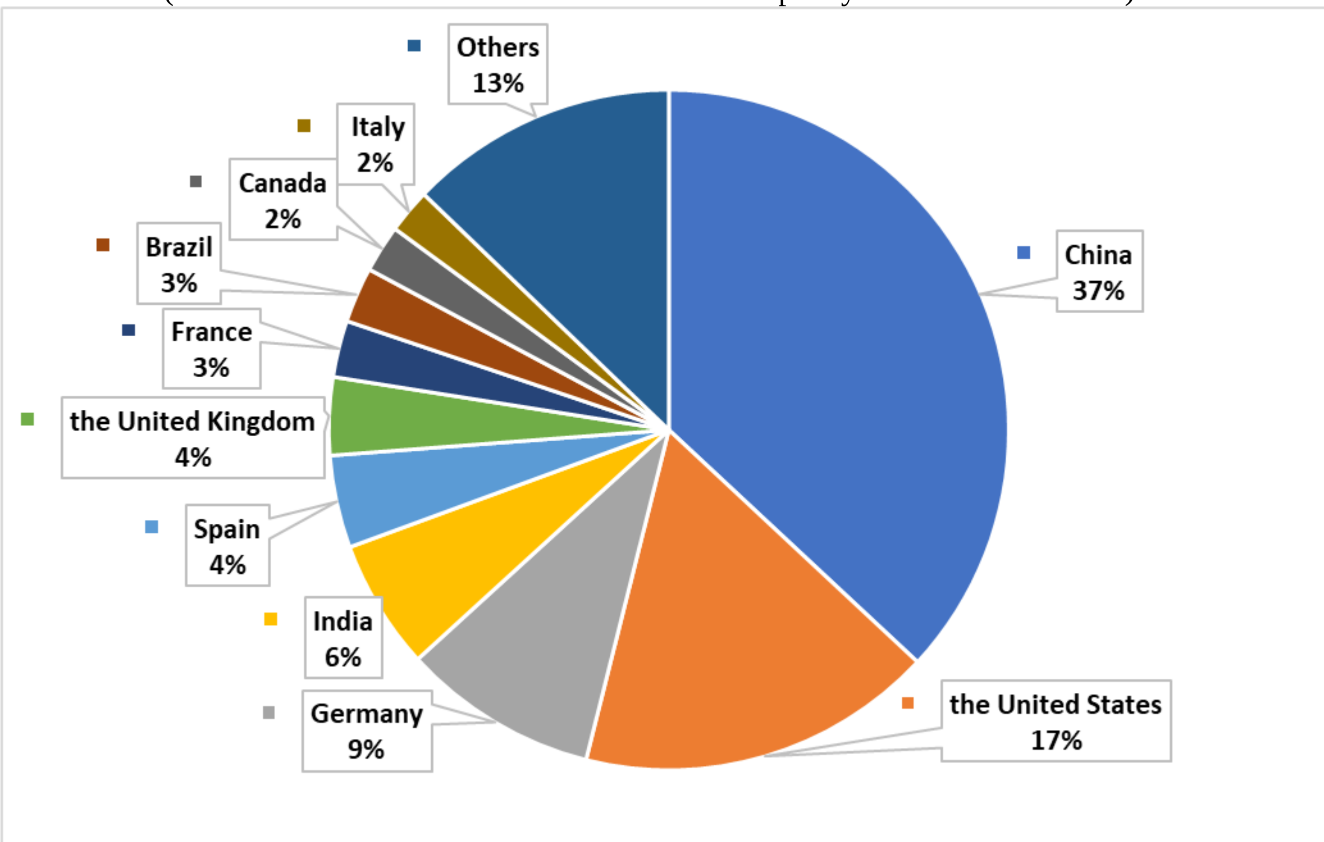
Table 1. Core wind power supporting policies implemented by the government.

Policy	Issuer	Year	Objectives
the *Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy*	The NDRC	2009, 2014, 2015, 2016, 2017	Gradually decrease the wind FIT benchmark price in areas located in four wind resource categories. From 2009 to 2018, the wind FIT benchmark price in areas in Category I has been deducted from 0.51 CNY/kWh to 0.40, areas in Category II has been deducted from 0.54 CNY/kWh to 0.45, areas in Category III has been deducted from 0.58 CNY/kWh to 0.49, and areas in Category IV has been deducted from 0.61 CNY/kWh to 0.57.

the *Notice on Curbing the Overcapacity and Redundant Construction of Several Industries and Promoting the Healthy Development of Industries*,	The SC	2009	Solve the wind power overcapacity problem. Improve the healthy development of wind power industries.
the *Notice on Value-added Tax Policy of Wind Power Generation*	The MF	2009	Provides favourable tax preferential incentives for enterprise income tax (EIT) and value-added tax (VAT). The *Notice* stipulated that for wind energy project in China, The VAT was deducted from 17% to 8.5% while the EIT was exempted during the first three years, and then deducted from 33% to 15% during the second three years
the *Opinions for Promoting the Internationalization Development of Strategic Emerging Industries*	The SC	2011	Promote the exportation and internationalization of wind power manufacturers.
the *Notice on Pilot Work on Carbon Emissions Trading*	The NDRC	2011	Announces seven pilot provinces and cities to launch the carbon trading scheme in October 2011, they were Beijing, Shanghai, Fujian, Guangdong, Hubei, Chongqing and Tianjin. During the pilot operation, the carbon price is fluctuated between 5-50 RMB/tCO_2e.
the *Notice of the National Energy Administration Concerning Issuing the Guiding Opinions on Energy-related Work*	The NEA	2012	Requires collecting data on wind curtailment rate and abandoned wind power in order to address relevant problems.
the *Notice on the Feed-in-tariff Policy for Offshore Wind Farms*	The NDRC	2014	Stipulates the FIT price of 0.75 CNY/kWh for the inter-tidal wind power and 0.85 CNY/kWh for the offshore wind power
Notices on Wind Power Grid Connection and Consumption	The NEB	2015, 2016	Privilege the use of wind power areas of heavy wind curtailment rate

After the implementation of a series of supporting policies, the wind power development of China has witnessed to be dramatically increased, as the total cumulative wind power installed capacity in 2018 ranks the top (Fig.1) among various developed countries (REN21 Secretariat 2019).

Fig.1 The share amount of cumulative installed wind capacity in wind energy leading countries to the world (worldwide total onshore wind farm installed capacity is 568.4GW in 2018).



To systematically help the readers understand the status quo of the onshore and offshore wind power development in China that is regulated and oriented by the aforementioned policies, this paper is organised as follows: the research aims and objectives are stated in Section 2, the research methodology is introduced in Section 3, the main body is arranged in Section 4 and Section 5, and finally is it followed by the conclusion section.

2. **Research Aims and Objectives**

The key features of existing review papers on the wind energy policies and wind energy development in China are summarized as follows: (1) At a national level, the details (laws or regulations) of national wind energy policies are provided or compared with those of other countries; (2) Installed capacity is the main indicator for evaluating the effectiveness of wind energy policies; (3) Relationship between the wind energy policies and the wind power development is not clearly described.

This work will fill the research gap in terms of the following aspects (1) The wind energy policies and the development of wind energy are based on 31 administrative areas (provinces, autonomous regions and municipalities, see Appendix B, instead of only at a national level; (2) The timeline of the collected data is continuous from 2005 to 2018 while the previous reviews reported data up to 2012, which means that the development of wind energy during the 12th FYP and the 13th FYP is incomplete in the existing literature but is covered in the present paper; (3) The indicators for effectiveness evaluation include not only installed capacity (both cumulative and newly added installed capacity), but also other parameters such as the amount of wind power connected to grid, wind farm capacity factor, abandoned wind power, wind curtailment rate (4) The localization and industrialization of wind power enterprises are demonstrated, including onshore and offshore wind turbine manufacturers and wind power developers (5) The competitiveness of wind power enterprises is illustrated by means of Social Network Analysis (SNA), which provides the readers a straightforward visual grasp of the competitive relationships among wind power enterprises.

3. Research Methodology

3.1. Data Collection

A series of data is collected from the official websites of government (such as State Council, National Development and Reform Commission and National Energy Association, etc), research institutions (such as Chinese Wind Energy Association), official documentation (such as Statistical Yearbook China), journal articles and the official website or reports of wind power enterprises. It should be noted that the data of provincial-based wind power connected to the grid, abandoned wind power and wind curtailment rate are available only from year 2013, because the National NEA stipulated the *Notice of the National Energy Administration Concerning Issuing the Guiding Opinions on Energy-related Work in 2012* (National Energy Administration 2013). The wind farm capacity factor (C, in the unit of %) is then calculated by the following formula:

$$C= \coprod n/(Pt*h)$$

This theoretical formula is widely employed for simplifying the calculation process of the wind farm capacity factor in the field (Cheng and Yu 2013; Xu and Zhong 2014), where $\coprod n$ denotes the amount (GWh) of generated wind power connected to grid; Pt denotes the rated wind power capacity (MW); and h denotes the total annual hour, which is equal to 8760 hours.

3.2. Social Network Analysis

Social Network Analysis (SNA) is a methodology that identifies correlation of participants and their performance in a social network (De-Marcos et al. 2016; Milovanović et al. 2019). In this study, it is employed to depict the competition relationship among manufacturers and developers. SNA is able to map the flows and competition strengths among each enterprise based on their market share ranking of wind power installed capacity. The firm nature is denoted by different shapes and colors of legend, and the cumulative wind power installed capacity of enterprise is denoted by different size of legend. The links between every two nodes represent the existence of significant competitive relationships. The direction of the links indicates the competition direction of two competitors and the width of links indicates the strength of competitiveness. The data source mainly comes from the Chinese Wind Energy Association.

4. Status Quo of Onshore and Offshore Wind Power Development

4.1. Cumulative and Newly added Wind Power Installed Capacity

4.1.1. Onshore Wind Power Development

The *Notice on Improving Wind Energy Generated Electricity On-grid Power Tariff Policy* stipulated by the NDRC classified China into four wind resource areas and provide Feed-in Tariff (FIT) as subsidies to the wind power developers. Zhao et al. (2016) applied fixed effect model and random effect model to analyse the policy effect on wind power generation in China and the results indicated that FIT policy had a greater impact than non-price policy. The classification criteria and historical FIT benchmark price levels are explained in Appendix C[2] and D. It is remarkable that the FIT benchmark price differentiation is a highlight of the policy and it indeed helps the government solve the regionally inconsistent problem between wind power overcapacity and electricity consumption.

Fig.2 and Fig.3 illustrate the cumulative and newly added wind power installed capacity (MW) in China from 2005 to 2018 by 31 administrative areas, respectively. Among the 31

[2] Appendix III introduces the wind resource areas in China, which are Category I, II, III and IV, it also introduces the six regional power grids in China (North, Northeast, Northwest, South, Central and East) classified by geographical location. The following paper will directly use these terms.

provinces/autonomous regions and municipalities, Inner Mongolia (30,570 MW), Xinjiang (19,912 MW), Hebei (17,448MW), Shandong (14,142 MW), Gansu (13,115 MW), Ningxia (10,740 MW), Jiangsu (9,396 MW), Liaoning (8,788 MW), Yunnan (8,635 MW) and Heilongjiang (6,692 MW) are the top ten regions in terms of the cumulative wind installed capacity by the end of 2018. In particular, Shandong, Jiangsu, Liaoning and Yunnan are located in wind resource area of Category IV. The increase rate of wind power installed capacity is almost as tenfold as that in Shandong (1,219 MW) and Jiangsu (1096 MW) in 2016, Liaoning (2,425 MW), and even as much as seventy times in Yunnan (121 MW) in 2009. Before 2011, the most amount of newly-added wind power installed capacity is added to the regions located in North, Northeast and Northwest China grids. However, after 2011, plenty amount of wind power installed capacity is found to be added in the regions located in South, Central and East, such as Yunnan, Guizhou, Guangdong, Jiangsu, Hubei and Hunan. Take Yunnan and Jiangsu as examples, from 2014 to 2016, the amount of newly-added wind power installed capacity in Yunnan reaches 5,485 MW, which accounts for 64% of the cumulative wind power installed capacity by the end of 2018. The deployment of offshore wind farm in Jiangsu is proved notable success, that the amount of newly-added wind power installed capacity is 5719 from 2015 to 2018 and accounts for more than a half of the cumulative wind power installed capacity by the end of 2018.

