# China Wind Power Development Towards 2030

# -Feasibility Study on Wind Power Contribution to 10% of Power Demand in China

## Executive Summary

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## 1. Introduction

With the economy rapidly developing, the energy demand has also increased in China's. Currently, the fossil-based energy mix is confined to the resources and environment, which makes it obviously unsustainable. In this respect, it is crucial to improve energy efficiency, energy saving and emission reduction technology, and also it is necessary to develop clean energy technology, particularly accelerate the development and utilization of renewable energy to increase clean energy supply.

As a clean primary energy, wind power plays a crucial role in China's energy supply. Through the demand analysis of renewable energy based on the economic development, or comparing analysis of wind power development from international experience, international and national partners expect scale-up of the wind power can be competitive with the thermal power, hydropower and nuclear power in near future, and will become the top four power by 2030 in China.

This study evaluated the development status and potential of wind resources, technology, manufacture and power grid and analyze the roadmap to realize wind power large-scale development in China. The policy and measures for support the wind power development was also proposed from four aspects, including wind resource evaluation, technology R&D, market supervisor and power grid policy. At last, the report elaborated the feasibility of wind power to meet 10% of power demand. The report is divided into six parts:

- In Chapter 1, the future role of wind power is analyzed based on social economy development. We concluded the forecast results of energy and electricity demand in the future from international and domestic institute. The difference of technology cost and environmental benefit between the wind power and the other energy technology was also compared in this report. On the basis of the above analysis, the 2030 development goal of wind power to meet 10% of power demand is proposed in this chapter.

- In Chapter 2, author evaluated the wind energy resource of China. The different results of wind resource assessment from domestic research institute were analyzed. Considering the technology availability and economical quantity, the report described the wind resource location and available quantity in key region of China.

- In Chapter 3, we discussed the manufacture and technology development for wind power large-scale development. The international wind power development experience and wind power status of China were analyzed. The report confirmed the wind technology roadmap and incentive policy in 2030.

- In Chapter 4, the power grid conditions for wind power development are evaluated. The report described the advanced international experience of wind

power integrated into grid. China's power system features and power grid development planning was discussed in this report. At last, the challenges and feasibility for large-scale wind integrated into grid were proposed.

- In Chapter 5, the forecast of 2030 wind power development was described in detail. Under different scenarios, we calculated the wind power development targets. At the same time, the report also analyzed the economic, social and environmental benefits to realize these targets.

- In Chapter 6, measures and proposals are provided for the power grid to integrate large-scale wind power.

## 1. Demand analysis of China's economic and social development on energy

### 1.1 Long term energy and electricity demand in China

According to statistics from both Chinese and international research institutions, China's power demand in 2030 will reach at least 5000 to 6000 TWh, up to 8000-10000 TWh (see Figure 1). China's current coal-fired energy mix may be optimized in the future but cannot be totally changed in a short period. Our power supply will continue to rely heavily on coal, which is obviously unsustainable from both the environmental, economic and social view. Therefore, future development of wind power and other renewable energy is extremely important in China.