Fig.2 Cumulative onshore wind power installed capacity in China

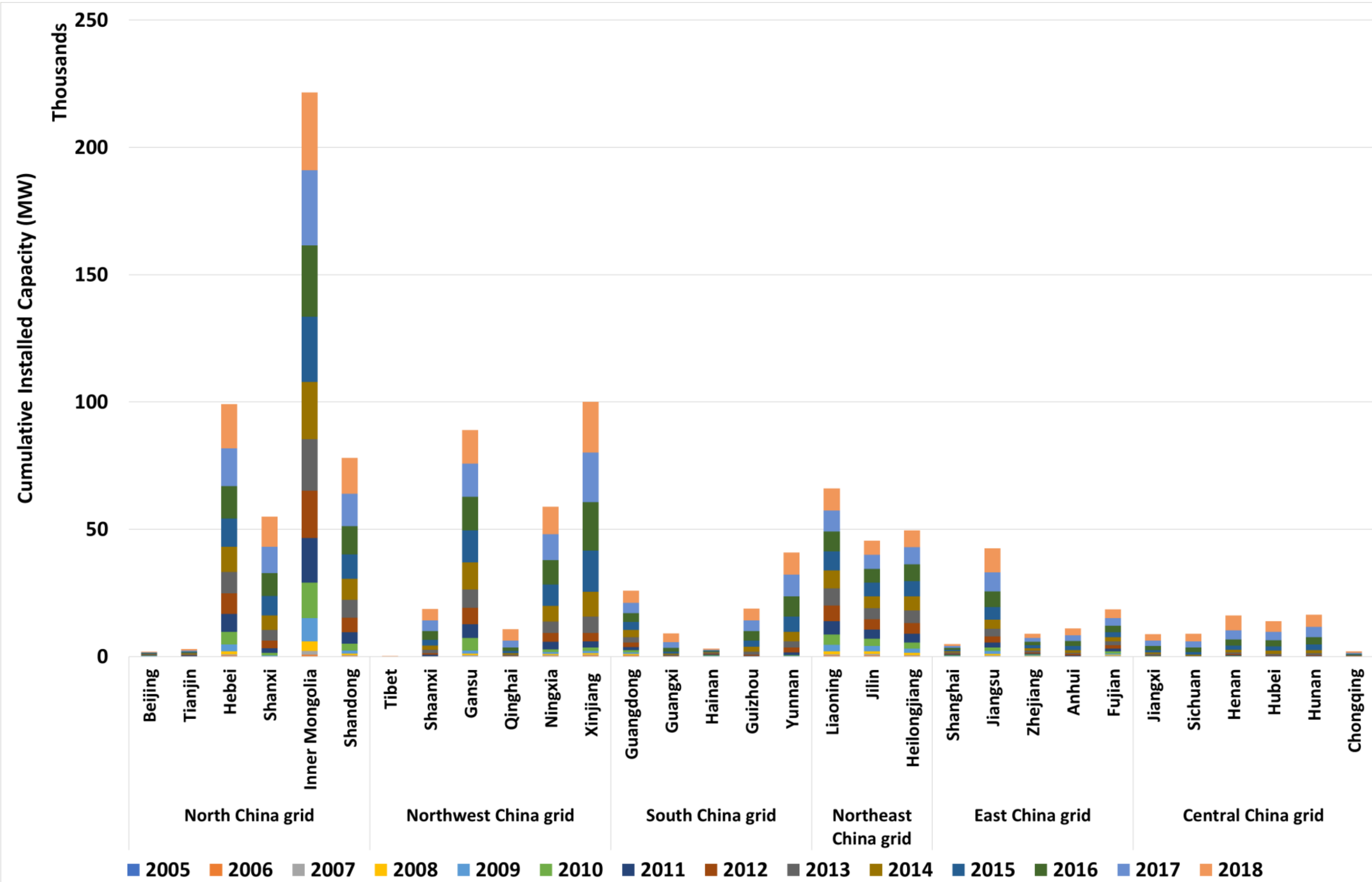
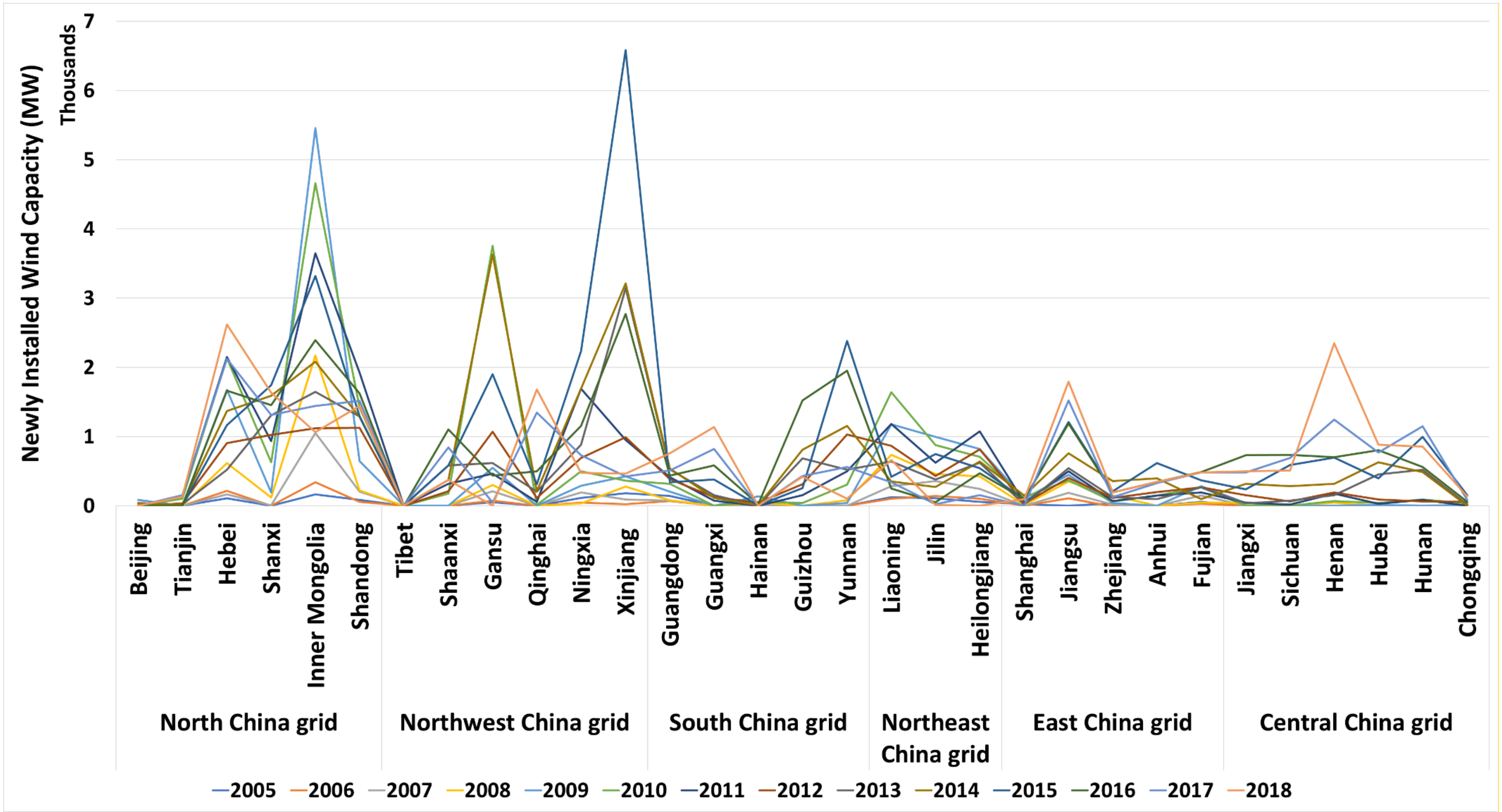


Fig.3 Newly-added wind power installed capacity from 2005 to 2018.



The impact of subsidy advantages stipulated in FIT policy of wind farm construction in the regions located in Category IV is illustrated in Fig.4 The share of cumulative wind power installed capacity in Category I, II and III indicates a parabolic line from 2005 to 2018, the share amount is found to be stably decreased since 2009. By contrast, the share of cumulative wind power installed capacity in Category IV increases from 28% to 50% from 2009 to 2018, and is foreseeable to exceed the share amount in Category I, II and III from 2019 on. The price differentiation of FIT policy has stimulated the development of wind power in poor wind resource areas, except from Jiangsu and Yunnan that are aforementioned, Guangdong (4,806 MW) and Guizhou (4,638 MW) in South China grid, Fujian (3,475 MW) and Anhui (2,629) in East China grid, as well as Henan (5,956 MW) and Hunan (4,827 MW) in Central China grid are witnessed great development. With reference to Fig.5 by the end of 2018, North China grid and the Northwest China grid are two leading grids with the total grid-connected wind power of 135,200 GWh and 88,610 GWh, respectively, followed by the South China grid (39,800 GWh) and the Northeast China grid (39,500 GWh). The East China grid and the Central China grid have the grid-connected wind power of 34,400 GWh and 28,500 GWh, respectively. Fig.6 depict the regional electricity consumption in China from 2005 to 2017. It is found that the load centres of electricity consumption areas are clustered in North China grid and East China grid (each accounts for 24.8% of national electricity consumption), followed by Central China grid (17.6%) and South China grid (16.8%), which are non-rich wind resource areas. For comparison, the abundant wind resource areas share only around 16% of the national total electricity consumption (with Northwest China grid of 10.1% and Northeast China grid of 6.0%). Therefore, the quick development of wind power installed capacity in Category IV is expected to balance the inconsistency between wind power generation and grid power planning, which could release the electricity generation burden in load centres.

Fig.4 The proportion of wind power installed capacity in four categories to the national total wind power installed capacity from 2005 to 2018.

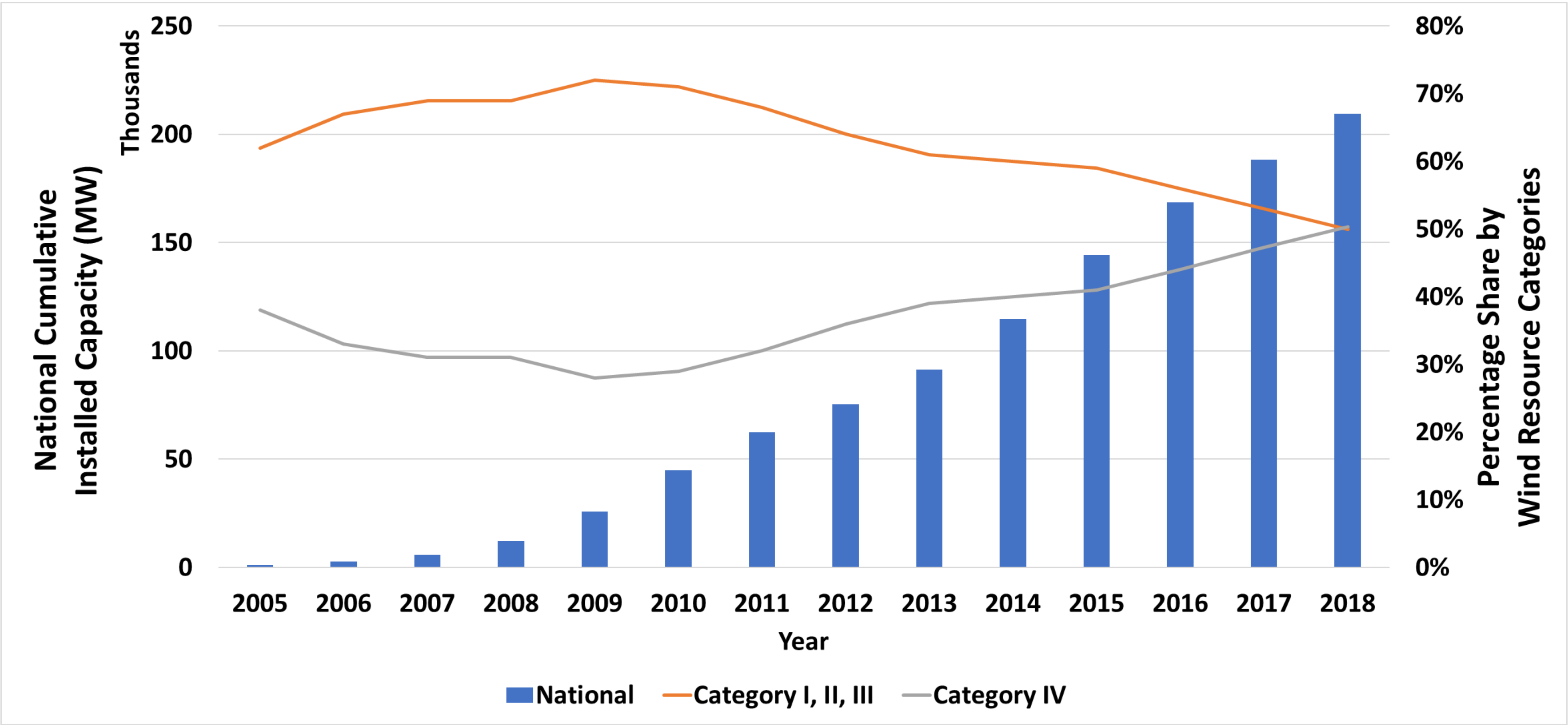


Fig.5 Cumulative grid-connected wind power by regional power grids from 2013 to 2018.

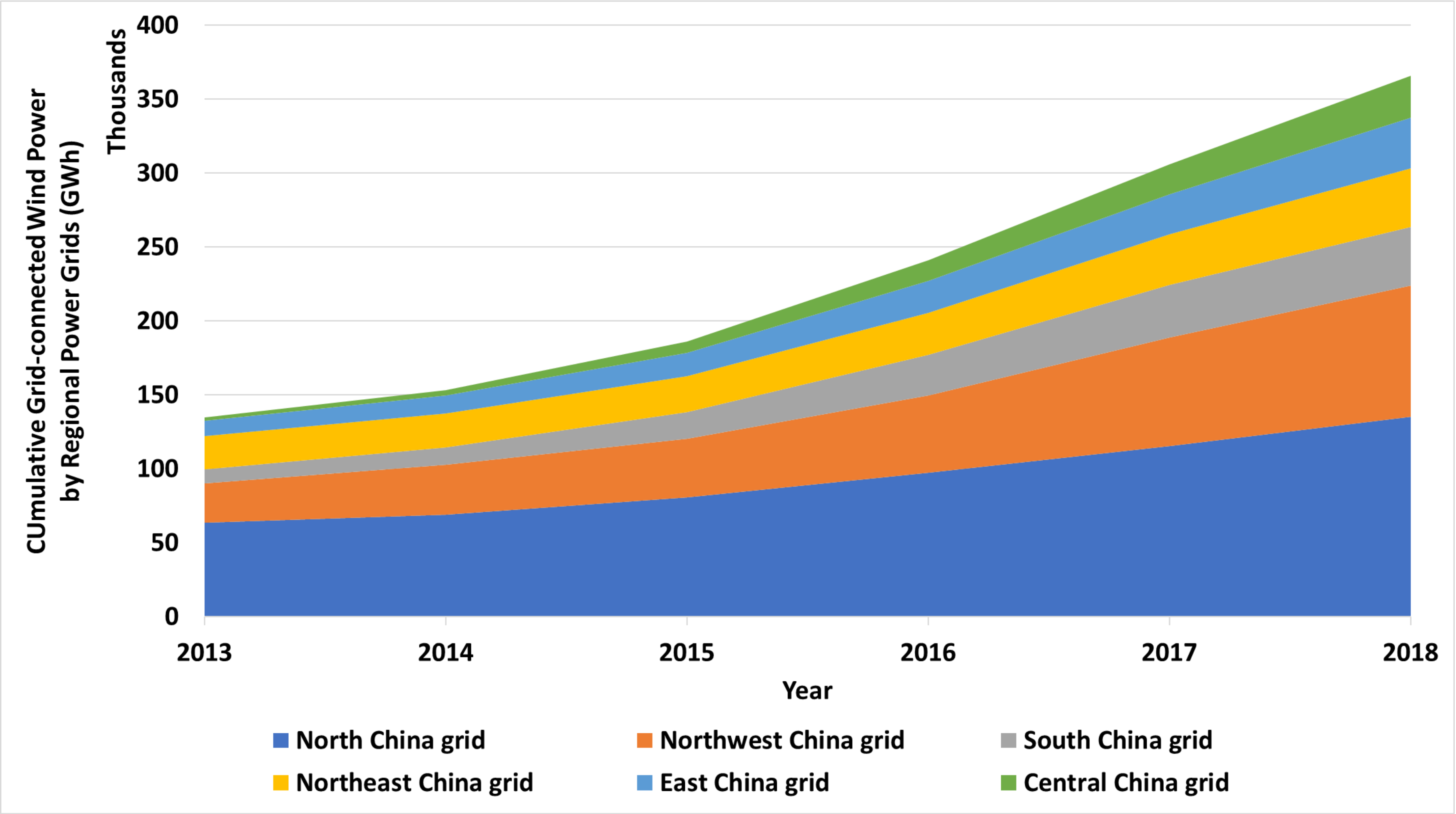
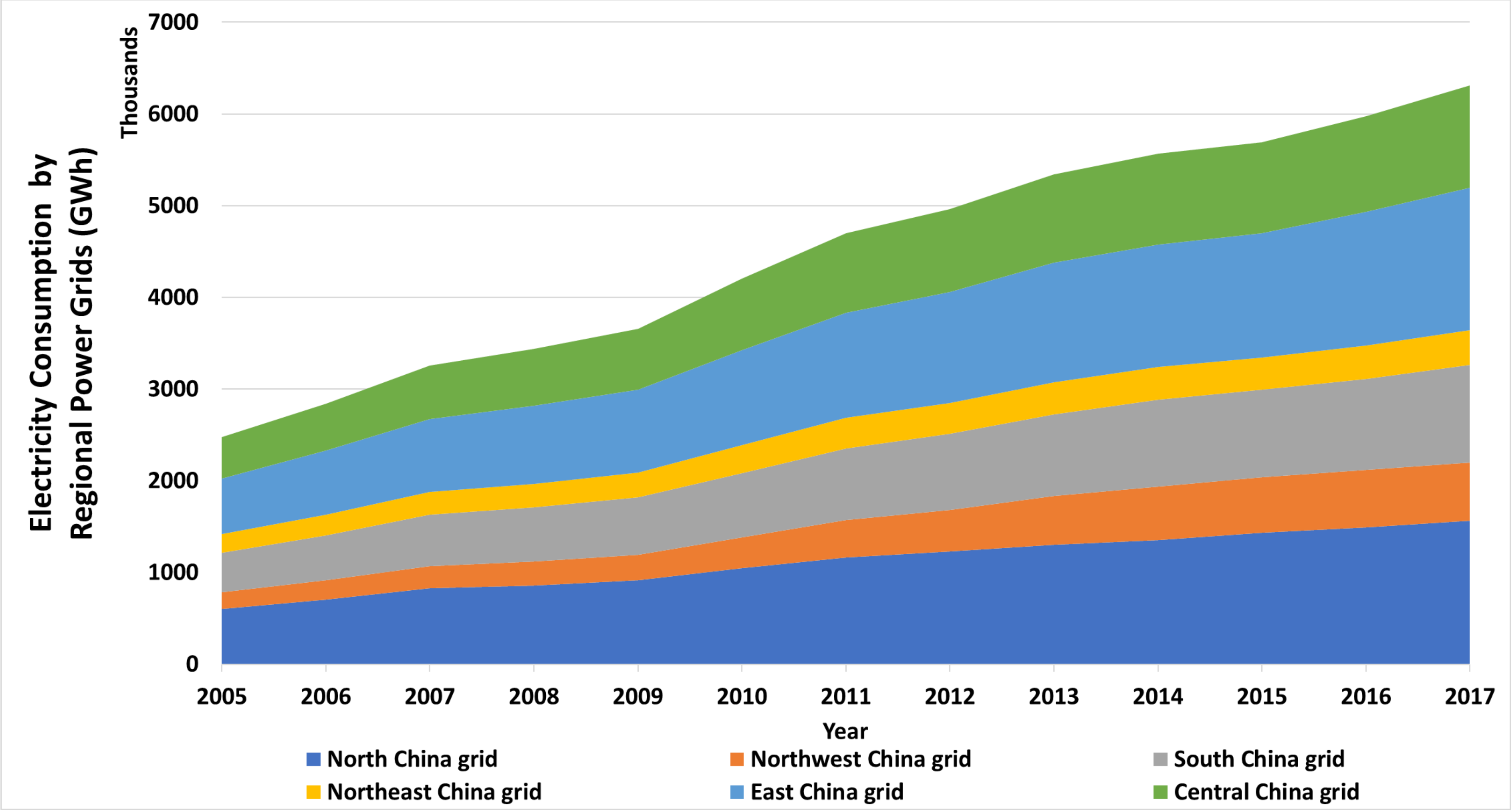


Fig.6 Regional electricity consumption in China from 2005 to 2017

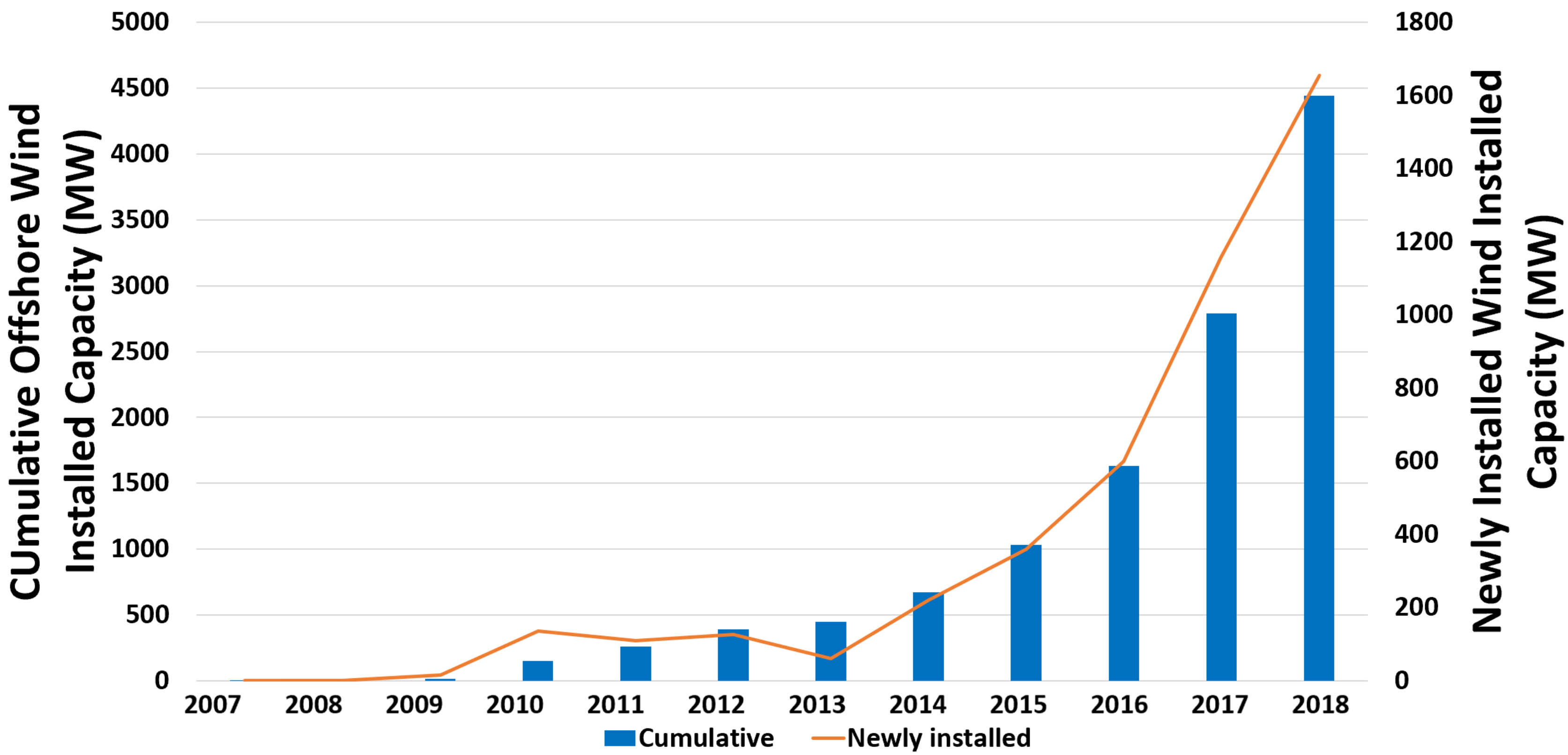


4.1.2. Offshore Wind Power Development

In year 2003, the Wind Power Concession Program was enacted by NDRC to encourage the development of wind power generation in coastal provinces. The *Wind Power Concession Program* allowed invited investors for large wind power projects to submit tender offers to specify their willingness of the lowest bidding price. Then the investor with the lowest bidding price would win the contract and the government would purchase the generated wind power. However, this bidding strategy has led to negative interfering mode since State-owned enterprises (SOEs) are able to offer lower bidding price due to fewer budget constraints than other enterprises (Liu and Kokko 2010; Q. Wang 2010). Consequently, some wind power projects under wind concession program encountered severe delay due to financial deficit and the low quality of wind turbines made the wind power projects a waste of resources. To address the excessively low bidding price problem, the NDRC amended the selection criteria of wind power projects from the lowest bidding price to the average bidding price in year 2007, but it was subsequently replaced by FIT policy (Li et al. 2018). In April 2009, the NEA categorized three zones of China's offshore wind sites, namely an "inter-tidal" zone for water depth less than 5m, an "offshore" zone for water depth of 5-50m, and a "deep-sea" zone for water depth more than 50m. From 2009 to 2014, the Chinese government enacted a series of construction management and project planning related policies, which aims to formulate the offshore wind farm construction principles, scopes and standards (Zhao and Ren 2015). such as *"Outline of offshore wind farm projects planning", "Development and construction scheme of offshore wind power", "Interim measure for the management of the development and construction of offshore wind power"*. In year 2014, the NDRC issued the *Notice on the Feed-in-tariff Policy for Offshore Wind Farms*, which stipulated the FIT price of 0.75 RMB/kWh (0.11

USD/kWh) for the inter-tidal wind power and 0.85 RMB/kWh (0.13 USD/kWh) for the offshore wind power, and both prices were eligible for the projects commissioned before year 2017 (NDRC 2014). For the wind farm projects commissioned after year 2017, the FIT prices for inter-tidal and offshore wind power would be deducted by 0.5 RMB/kWh (0.074 USD/kWh). As shown in Fig.7 the FIT policy has greatly encouraged the development of offshore wind energy since 2014. The cumulative offshore wind power installed capacity in 2018 (4,445 MW) is almost eight-fold of that in 2014 (220 MW), and the newly-added offshore wind power installed capacity in 2017 and 2018 even reaches 1,160 MW and 1,655 MW , respectively, which accounts for 63.3% of the cumulative amount.

Fig.7 Newly added and cumulative wind energy from year 2007 to 2018.



4.2. Wind Power Connected to Grid and Wind Capacity Factor

Fig.8 illustrates the wind power connected to the grid from year 2013 to year 2018, as well as the wind capacity factor. Fig.9 demonstrate the national average wind farm capacity factor change trend. It is estimated that, among 31 administrative areas in China, only four regions have an average wind farm capacity factor higher than 20%, including Fujian (24.7%), Yunnan (22.4%), Shanghai (21.9%), Inner Mongolia (20.1%). The national average wind farm capacity factor in 2018 is only 15.9% and is even as lower as 14.7% in 2015. When we look at the wind farm capacity factor by regional power grids, it is found that East China grid ranks the highest of 20%, and its followed by North China grid (17.7%), Northeast Chia grid (17%) and South China Grid (16.3%). Central and Northwest China grids have the lowest wind farm capacity factor as 13.1% and 12.7%, respectively. To have a better understanding of the level of wind farm capacity factor in China, this paper compares the average wind farm capacity factor of China in recent years with those of other prominent countries that mentioned in Fig.1, including the United States, Germany, Spain, the United Kingdom, France, Canada and Italy. By comparison, the United States has an average wind farm capacity factor of above 32%, and the United Kingdom is of around 30%, much higher than other countries. Spain and France have an average wind farm capacity factor of around 25% and 22%, respectively. The average wind farm capacity factors of Italy and Germany are lower than those of the aforementioned countries, but still higher than that of China.

Fig.8 Wind power connected to the grid and wind capacity factor in China from 2013 to 2018

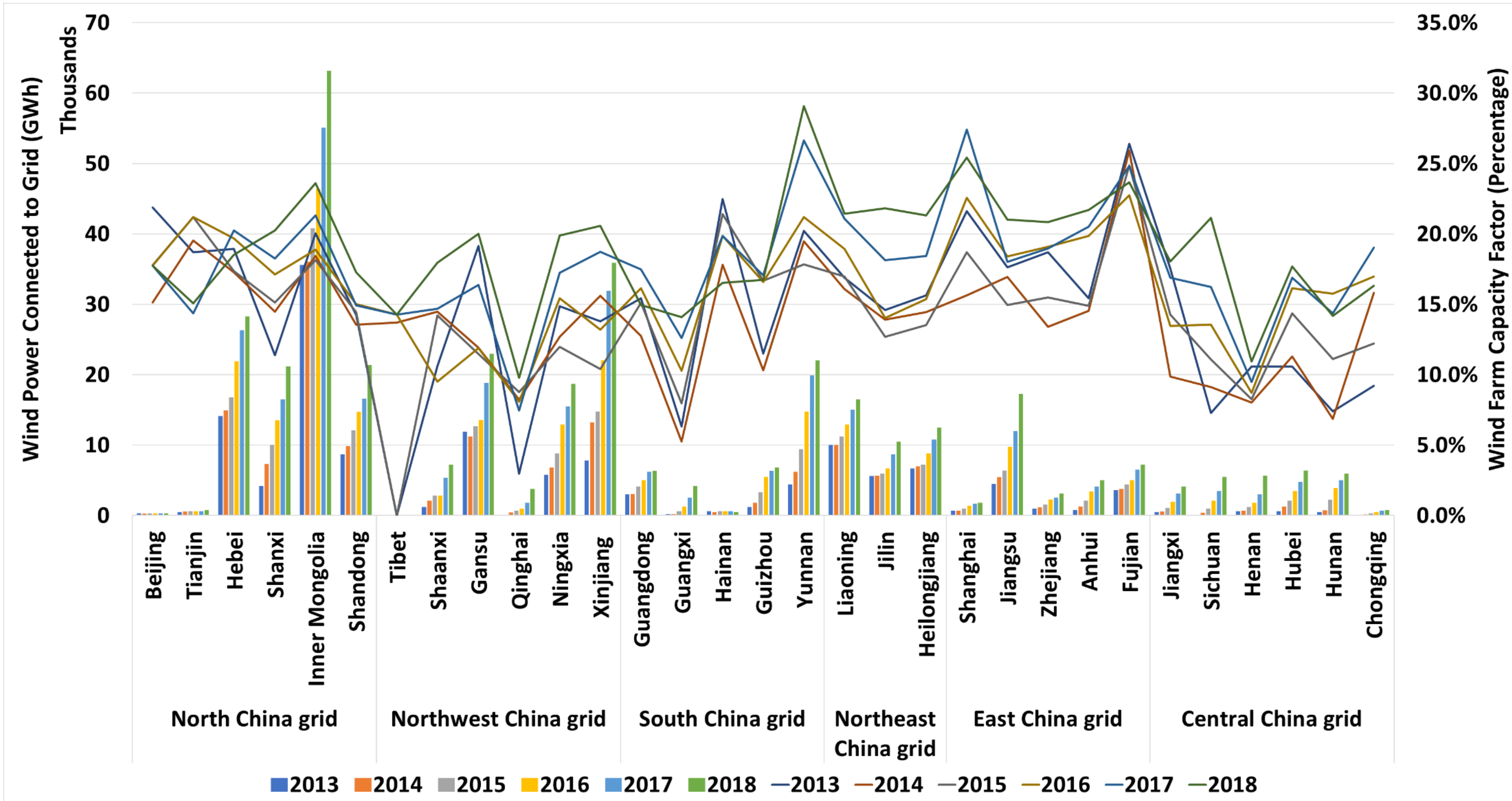
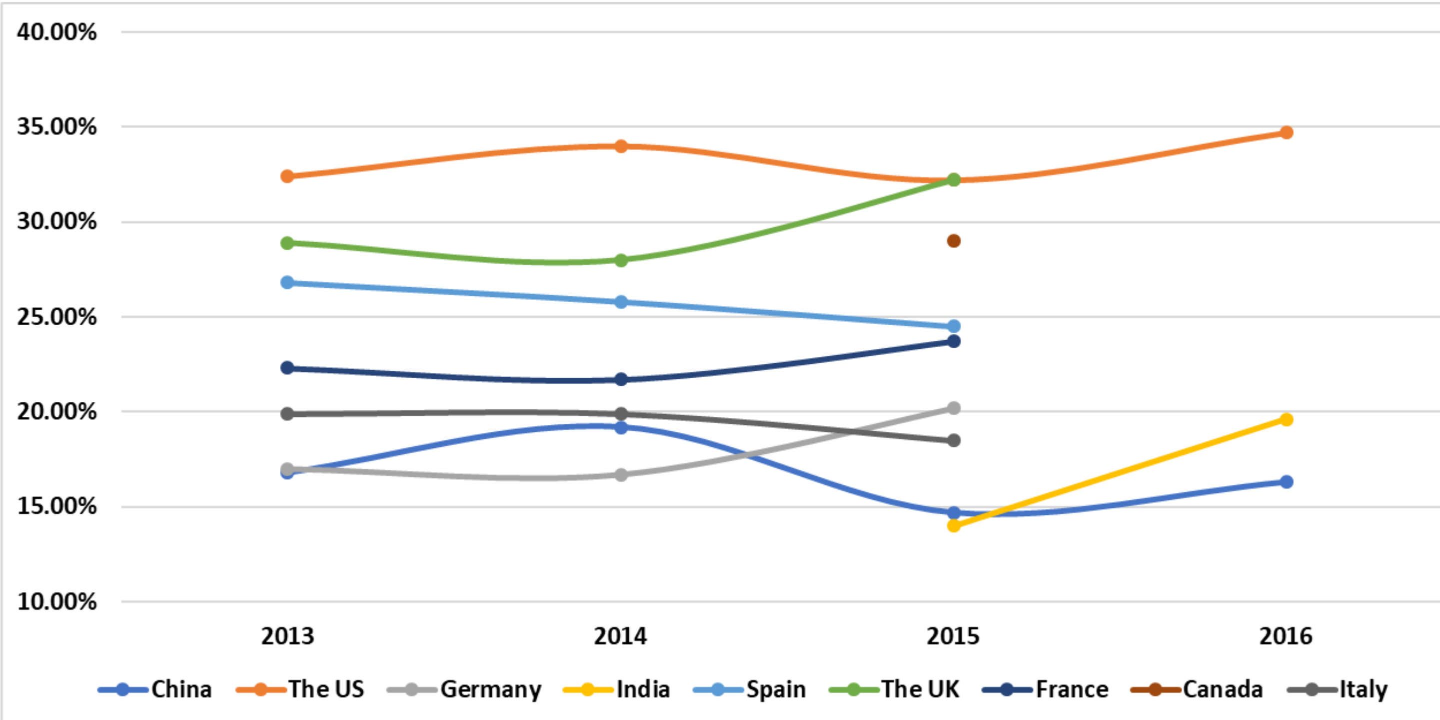


Fig.9 The national average wind farm capacity factors in wind energy leading countries.