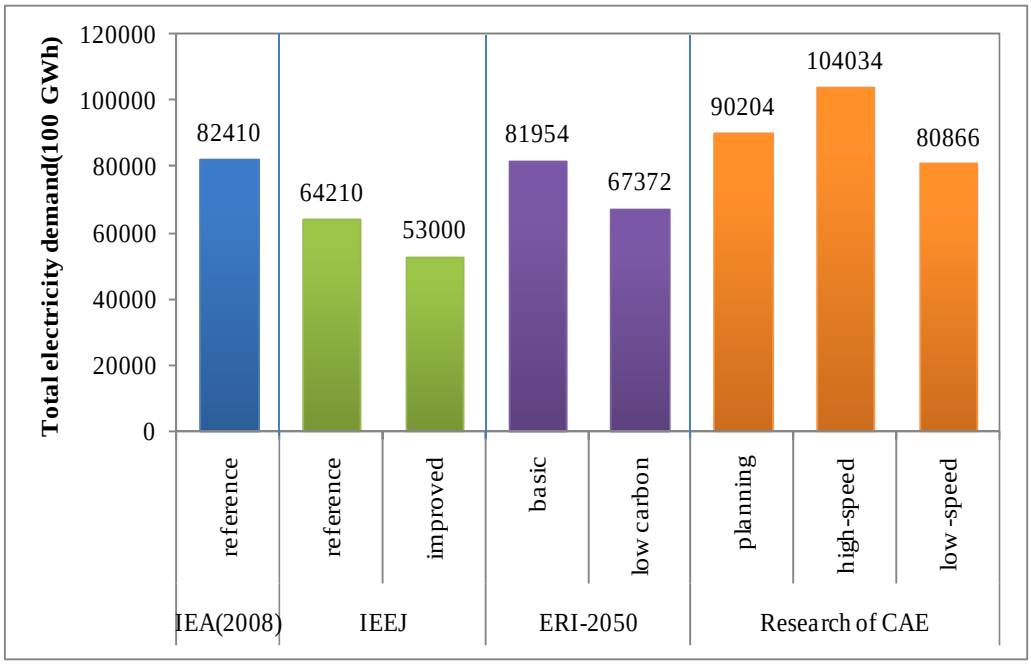



Figure1: China's 2030 power demand forecasts by different institutions

## 1.2 Economical analysis of power generation technology

At present, the cost of coal-fired generation power and electricity price was cheap than the RE power generation. The electricity price of wind power was more expensive the coal-fired generation, and the same as the nuclear power and nature gas power.(Shown as the Figure 2).

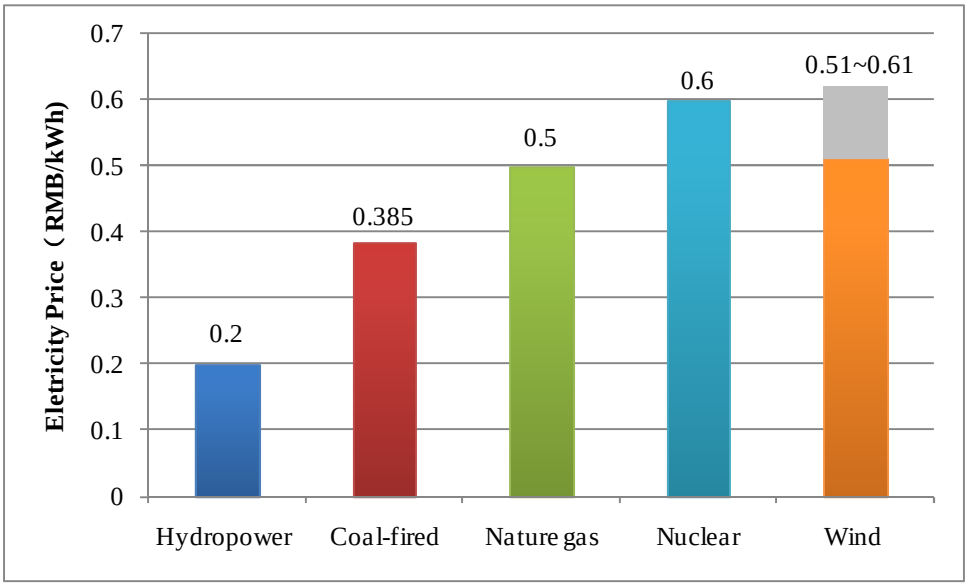



**Figure 1 : Electricity price of different power generation technology of China in 2007**

In the future, the power generation power technology with the high efficiency, safety, non-pollution and economy will be selected as the major technology in the power sector of China. With the policy for environment protection strengthening, the operation cost of coal-fired and nature gas generation power will increase. After 2020, because of the confines of environment and resource, the cost of coal –fired and nature gas generation power will have no advantage in the power sector. The cost of wind power will reduce with the technology improving. Currently, the electricity tariff of wind power is confirmed on the four type wind resource, which from 0.51 to 0.61 RMB/kWh and the cost is about 0.36 to 0.44 RMB/Yuan. In 2020, the cost of wind power will decrease by 20% and be lower than 0.4RMB/Yuan, which competing with the coal-fired generation power.