4.3. Abandoned Wind Power and Wind Curtailment Rate

Fig.10 and Fig.11 illustrate the abandoned wind power and wind curtailment rate in specific regions from 2013 to 2018. A common reason for wind curtailment could be attributed to local network transmission congestion due to overcapacity and grid planning mismatching between grid companies and wind power developers (Gu and Xie 2014; Z.-Y. Zhao, Chang, and Chen 2016). In year 2013, about 16,300 GWh of wind energy was curtailed over China, or about 8.4% of total wind power production, following 20,820 GWh in 2012 (Bai 2014). Although about 7.3% of wind generation was curtailed in 2014, the wind curtailment problem was even worse in year 2015 and 2016, with 18% and 21% of wind generation being abandoned, respectively. The wind curtailment rates are extremely severe in Hebei, Inner Mongolia, Gansu, Xinjiang, Liaoning, Jilin and Heilongjiang. Most of them are the leading regions in terms of installed capacity and are also areas with abundant wind resource. Therefore, the wind power curtailment is highly related to the wind turbine installed capacity and mainly occurs in North China grid, Northeast China grid and Northwest China grid where most of the wind farms are located, whereas the power demand is relatively low, and the transmission capacity to higher power demand regions is rather insufficient. Due to an urgent need to solve this problem, in 2015 and 2016, the National Energy Bureau (NEB) has consecutively issued the two *Notices on Wind Power Grid Connection and Consumption*, which stipulates those areas to privilege the use of wind power and cut down the wind curtailment rate. As a result, the wind power curtailment rate in 2017 and 2018 decreases heavily, which is 13.2% in 2017 and 7% in 2018.

Fig.10 Abandoned wind power from 2013 to 2018

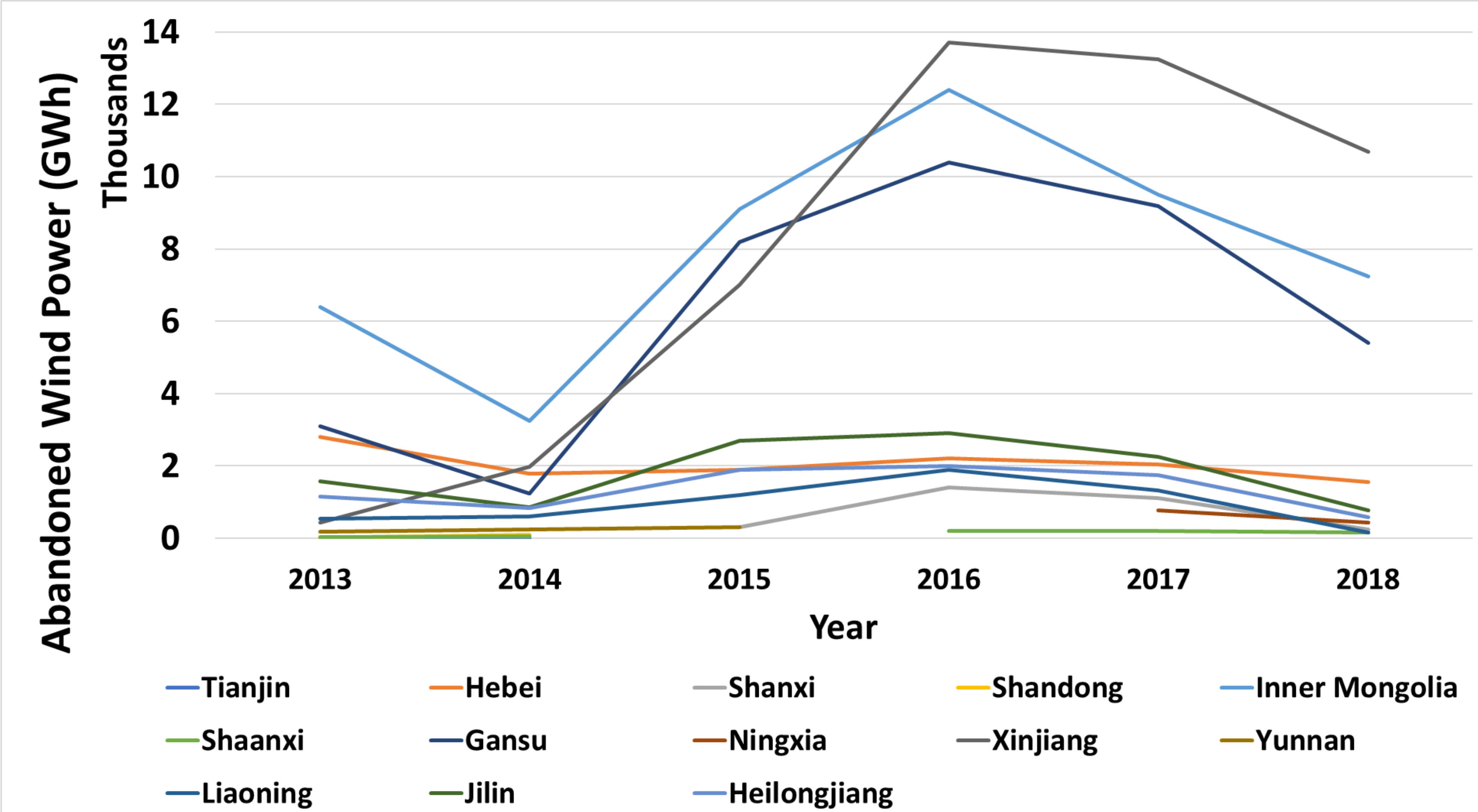
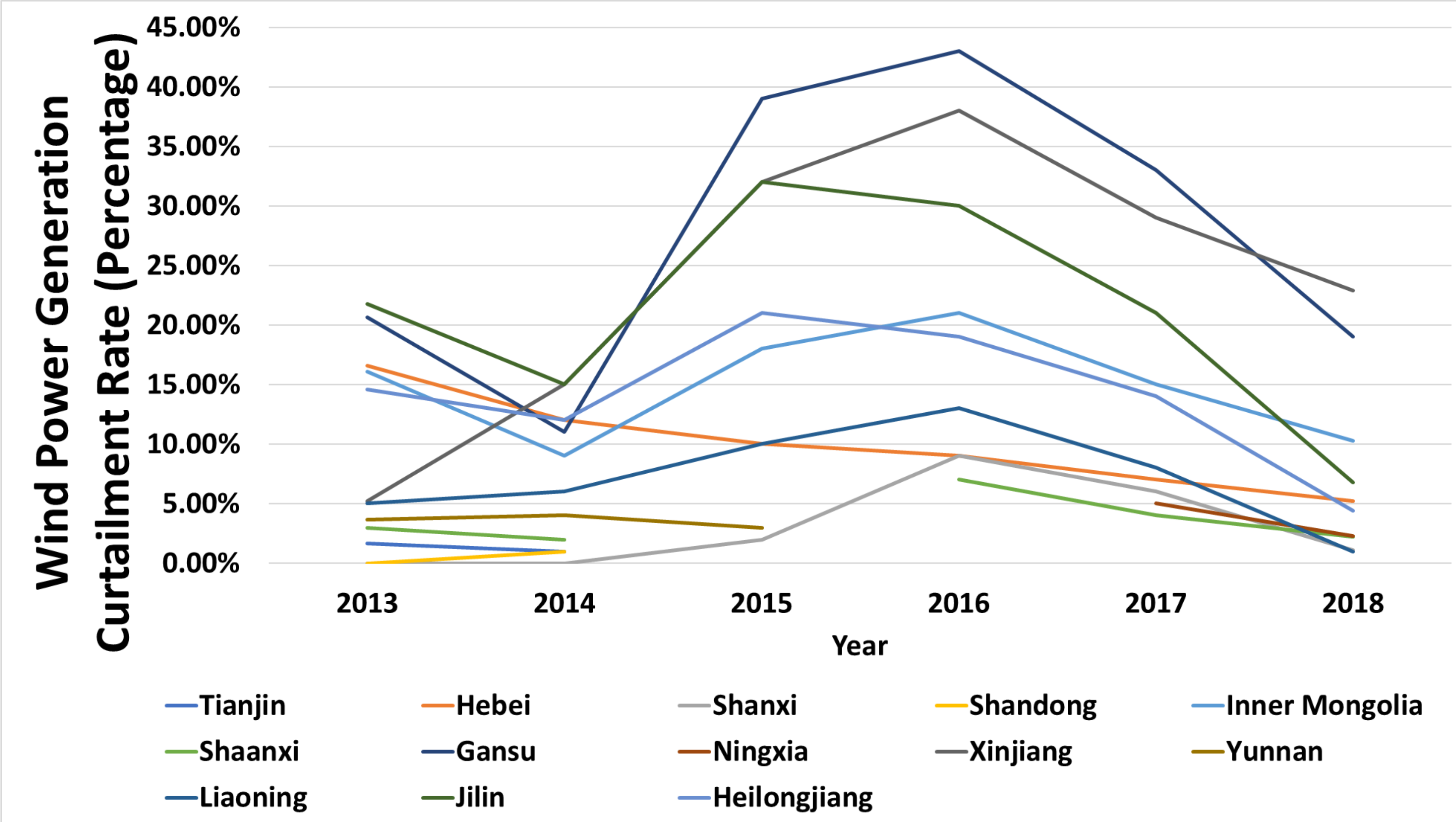


Fig.11 Wind power curtailment rate from 2013 to 2018



Extensive studies have analysed the causes of low capacity factor and severe wind power curtailment in China. The manufacturers, power generation enterprises, grid companies, local government and central government are main parties to be engaged in the wind energy industry in China. Shen and Luo (2015) pointed out that the central government plays the most crucial role of policy-making and affects the actors' behaviours in the wind power supply chain. Thus, the implementation and coordination rights of renewable energy development are under insufficient consideration of energy planning. However, without comprehensive power grid planning, the accommodated wind power is far less than the constructed wind power. The central government failed to coordinate the national power generation and transmission, but only meet a magnificent data of installed capacity (Luo et al., 2016; Si et al., 2011; Wang et al., 2012; Zeng et al., 2014, Luo et al., 2012). Even the attractive wind FIT incentive policy which provides subsidies to wind power investors is criticized that the fix price determined by the government could not effectively reflect the demand and supply situation of the electricity market (Z.-Y. Zhao, Chen, and Chang 2016). In addition, the coordination between central and local policies is hindered by excessive centralization. Local governments have to obey the command-and-control decision making system to push the development of wind power in locality. As a result, over-intervention by the local government happens all the time. Take the Jiangsu coastal wind-power industry cluster as an example, the over-intervention by Jiangsu government results in unhealthy wind power development in the local area. Under the vigorous government-led format of tax competition, performance evaluation and the quest for policy benefits (He et al. 2016), the enterprises were directly affected by the government behaviour rather than driven by the market.

Besides, the renewable power enjoys a lower priority in power dispatch. China's power dispatch follows a coal-fired power dominated approach and capacity-based pattern. The quota of coal-fired power generators is equally assigned according to scheduled generation capacity by the local government (Wei et al. 2018; Yin et al. 2017). For example, a 400 MW unit is equivalent to two 200 MW units. In most of the other countries, the governments utilize a merit-order-based approach to dispatch power. The merit-order-based approach allows the most economically efficient power to take the priority. Unlike other countries, China treats all the coal-fired power generators fairly. Regardless of high or low efficiency of power generation, the generators with similar size and capacity share the same generation quota. Thus, some certain amount of power is failed to be accommodated effectively. Similarly, wind power dispatch is encountering even more difficult situation. On the one hand, the wind power is intermittent and only serves as back-up power. In Zeng et al. (2014)'s research, with Inner Mongolia as an example, they illustrate the prominent installed capacity of thermal power in year 2014 is 31,072 MW, and among it the heating units account for 57.35%. In winter, the insufficient load regulation results in wind power abandoning to "give way" to the heating units. The same case also happens in other regions. The integration of wind power with other power sources always conflicts, and thus wind power is abandoned due to the random and intermittent characteristics.

5. Localization and Competitiveness of Wind Power Enterprises

5.1. Onshore Wind Turbine Manufacturers

During the past ten years, the development of domestic wind turbine enterprises became various in terms of firm nature. The industry localization trajectory is depicted by Fig.12 and Fig.13 In year 2006, among the top 20 wind turbine manufacturers in the Chinese market, only 4 of them are Chinese-owned enterprises, including Goldwind, Sinovel, Windey and DEC. In the year 2018, among the top 20 wind turbine manufacturers, 15 of them are Chinese-owned enterprises, namely

Goldwind, Mingyang, Sinovel, Envision, DEC, XEMC, Haizhuang Windpower, Windey, China Creative Wind Energy, CRRC and SANY HEAG, ENERGIE, Jingcheng New Energy and Xuji. The Chinese-owned manufacturer Goldwind has ranked the first from 2006 to 2018, and the share of cumulative wind power installed capacity of Goldwind has kept a stable level which ranges from 20% to 25%. The share value of Sinovel was 17.75%, 22.4%, 18.8% in year 2008, 2010 and 2012, respectively, but dropped to 13.79% in 2014 and further dropped to 9.8% in year 2016. The Chinese-foreign owned manufactures United Power and Sewind have kept to account for around 15% of the capacity share from 2015 to 2018. The competition among various Chinese-owned manufacturers was fierce from year 2010 to 2018. Some of the enterprises appeared in the top manufacturers' list but gradually faded out, such as New Unite, Zhuzhou Csr Times, HEAG, Yinxing, CASC-Acciona, Xuji wind electricity, etc. This might be due to the enactment of two important policies in year 2009, one being the aforementioned distinguished FIT price of wind resource, another being the *Notice on Value-added Tax Policy of Wind Power Generation* stipulated by the Ministry of Finance, which provided favourable tax preferential incentives for enterprise income tax (EIT) and value-added tax (VAT). The *Notice* stipulated that for wind energy project in China, The VAT was deducted from 17% to 8.5% while the EIT was exempted during the first three years, and then deducted from 33% to 15% during the second three years. This tax deduction policy is extremely beneficial and attractive for the localization of domestic manufacturers, that the change of wind turbine market become more vibrant and active and many enterprises are willing to produce wind turbines, leading to frequent market alternating and refreshing.

Fig.12 Top-ranking wind turbine manufacturers regarding the share of total installed capacity in 2006.

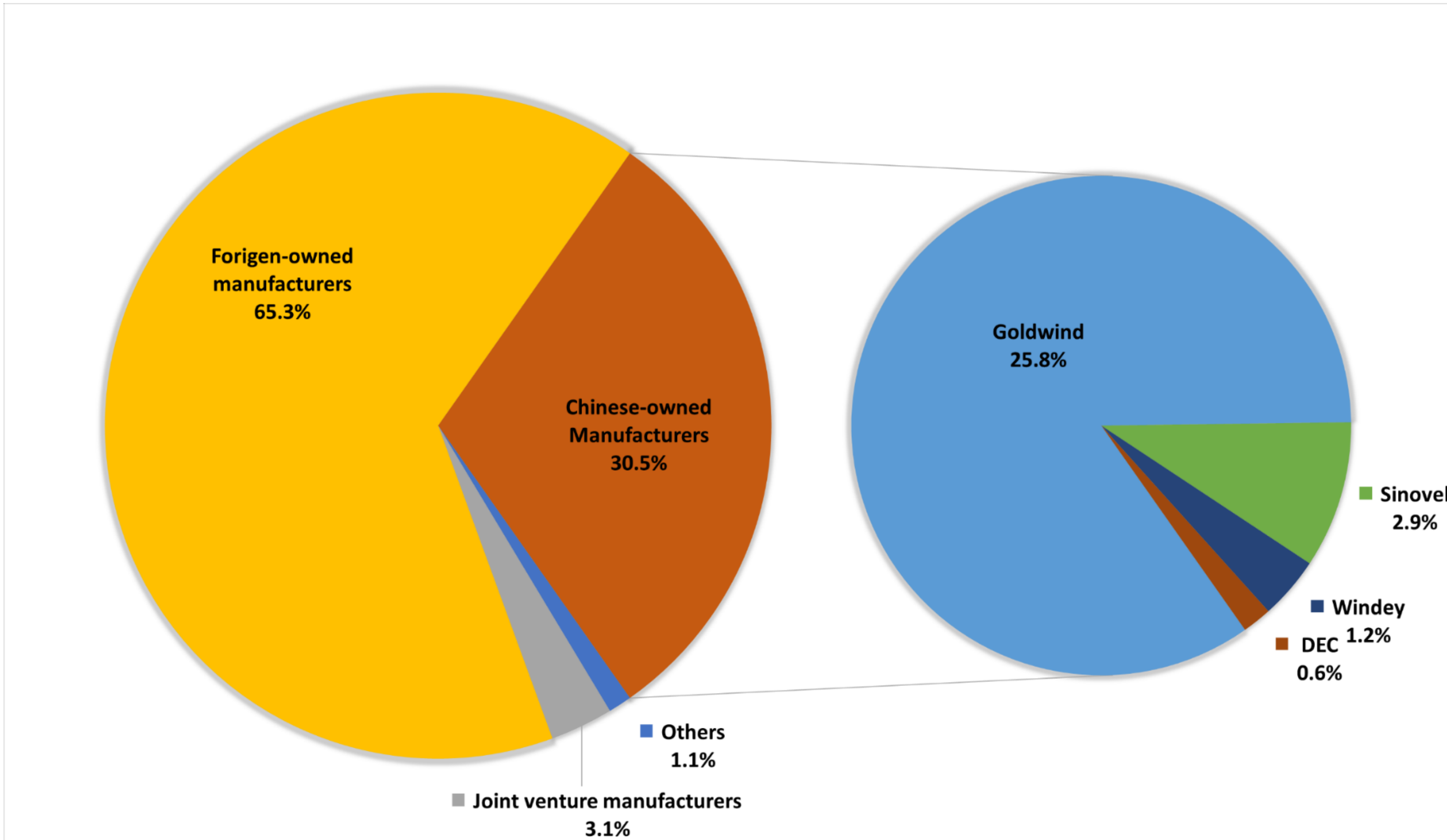
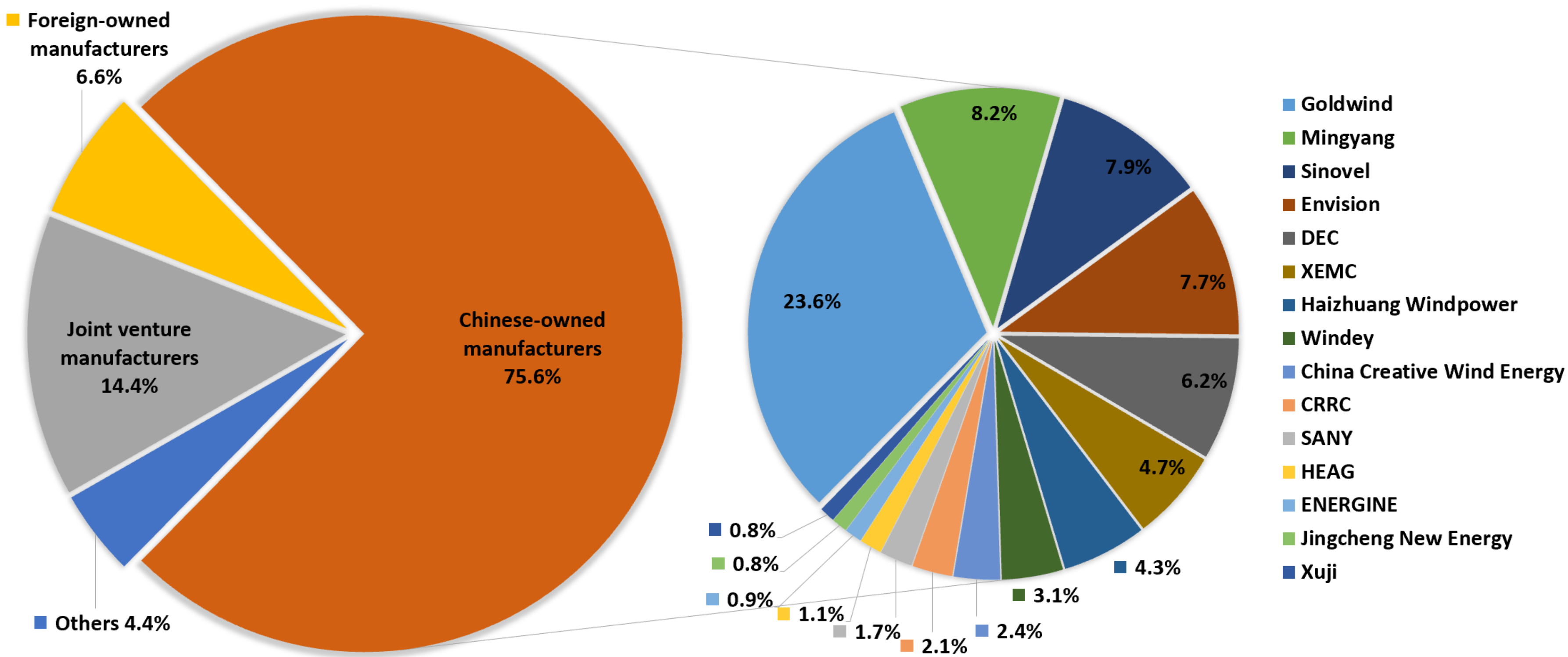


Fig.13 Top-ranking wind turbine manufacturers regarding the share of total installed capacity in 2018.



The total installed capacity of top Chinese-owned, joint venture, and foreign-owned manufacturers from 2006 to 2018 is shown in Fig.14, and the trend of structure change of firm nature is illustrated in Fig.15. The most prominent feature is the significant increase of wind installed capacity by Chinese-owned manufactures. In year 2006, the national total installed wind capacity was 2,589 MW and more than half was produced. by foreign-owned manufacturers. The wind installed capacity by Chinese-owned manufactures increased abruptly between year 2008 and 2009 and achieved 31,649.98MW in 2010. From year 2006 to year 2018, the average annual increase rate of total installed capacity was around 51.8%, and the increase rate of total installed capacity by Chinese-owned manufactures was 64.9%, which directly promoted the development of wind energy in China. It is found that there is a trend of structure turnover from foreign-owned manufacturers to joint-venture and Chinese-owned manufacturers. In year 2006, the foreign-owned wind turbine manufacturers had dominated China's domestic wind energy market, with 65.33% share of total installed capacity. However, in year 2008 and 2010, the share of foreign-owned enterprises sharply dropped from 35.56% to 17.5%. Afterward, the share of foreign-owned enterprises kept dropping annually, and in year 2016 the share value was only 5.97%. For comparison, the share of Chinese-owned enterprises in terms of the total installed capacity increased abruptly from only 30.48% in year 2006 to 70.70% in 2010 and kept steady from year 2010 to year 2018 (share value of 75.5%). In addition, joint venture enterprises kept increasing steadily but sluggishly from 3.05% in year 2006, and for the first time exceeded foreign-owned enterprises with a share of 14.6% in year 2014, and finally reached 15.06% in year 2016.

Fig.14 The total installed capacity of top wind turbine manufacturers regarding firm nature.

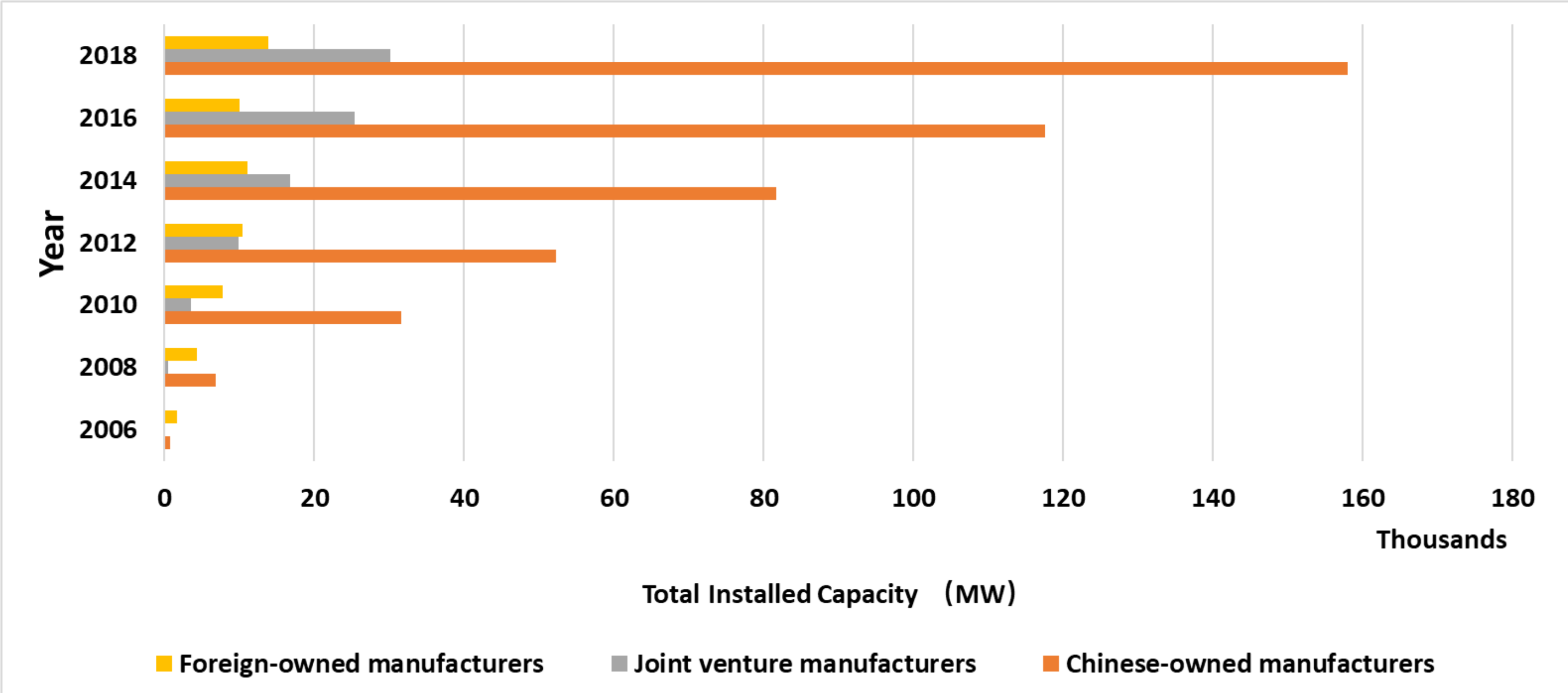


Fig.15 Firm nature change of wind turbine manufacturers in China's domestic market from 2006 to 2018.

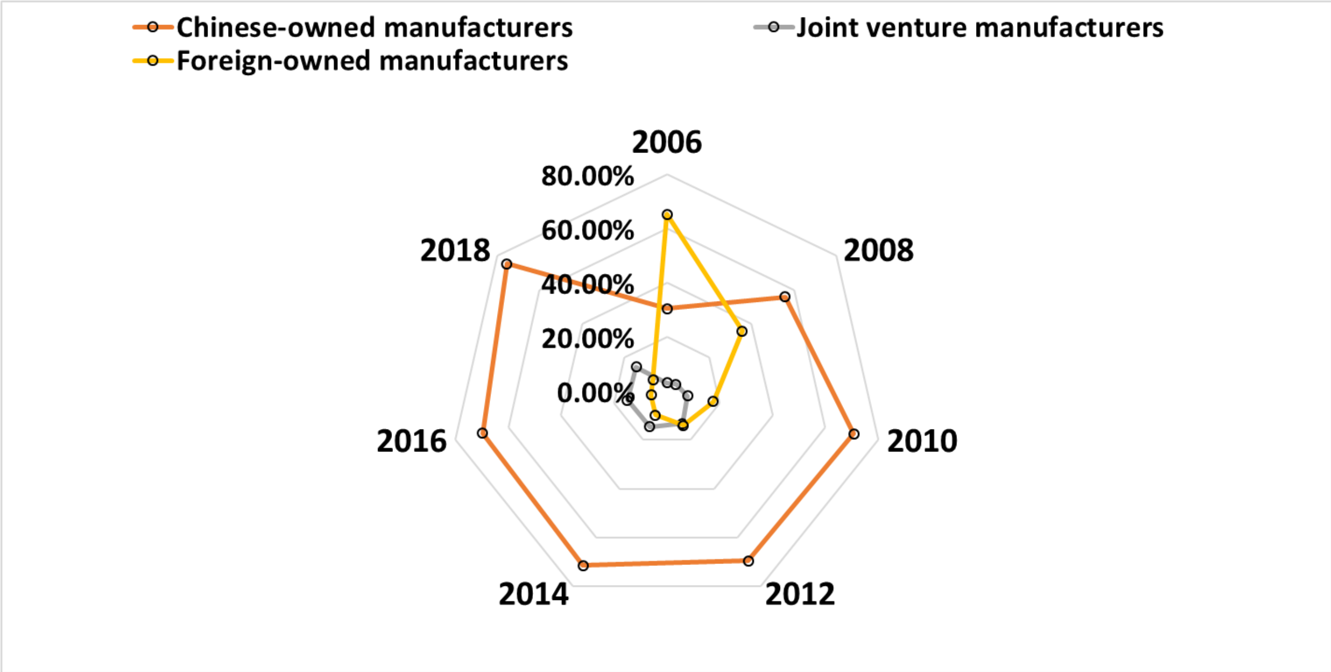
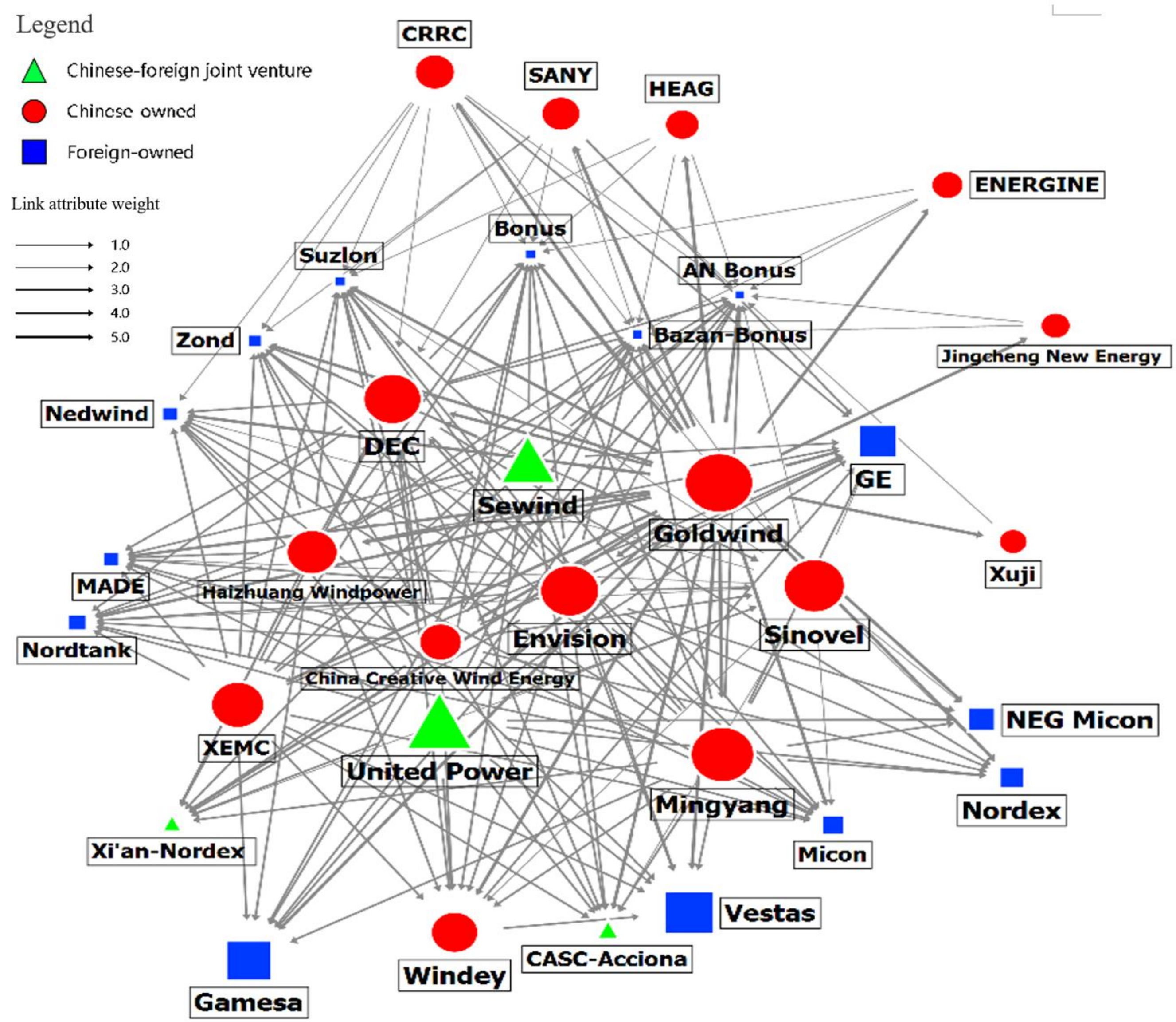