## 1.3 Wind power role in future energy and electricity structure

With the wind power rapidly developing, the current targets of wind power have not met with the demand of development. As a new target, the wind power will reach 100 to 150 GW installed capacity in 2020. It will be a important basis to develop the more large-scale wind power in 2030. Furthermore, the international institutes have also envisaged an optimistic blueprint for the wind power development of China in 2030. They thought that the wind power should play an important role in the power sector,

which be same as the fossil energy power, hydropower and nuclear.

Some results from the other research agencies showed that the electricity demand will reach beyond 5000 TWh to 6000 TWh or within 7000 to 8000 TWh. Based on the technology availability of wind resource with 800 to 1300GW installed capacity, the installed capacity of wind power will be 300GW in 2030, equal to 700 TWh electricity output. The penetration of wind power will meet with 10% electricity demand of the whole country in 2030. It is testified that the wind power development have strong potential in the future.

## 3. Resource basis for large-scale wind power development

### 3.1 Overview of wind resource assessments

The wind resource assessment involves macro, medium, and micro assessment, each of which plays a crucial role in studying the wind development planning, the layout and the project design. At Early in 1970s, China Meteorological Administration (CMA) had given out the total resource potential and location of wind resource for the first time and made several national surveys since then. Nowadays, with the spread of China's wind market, its assessment work has been furthered, the results of which are shown in the following Table1.

Table1: China's mainland wind resource assessments by different institutions

| Institutions | Developable area (10 000 $km^2$) | Height (m) | Technical potential (100 GW) | Assessment methods |
|---|---|---|---|---|
| The second survey (1990s) | | 10 | 2.53 | based on meteorological data, taking up 10% of the theoretical value of wind resource from the height of 10 m |
| The third survey (2007) | 20 | 10 | 2.97 | based on meteorological data, considering areas whose wind power density > 150W/$m^2$ from the height of 10 m |
| CMA (2007) | 54 | 50 | 26.8 | numerical simulation technique; considering areas where wind power density ≧ 400W/$m^2$ (not including Xinjiang, Qinghai, Tibet and Taiwan) from the height of 50m; turbine layout: 5MW/$km^2$ |
| UNEP (2004) | 28.4 | 50 | 14.2 | not including Xinjiang, Qinghai, Tibet and Taiwan; |

| | | | | |
|---|---|---|---|---|
| | | | | using numerical simulation technique in the eastern coast of China and Inner Mongolia;<br>calculation of other regions is based on data from weather stations;<br>areas where wind power density ≧ 400W/$m^2$;<br>turbine layout: 5MW/$km^2$ |
| ERI (2007) | 20 | | 6~10 | 200,000 $km^2$ developable land area;<br>turbine layout: 3 to 5MW/$km^2$; |
| Center for Wind and Solar Energy Resources Assessment (CWERA2009) | | 50 | 23.8 | areas where Wind power density ≧ 300W/$m^2$;<br>using data from professional observation network and refined numerical model system |

The offshore wind resource has also been assessed by CMA, National Meteorological Center (NMC) of CMA, Institute of Geographic Sciences and Natural Resources Research (IGSNRR) and UNEP respectively. Using the statistical analysis and numerical simulation of the air circulation data, combined with satellite remote sensing technology, the offshore wind resource is estimated as follows:

Table2: Assessments of offshore wind resource by different institutions

| Institutions | Developable area (10 000 $km^2$) | Technical potential (100 GW) | Height (m) | Assessment methods |
|---|---|---|---|---|
| CMA (1990s) | | 7.5 | 10 | based on the second survey results, considering the offshore amount is 3 times that of onshore resource |
| UNEP (2004) | 12.2 | 6 | 50 | numerical simulation technique;<br>considering areas where wind power density ≧ 400W/$m^2$ |
| IGSNRR (2006) | - | 20 (Reserves) | 10 | use of remote sensing satellite data for numerical simulation;<br>at the areas 2 km from the coastline, the wind energy resource is 400 million kW; at the areas 10 km from the coastline, the wind energy resource is about 2 billion kW |

| | | | | |
|---|---|---|---|---|
| CMA（2007） | 3.7 | 1.8 | 50 | numerical simulation technique; considering areas where wind power density ≧400W/m$^2$ |
| NMC (2009) | | 7.58 | 50 | use of remote sensing satellite data for numerical simulation; considering areas 50 km from the coastline and the wind power density ≧400W/m$^2$; areas encountering three or more severe typhoons are not considered |
| ERI (2007) | 3 | 1.5 | - | In accordance with the area programmed by State Oceanic Administration; turbine layout: 5MW/km$^2$ |
| CWERA (2009) | | 2 | 50 | Considering offshore areas whose water depth is 5 to 25 meters and the wind power density≧ 300W/m$^2$ |