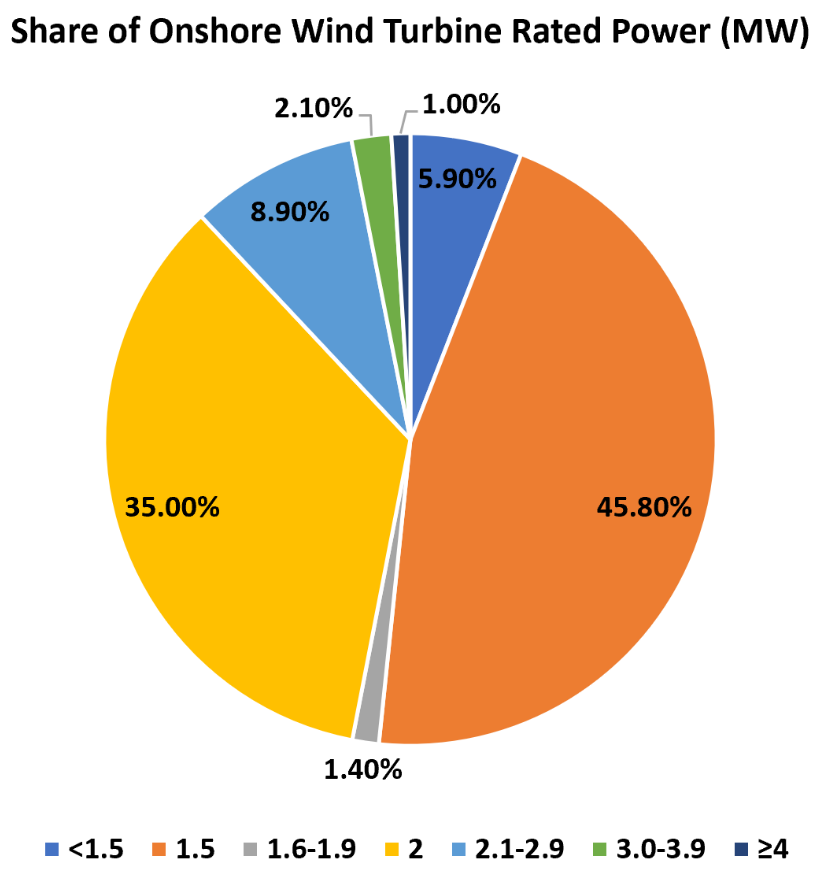
Fig.16 demonstrates the competitive relationship among onshore wind turbine manufacturers from 2006 to 2018 by SNA methodology. As Fig. shows, a significant change of onshore wind turbine manufacturers is the change of firm nature. At the beginning stage of wind power development, the foreign-owned manufacturers are dominating the Chinese manufacture market. After a series of tax reduction policies implemented by the government, the Chinese-owned manufacturers as well as two Chinese-foreign joint venture manufacturers (Sewind and United Power) are protected from taxation and become more competitive agsinst foreign-owned manufacturers. Consequently, the foreign-owned manufacturers are eliminated by the market as they are marginalized by a lot of Chinese-owned manufacturers which are at the central in the figure

Fig.16 SNA of competitive relationship among onshore wind turbine manufacturers from 2006 to 2018.



In addition, the share of manufacturers' onshore wind power plant rate power is illustrated in Fig.17 More than 90% of the wind turbines are large-sized wind turbines (≥ 1.5 MW). Nearly half of the wind turbines are rated 1.5 MW while 35% of the wind turbines are rated 2 MW. Only 5.9% of the wind turbines are small-sized or medium-sized that are rated less than 1.5 MW. The rapid commercialization of large-sized wind turbine production is benefited from a series of industry policies, such as the importation of main conmponents of large-sized wind turbines, the revitalization on equipment manufacturing, and the standardization of the technology (Yuan et al. 2015). The mass production of large-sized wind turbines by the leading Chinese-owned manufacturers enables their expansion from regions in Category I, II and III to Category IV. Therefore, their ability of controlling the market is rather high (Zhao, Ling and Zillante 2012).

Fig.17 Situation on onshore wind turbine rated power



5.2.Offshore Wind Turbine Manufacturers

Fig.18 and Fig.19 demonstrate the share of offshore wind turbine manufactuers in 2015 and 2018, and Fig.20 illustrates the competitive relationship among offshore wind turbine manufacturers from 2015 to 2018. Unlike the fierce competition among onshore wind turbine manufacturers, the competition among offshore wind turbine manufacturers is not intense. The manufacturers which are leading in onshore wind turbine manufacturing are also dominating the offshore wind turbine manufacturing market, such as Sewind, Goldwind, Envision, Mingyang, Haizhuang Windpower, United Power and GE. Regarding the firm nature, the Chinese-foreign joint venture manufacturer Sewind remains to toplist the market share, and the Chinese-owned manufacturers Envision and Goldwind shows great competitiveness. The non-intense competitive situation at current stage among offshore wind turbine manufacturers is due to the unmature technological development of wind turbine manufacturing, and the upfront expenditure is around 50% higher than that of the onshore wind turbine manufacturing (Wu et al. 2019). Nevertheless, the competition among existing offshore wind turbine manufacturers is foreseeable to be as fierce as onshore wind turbine manufacturers in the coming ten years, and the participation of new offshore wind turbine manufacturers is able to be as much as the situation of onshore wind turbine manufacturers.

Fig.18 Offshore wind turbine manufacturers regarding the share of total installed capacity in 2015

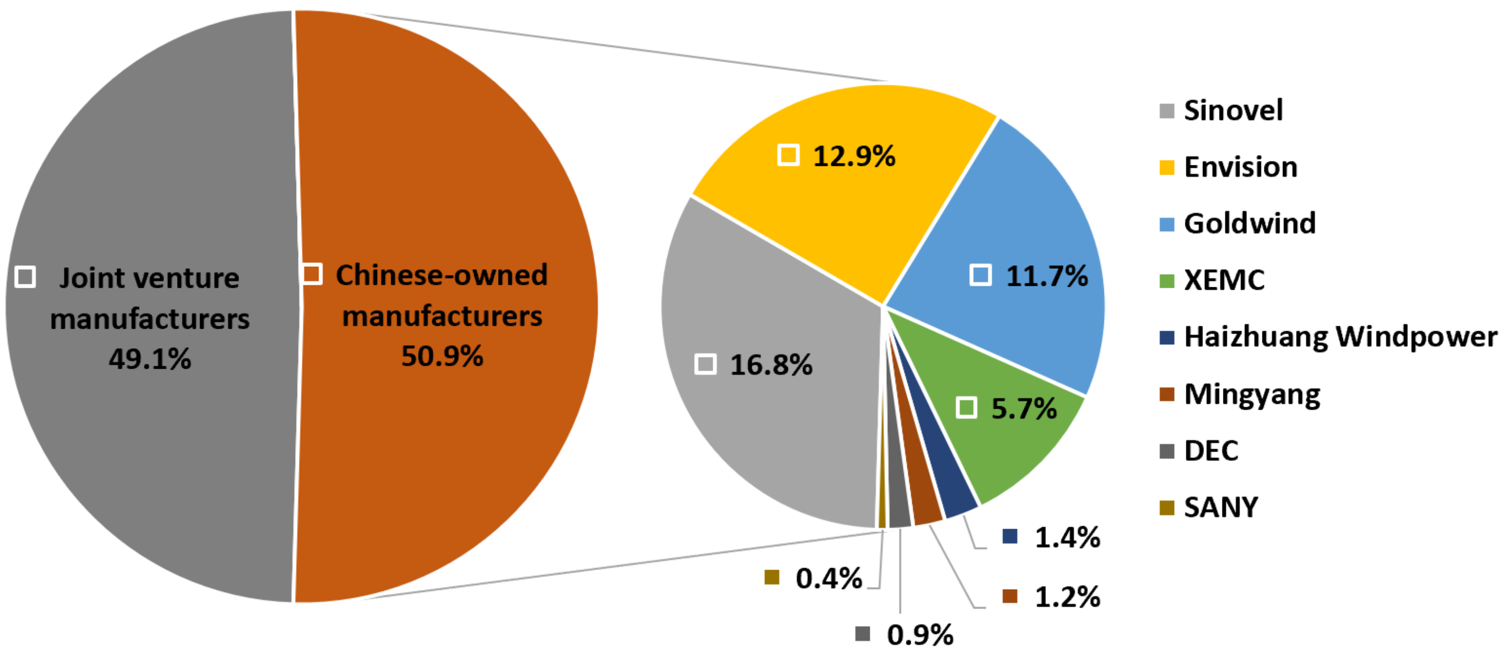


Fig.19 Offshore wind turbine manufacturers regarding the share of total installed capacity in 2018

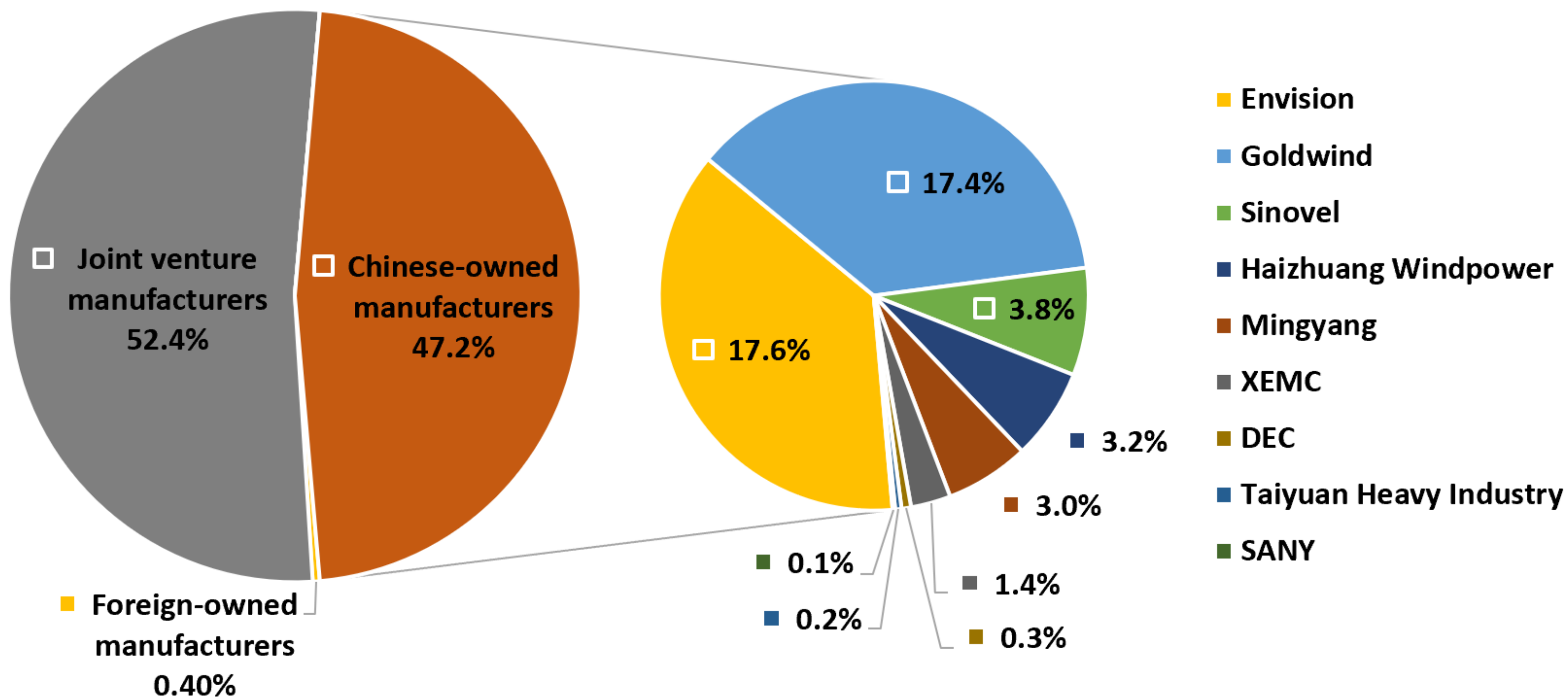


Fig.20 SNA of competitive relationship among onshore wind turbine manufacturers from 2015 to 2018.

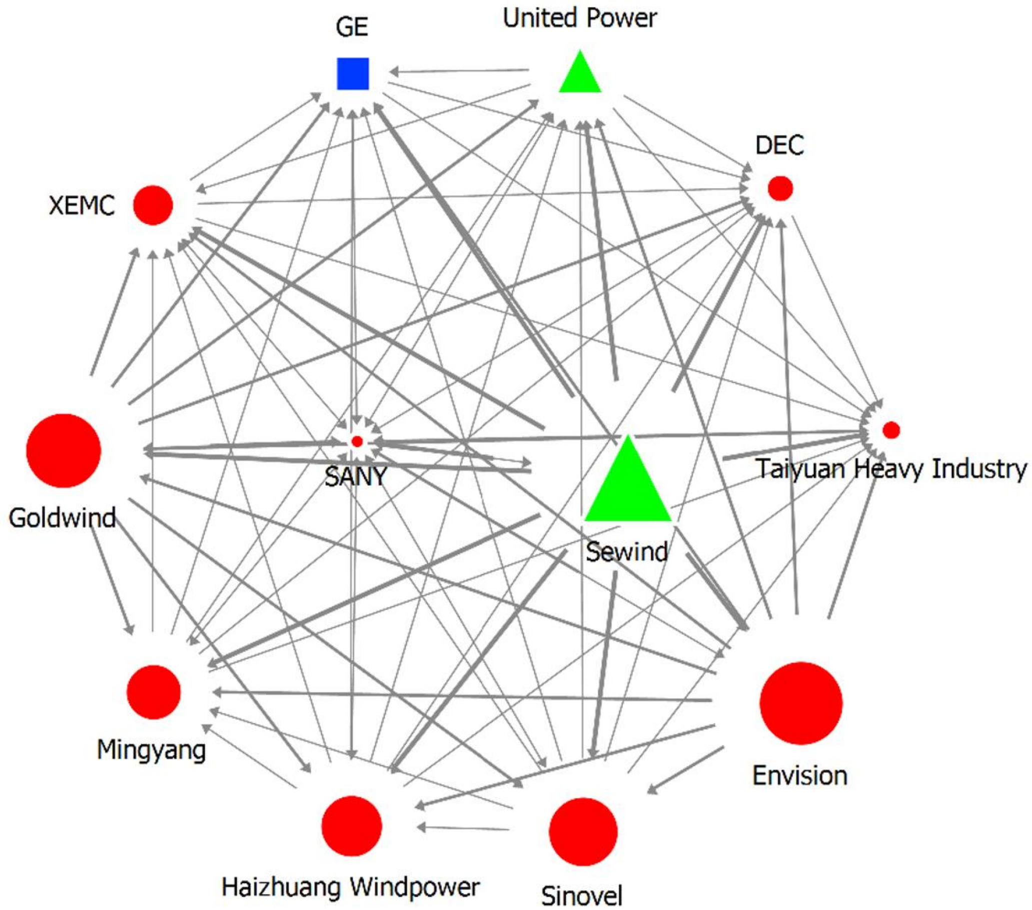
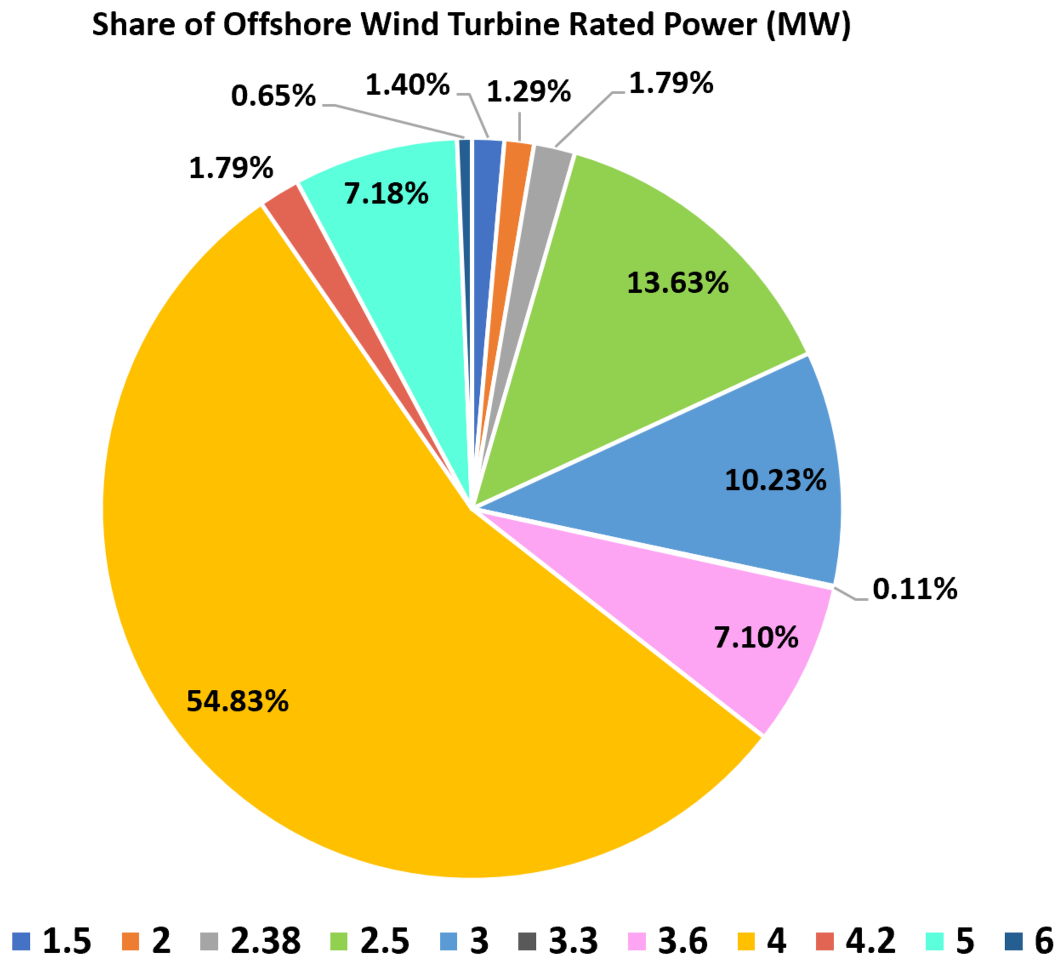


Fig.21 demonstrate the share of offshore wind turbine rated power. It is found that offshore wind turbine rated 4 MW takes more than half of the share, wind turbine rated 2.5 MW and 3 MW take 13.63% and 10.23% share, respectively.

Fig.21 Situation on offshore wind turbine rated power

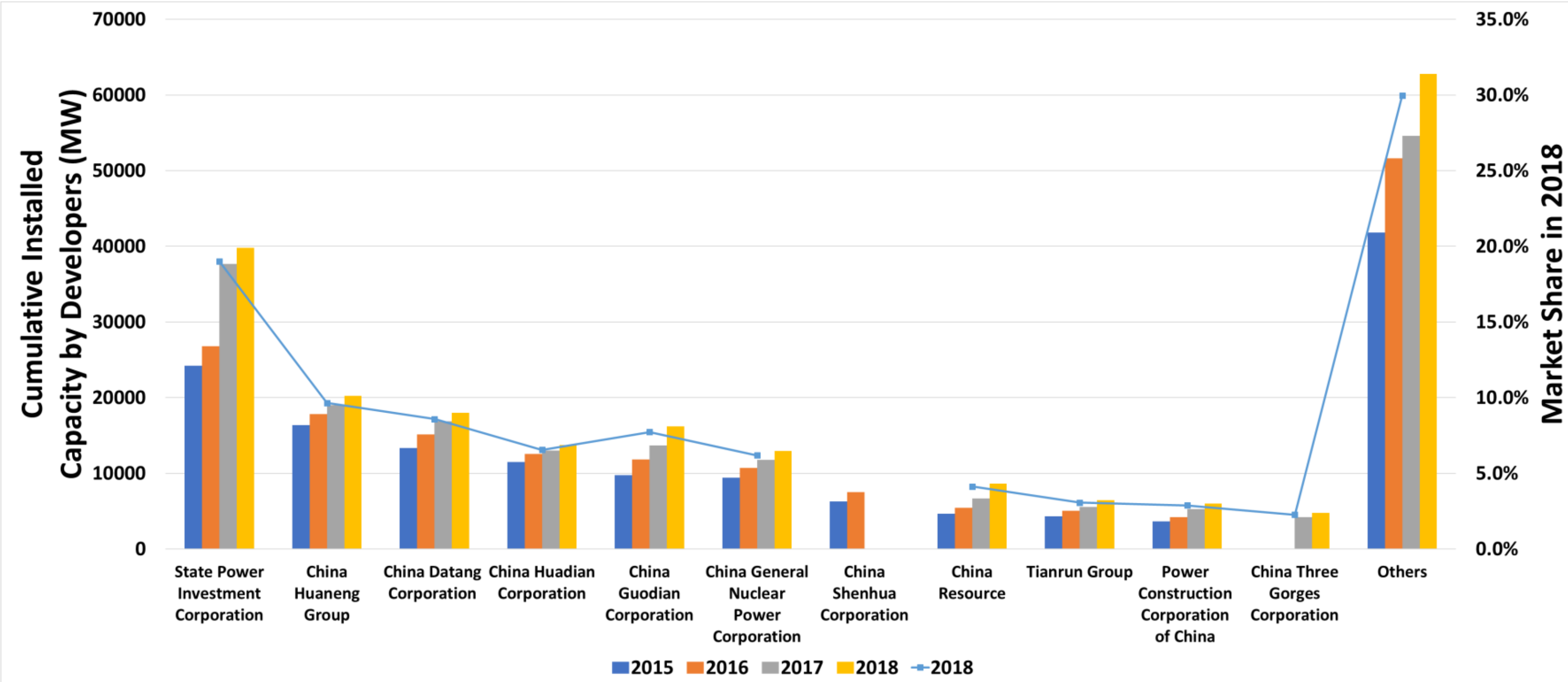


5.3.Wind Power Developers

As shown in Fig.22, the top-ranking wind power developers are all state-owned enterprises (SOEs). The ranking of wind power installed capacity market share is stable over years. As the so-called “state capitalist” in the electricity market by (Zhu et al. 2019), “Big Five” and “Small Four” enterprises[3] account for 61.7% of the market share. Among which CHN Energy, Huaneng, Datang, Huadian, GD Power and CGN are inevitably dominating the wind power investment market. China Shenhua Corporation has announced its jointly restructured to China Guodian Corporation in 2017, so the installed capacity of Shenhua is removed from the figure. Due to the concession of Shenhua, China Three Gorges Corporation has taken part in the ranking list, as well as China Resource, Tianrun Group and Power Construction Corporation of China, has shown its competitiveness among all the developers. Besides, it is found that the cumulative installed wind power capacity by other enterprises is increased from 25% of market share in 2013 to 30% in 2018, which includes a large amount of non-SOEs. This situation indicates that the wind power investment market is regulated by the Chinese government so that the SOEs are more favourable, but at the same time, the non-SOEs are increasingly inclusive by the market.

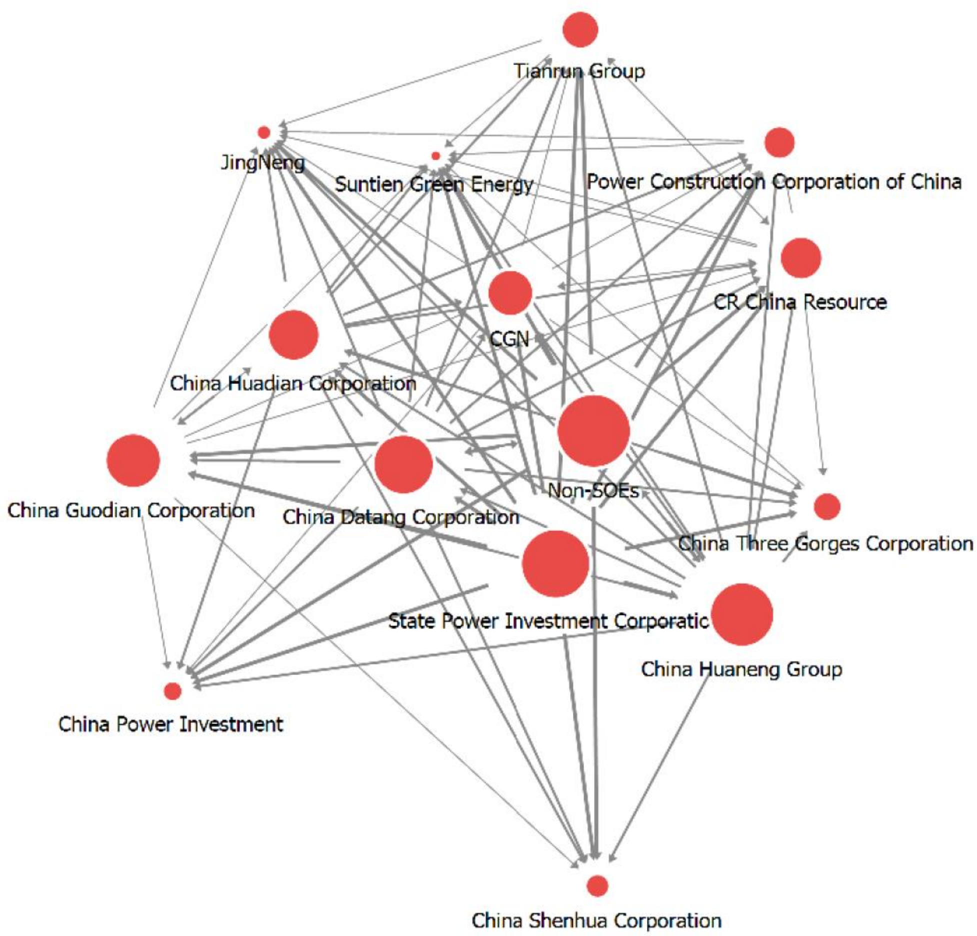
[3] “Big Five”: China Huaneng Group, China Datang Corporation, China Huadian Corporation, China Guodian Corporation, State Power Investment Corporation.
“Small Four”: China Resource, State Development and Investment Corporation, China General Nuclear Power Generation (CGN), Guohua Electric Power Company.

Fig.22 Top-ranking wind power developers from 2015 to 2018.



The SNA result of the competitive relationship among wind power developers from 2011 to 2018 is presented in Fig.23. Jingneng and Suntien Green Energy, which ranked the top ten wind power developers in 2013 are eliminated from the list in 2018. The competitiveness of “Big Five” and “Small Four ”is inevitably stable, but Tianrun Group and China Three Gorges Corporation also show great potential of developing wind power.

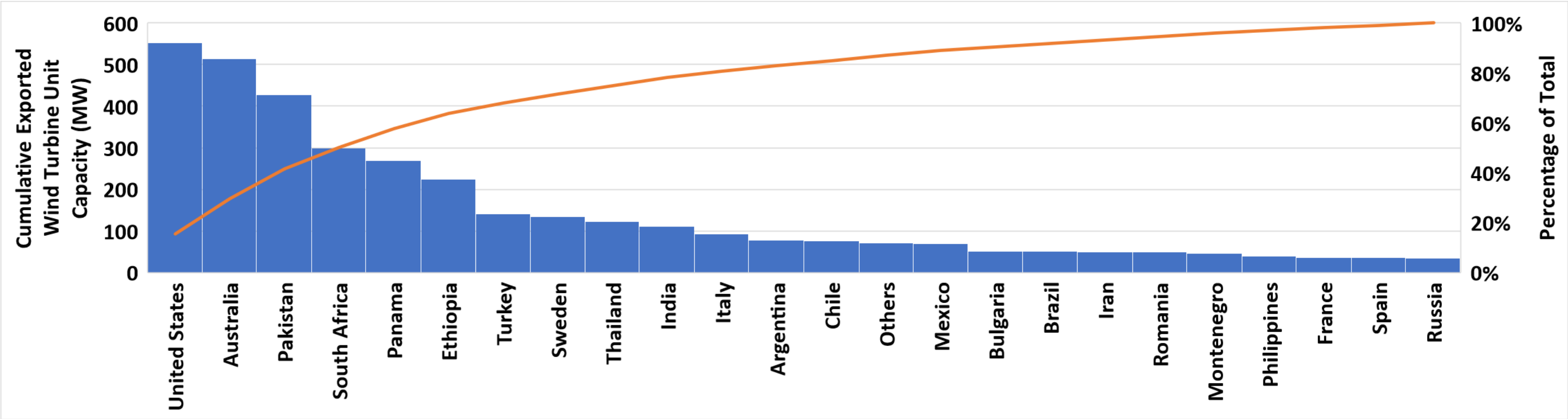
Fig.23 SNA of competitive relationship among wind power developers from 2011 to 2018.