## 2.2 Wind resource location in China

Based on GIS method, CWERA estimates that, at the height of 50 meters, the onshore wind resource of force three and above is approximately 2380 GW and the offshore wind resource (5 to 25 m water depth) is about 200 GW. The update research of wind resources shows that there is abundant wind resource of mainland in China to meet with the demand of wind power development in the future.

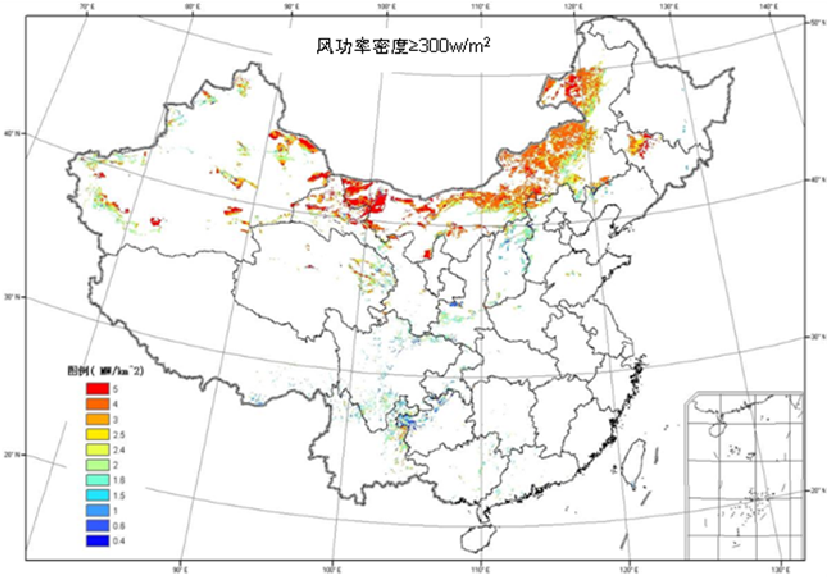



Figure4: Location of wind resource above class 3 in China

### 2.3 Economical quantity of wind resource in key region

Combining GIS with wind supply curve, hydro-china assesses the economical quantity of wind resource. The result indicates that the total amount has exceeded 700 GW, fulfilling the construction demand of 1 GW wind power bases.

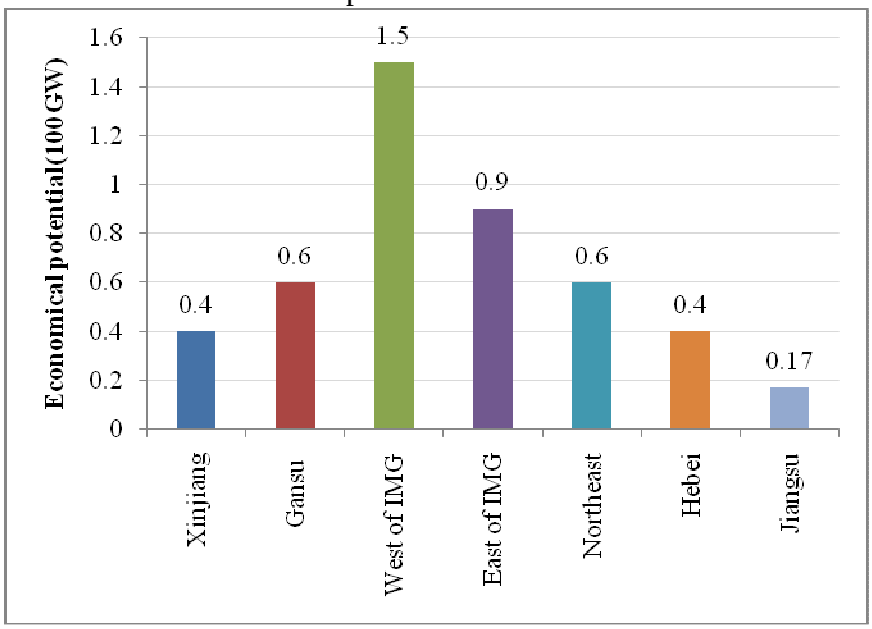



Figure5: Economical potential of wind resource in China's key areas

## 4. Industrial and technological basis for large-scale wind development

### 4.1 Current Development of Wind Power in China

Though began at a very early time, China's wind energy had developed very slowly for a long time, due to high construction cost and lack of policy support and government stimulus. Ever since 2003, such policies and measures have been carried out to facilitate wind power development, especially the policy of concession tender for wind farm that promotes large-scale wind power development. Subsequently, *Renewable Energy Law* and the series of relative policy implementation boost further the wind power development. From 2006 to 2009, China's total wind power installed capacity has reached a growth rate of over 100% for four consecutive years. Till the year 2009, the cumulative wind installed capacity has reached 24.12 GW and China has become the world's fastest growing and also most potential wind power market.

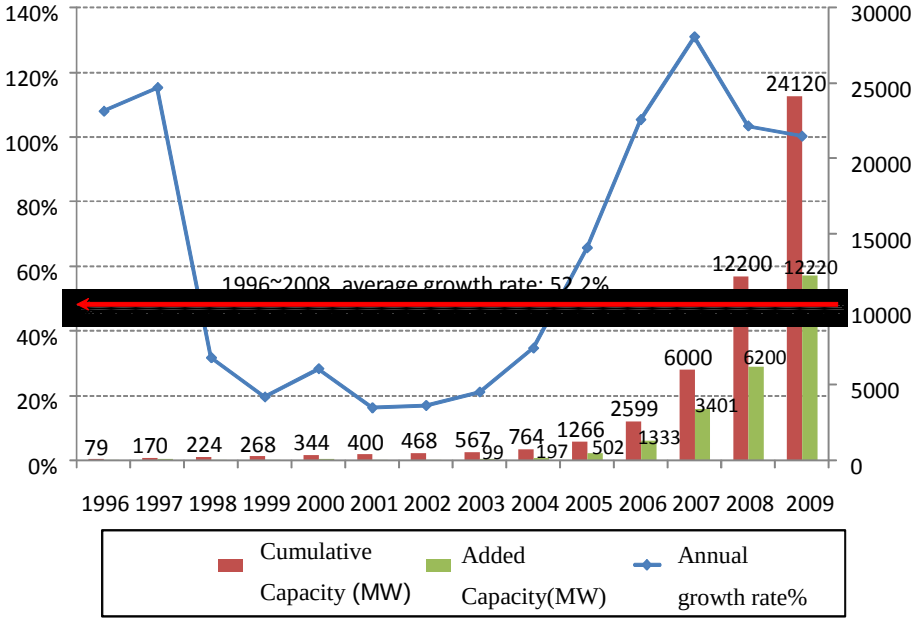



Figure6: The growth rate of wind power for the last ten years

### 3.2 Wind turbine development

The acceleration of the wind power development in China contributes significantly to the localization process of wind equipment. As of the end of 2009, about 80 companies work on wind turbine development, including wholly foreign owned enterprises, equity joint ventures and domestic enterprises. In the same year, the new added wind installed capacity has reached 12.01 GW in China (except Taiwan), among which Sinovel Wind, Gold wind and Dongfang Turbine corporations all take up more than 1 GW and rank among the top ten global turbine manufacturers.

China's domestic enterprises have experienced a dramatic development in wind power and an increasing market share in recent years. In 2007, our products had surpassed the foreign counterparts for the first time and taken up as high as 55.9% of the added market. In 2009, this number increases to 87% and the cumulative market share is more than 50%.