5.4. Exportation and Internationalization

Fig.24 illustrates the main exportation countries of wind turbine units from Chinese manufacturers. The United States and Australia are two largest export destinations for wind turbine manufacturers, which account for 30% of the total exported capacity. Besides, Pakistan, South Africa, Panama and Ethiopia account for around 35% of the exported capacity. It is fount that the top-ranked exportation countries are mainly located far from China, such as countries in North America, South America and Europe. Whereas there are only a few adjacent countries to China which are export destinations. It is also found that the internationalization of Chinese wind turbine manufacturers considers both developed countries and developing countries, which is consistent with Zhang et al. (2015)'s conclusion. The amount of wind turbine unit exportation drastically increases from 45 MW in 2009 to 3581 MW in 2018. Apart from the reason that the competition of domestic wind turbine manufacturers is intense and the reason that wind power curtailment problem has weakened some manufacturers' confidence in domestic market, the supporting policies enacted by the government play a crucial rule. In 2009, the State Council (SC) issued the *Notice on Curbing the Overcapacity and Redundant Construction of Several Industries and Promoting the Healthy Development of Industries*, which encourages to promote the internationalization of wind power industry (SC 2009). Soon in 2011, the government's ministerial departments co-issued the *Opinions for Promoting the Internationalization Development of Strategic Emerging Industries*, which has boosted the fast exportation and internationalization of wind turbine manufacturers.

Fig.24 Main exportation countries of wind turbine units from Chinese manufacturers in 2018.



6. Conclusion

This paper has provided a comprehensive overview on the wind power development from the commencement of REL to the end of 2018. Data collected from official websites of government (such as State Council, National Development and Reform Commission and National Energy Association, etc), research institutions (such as Chinese Wind Energy Association), official documentation (such as Statistical Yearbook China), journal articles and the official website or reports of wind power enterprises are used to illustrate the status quo of onshore and offshore wind power development. Installed capacity, gird-connected wind power, wind farm capacity factor, abandoned wind power and wind curtailment rate are introduced by meanings of explaining the implementation of series of supporting policies. The top-raking manufacturers and developers in domestic wind power market are presented in the overview, while the change trend of firm nature and competition relationship among the enterprises are illustrated. Besides, SNA has been employed to demonstrate the competitiveness of wind power enterprises over the past years, which shows the policy effectiveness on localizing the wind power industry. All in all, this paper concludes that the effectiveness of wind power policies enacted is high, and they play a vital role in Chinese wind power market. In addition, it is foreseeable that in the near future, the Chinese wind power market will be regulated also under a policy-oriented mechanism.

Appendix A. Explanations of the abbreviations.

Abbreviation	Full name	Explanation
FYP	Five Year Plan	A series of social and economic development initiatives issued since 1953
UNFCCC	United Nations Framework Convention on Climate Change	An international environmental treaty aims to address climate change problem
CDM	Clean Development Mechanism	An mechanism under Kyoto Protocol which allows emission-reduction projects in developing countries to earn certified emission reduction credits
REL	Renewable Energy Law	China's first renewable energy law which enacted in 2005
NDRC	National Development and Reform Commission	A macroeconomic management agency under the Chinese State Council. It holds the administrative power to manage the economic structure in China.
MF	Ministry of Finance	A department under State Council to handle financial affairs
FIT	Feed-in-Tariff	A subsidy policy which aims to encourage wind energy investment
CWEA	Chinese Wind Energy Association	A non-profit entity that aims to promote academic, technical and social connection among China and international countries
NEA	National Energy Administration	A department under the NDRC to implement energy-related policies
SGCC	State Grid Corporation of China	One of two state-owned electric utilities of China which provides electricity to North, Northeast, Northwest, East and Central China grids
CSG	China Southern Power Grid Corporation	One of two state-owned electric utilities of China which provides electricity to South China grid
SOEs	State-owned enterprises	A business enterprise where the government or state has significant control through full, majority, or significant minority ownership
NEB	National Energy Bureau	A Bureau under the NDRC that supervises and regulate the energy development issues
NPC	National People's Congress	The chief legislative authority of China
SC	State Council	The chief administrative authority of China

Appendix B. China's Provinces, Autonomous Regions, Centrally Administered Municipalities and Special Administrative Regions.

Divisions	
Provinces	Hebei, Shanxi, Liaoning, Jilin, Heilongjiang, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Hainan, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Taiwan
Autonomous Regions	Inner Mongolia, Guangxi, Xinjiang, Ningxia, Tibet
Municipalities	Beijing, Tianjin, Shanghai, Chongqing
Special Administrative Regions	Hong Kong, Macau

Note: Due to political reason of One Country Two Systems, Taiwan, Hong Kong and Macau's situations are not applicable in this paper. The country is divided into provinces, autonomous regions and municipalities directly under the Central Government. Autonomous Regions are ethnic autonomous areas.

(Source: the website of the Central People's Government of the People's Republic of China: http://www.gov.cn/test/2005-06/15/content_18253.htm)

Appendix C. Classification of regional power grids and wind resource areas.

The 31 provinces, autonomous regions and municipalities are divided into 6 clusters according to the grid power connection zone planning. China has two state-owned grid companies, namely State Grid Corporation of China (SGCC) and China Southern Power Grid Corporation (CSG), respectively. SGCC provides power for 26 provinces/autonomous regions/municipalities and includes **North China Grid** (Beijing, Tianjin, Hebei, Shanxi, West Inner Mongolia and Shandong), **Northeast China Grid** (East Inner Mongolia, Liaoning, Jilin and Heilongjiang), **Central China Grid** (Henan, Hubei, Hunan, Jiangxi, Sichuan and Chongqing), **East China Grid** (Shanghai, Jiangsu, Zhejiang, Anhui, Fujian) and **Northwest China Grid** (Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Tibet). The CSG covers the remaining 5 provinces (Guangdong, Guangxi, Yunnan, Hainan and Guizhou).

Fig.C.1 Classification of six regional power grids in China

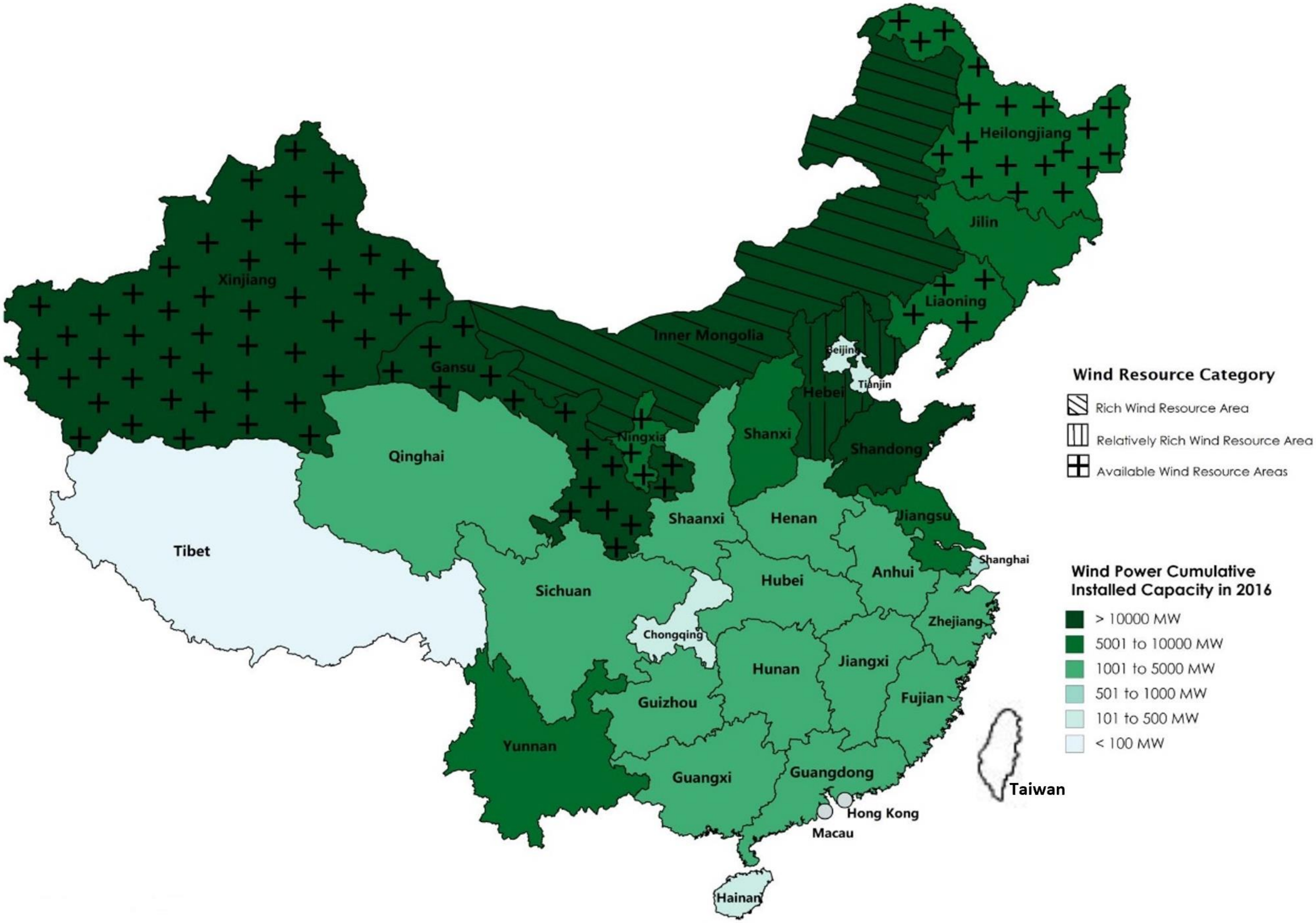
Table.C.1 Provinces/ Autonomous regions/ Municipalities included in four categories of wind resources (NDRC).

Administrative areas included (Hu et al. 2013)
Category I: Inner Mongolia autonomous region except: Chifeng, Tongliao, Xing'anmeng, Hulunbeier; **Xinjiang uygur autonomous region**: Urumqi, Yili, Karamay, Shihezi
Category II: Hebei province: Zhangjiakou, Chengde; **Inner Mongolia autonomous region:** Chifeng, Tongliao, Xing'anmeng, Hulunbeier; **Gansu province**: Zhangye, Jiayuguan, Jiuquan
Category III: Jilin province: Baicheng, Songyuan; **Heilongjiang province**: Jixi, Shuangyashan, Qitaihe, Suihua, Yichun, Daxinganling region, **Gansu province except:** Zhangye, Jiayuguan, Jiuquan, **Xinjiang autonomous region except**: Urumqi, Yili, Changji, Karamay, Shihezi, **Ningxia Hui autonomous region**
Category IV: Other parts of China not mentioned above

Table.C.2 Classification of four wind resource areas

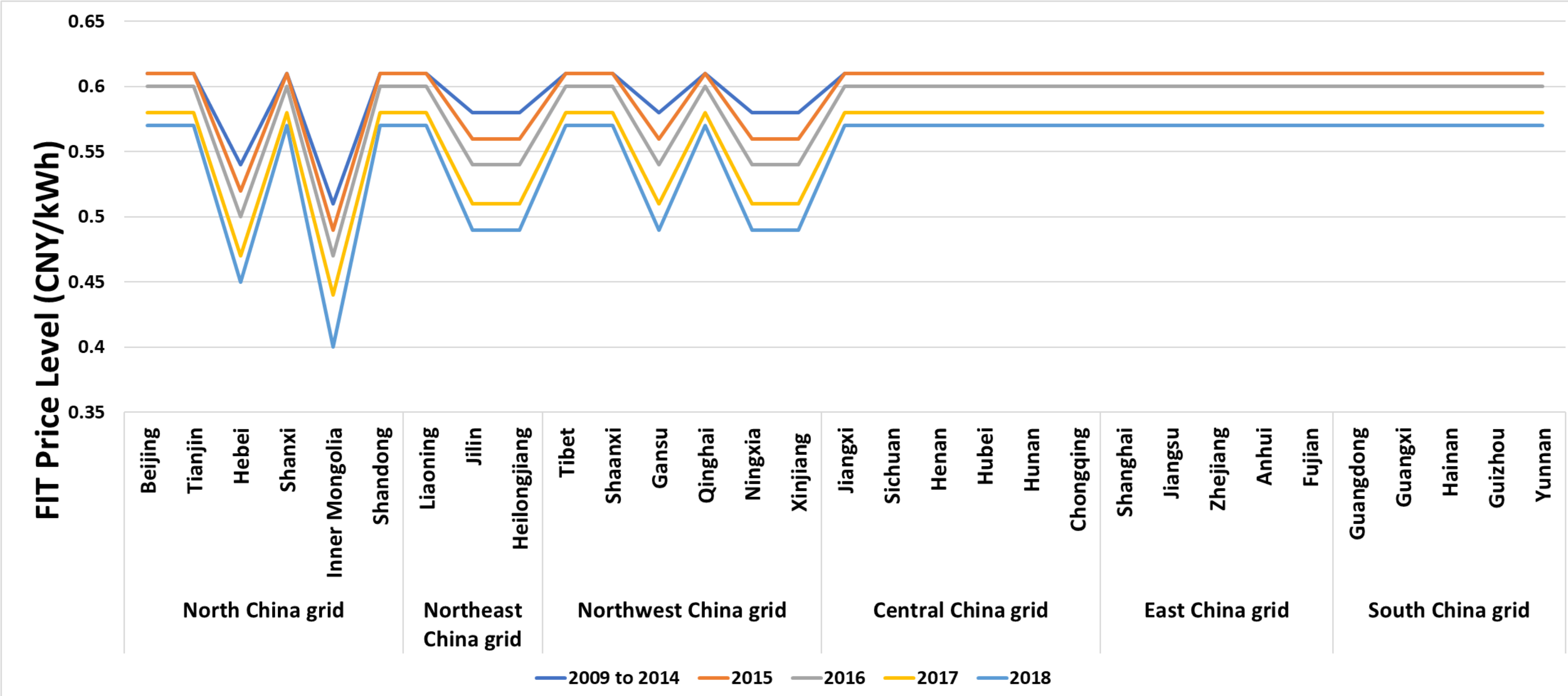
Category	Annual average effective wind energy density (D, W/m^2)	annual cumulative hours (H) of wind speed of 3-20 m/s	Occupation of national area
I - Rich	D > 200	H > 5000	8%
II – Relatively rich	150 < D < 200	3000 < H < 5000	18%
III - Available	50 < D < 150	2000 < H 3000	24%
IV - Poor	D < 50	H < 2000	50%

Fig.C.2 Wind resource classification and cumulative installed wind power capacity in 2016.



Appendix D. FIT Benchmark Price Level

Fig.D.1 Current wind power FIT price level



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