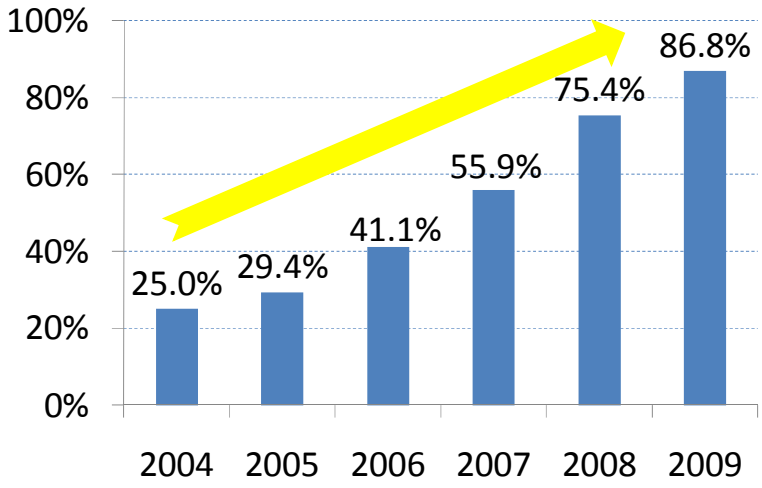


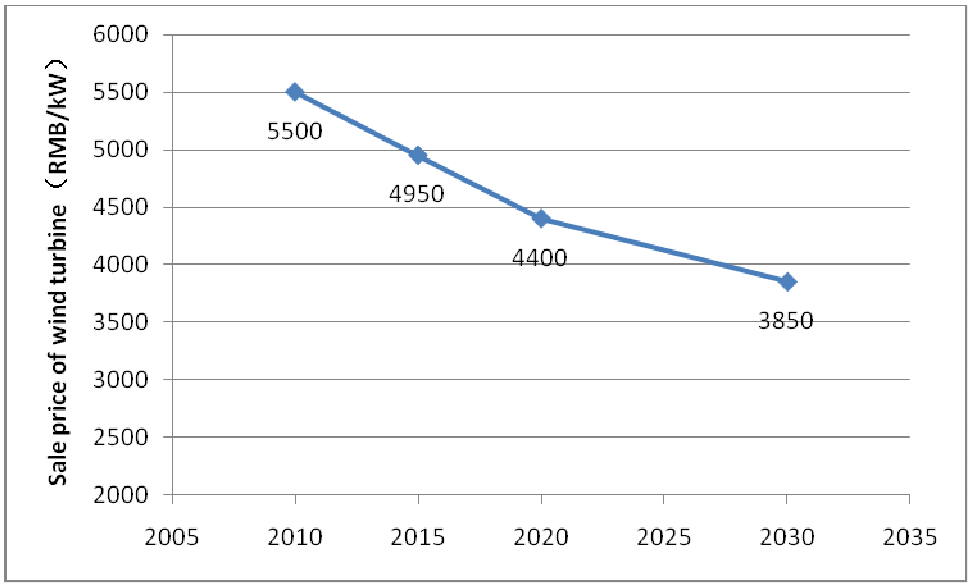
Figure7: China’s added market share of the domestic wind turbine manufacture in 2004-2009

### 3.3 Supply chains development of wind power

China's production capability of wind turbine components has gradually increased in recent years. Among which the supply of blades, gear boxes, bearings and control systems have greatly improved. In 2008, blade production capacity has reached 6 GW, with 14 blade enterprises beginning large-scale production of blades, basically meeting the domestic demand. And its production capacity continues to increase that some companies have already begun to expand to overseas markets; the gear box production such as the supply of yaw bearing and pitch bearing can fully meet the needs of the domestic market and have the ability to export. Although 2008 world bearing giants are still companies like FAG and SKF, China spares no efforts in improving the control system and bearing supply of wind turbine with installed capacity over 1MW. Domestic manufacturers of wind turbines are now capable of meeting the domestic markets through joint ventures and cooperation on technological R & D.

### 3.4 wind power cost development

According to the survey in early 2008, the cost of China's domestic wind turbines is 6,000 to 6,300 RMB per kW. While in April 2009, in the equipment bidding for the four wind farm with installed capacity with GW in Inner Mongolia and Hebei, the average offer has reduced to 5,500 RMB / kW, falling by 15%. The localization of wind equipment has promoted the decline of costs and will accordingly reduce the wind development costs, which is very conducive to wind power’s industrialization.



Fugure8: Declining trend for wind turbine costs

### 3.5wind power roadmap in the future

Wind power development mainly relates to technology such as resource assessment technique, wind turbine technology, wind integration technology, wind energy applications and offshore wind technology.

Till 2020, we will solve the obstacle of wind power development to establish the independent technology, manufacture and serve market of wind power in China. The targets of installed capacity will realize 180GW and the degree of wind power will be improved in the power sector. And to the year 2030, wind power capacity may reach 380 GW which would not only satisfy the domestic needs but also serve the international market. The detail roadmap is as followed:

Table3: 2030 wind power development roadmap

| Projects | Project details | 2009-2020 | 2021-2030 |
|---|---|---|---|
| Wind resource assessment techniques | | ➢ mesoscale meteorological model<br>➢ complex topography wind field model<br>➢ numerical simulation of wind energy resources | |
| Wind Turbine Technology | ➢ Design Technology<br>➢ Manufacturing Technology<br>➢ Standards, testing and certification technology | ➢ MW-grade wind turbine design；<br>➢ physics experiments and numerical simulation of wind turbine<br>➢ establishment of wind | ➢ multi-MW wind turbine design and manufacturing；<br>➢ reliability of wind turbine technology in severe weather |

| | | | |
|---|---|---|---|
| | ➢ Reliability in severe weather conditions | turbine industry system；<br>➢ establishment of standards, testing and certification system<br>➢ wind turbine on-line monitoring and diagnosis system | conditions |
| Wind integration technology | ➢ Simulation Technology<br>➢ Scheduling Management<br>➢ Wind power prediction<br>➢ Transmission technology | ➢ wind power simulation models and applications<br>➢ wind power management system demonstration<br>➢ wind power prediction model and demonstration<br>➢ fractional frequency transmission system demonstration<br>➢ DC transmission technology demonstration | ➢ technical standards and specifications for wind integration<br>➢ commercialization of wind power management system<br>➢ commercialization of wind power forecasting technology<br>➢ application of fractional frequency transmission technology<br>➢ application of DC transmission technology |
| Wind Energy Applications | ➢ Distributed Power System<br>➢ Energy Storage Technology；<br>➢ Direct application of wind power | ➢ distributed power and micro-grid demonstration<br>➢ R & D and demonstration of new energy storage system<br>➢ direct applications of wind power development | ➢ commercialization of distributed power systems<br>➢ commercialization of new energy storage system<br>➢ wind power demonstration in desalination, hydrogen production and high energy consumption projects |
| Offshore wind power technology | ➢ Offshore wind turbines<br>➢ Offshore wind farm | ➢ development & operation of offshore wind turbines<br>➢ offshore wind farm | ➢ scale offshore wind turbine production<br>➢ offshore wind farm demonstration |

| | | | |
|---|---|---|---|
| | | demonstration (offshore within 20km) | (offshore within 50km) |

## 4. Power Grid basis for large-scale wind development

### 4.1 Characteristics of China’s power system

China’s power system has its own features that are different from European countries:

- Thermal power is the main power and takes 75.9% of the nation's total capacity to the end of 2008;
- In most areas, the power supply can only meet its own demand and very little power can be exchanged and transmitted between regional grids;
- Interconnection between the major regional power grids can’t afford large-scale power transmission, which indicates that new transmission lines with high capability should be constructed.

### 4.2 Characteristics of China’s wind power development

The case is that China's onshore wind resource is mainly in northern, northeastern, and northwestern remote areas that are very far away from the centers of consumption. Therefore, the onshore wind development is characterized by large scale, high concentration and long distances.

In 2008, Chinese government put forward the idea of building large-scale centralized wind power bases in Gansu, Xinjiang, Western Inner Mongolia, eastern Inner Mongolia, Jilin, Hebei, and Jiangsu for the next ten years. The above bases, except for the wind power base in Jiangsu coastal area, are all faced with the situation of low load, small power systems and limited wind power demand. With the construction of these bases, the wind farm will access more than 330 kV and higher voltage and the wind power will supply in the regional areas and even nationwide, which needs for the construction of long-distance transmission lines specifically to meet the needs of large-scale development.

At the same time, in many areas that have rich resources, energy that has good adjustment ability takes up a very small proportion in the energy mix, which influences the wind’s integration into grid. In these areas, the main energy is coal-based thermal power, and the consumption of hydropower for peak shaving is very limited. Therefore, the integration of wind power in China is confined to the current energy mix. This brings unprecedented

challenges for large-scale wind power's integration into grid and there's no international experience to learn from.

In short, China's wind development is characterized by large-scale, high-concentration development features and long-distance, high-voltage transmission to centers of consumption. In this respect, it is crucial to build large bases and integrate them into power system under the trend of large-scale wind development.

### 4.3 Measures for wind power's integration into power grid

Large-scale wind power's integration into grid asks for advanced technology, acceleration of grid construction and improvement of management mechanism.

Firstly, according to European experience, establishment of strong grid and improvement of current grid structure provides basic conditions for large-scale wind development, and should be the most urgent work to do. Currently, China is faced with a lot of technological problems such as inadequate grid structure, weak links among major regional grids and limited exchange capability as well as policy problems such as economic mechanism. What's more, among the areas rich in wind resources, except for southeast coastal regions that are near the centers of consumption, other areas need to transmit their abundant resources far away to the centers of consumption, which needs large-scale, long-distance and high-voltage transmission lines. The solution of such problems above is beyond the capability of provincial governments and can only be achieved on the national level. Therefore, the national government should enhance the interconnection between regional grids which would balance the energy, increase the proportion of energy that has good peak shaving capability in the energy mix and reduce the transmission cost. Therefore, the construction of synchronized power grid is the first step to do in the process of large-scale wind power transmission.

Secondly, relevant policies should be completed. For the large-scale wind's integration into grid, there are basically two aspects to be concerned: the wind farm and the grid. Wind farms that meet the requirements of planning, technology and also forecasting accuracy should be rewarded with preferential acquisition price; while those whose forecasting error is more than 20% should be not only excluded from the acquisition but also punished to encourage more advanced technology. Due to the high costs, enterprises working on the wind integration and grid construction should be subsidized to encourage their initiative. Completion of relevant policies and the technology improvement should be carried out synchronously and as quickly as possible.

Thirdly, technology standards for wind integration should be established. It is one of the important conditions to guarantee the safe operation of power system and a crucial way to reduce the impacts on power system and the users.

Fourthly, some research work on the integration technology should be studied:

- Development of wind farm output power short-term forecast technology
- Increased support for R & D and demonstration projects on energy storage technology for peak shaving
- Research of grid-friendly wind turbines and wind farm technology;
- R & D of wind farm simulation technology

In short, on a very good basis, China's power grid needs to strengthen power grid construction and connect synchronous grid among key regions large area network connection, in order to realize 300 GW wind power generation capacity by 2030.

## 5. China’s 2030 wind power development strategy

### 5.1 Development scenario

Till the year 2009, China’s wind power development rate has doubled for four consecutive years. The added installed capacity reaches 12 GW, the total capacity about 24 GW, and China's wind power industry is capable of an annual growth of 10 GW.

According to a comprehensive wind resource assessment result, China’s wind power capacity will reach 400 GW at an acceptable cost (0.5 RMB / kWh). In this study, three scenarios are proposed. Among which the general scenario is relatively conservative, representing a low case; active scenario is supported by relevant policies and represents a high case; and the intermediate scenario takes both supernormal development and the actual needs into consideration, representing a middle case (see Table 4).

Table 4: Wind power development scenarios by 2030

| Scenario | External conditions | | 2030 installed capacity | 2030 total output | Average growth |
|---|---|---|---|---|---|
| | Production capacity (average annual added capacity) | Grid | | | |
| General scenario | 2010-2020: 12 GW<br>2020-2030: 15 GW | power grid construction slower than wind development | 220 GW | 473 TWh | 6% |
| Active scenario | 2010-2015: 13 GW<br>2015-2020: 17 GW<br>2020-2030: 22GW | grid planning and construction taking into account the actual needs of wind power development; construction of national strong grid with | 300 GW | 869 TWh | 8% |

| | | | | | |
|---|---|---|---|---|---|
| | | appropriate measures for dispatching and peak shaving | | | |
| Intermediate scenario | 2010-2020: 12 GW 2020-2030: 15 GW | grid planning and construction taking into account the actual needs of wind power development; construction of national strong grid with appropriate measures for dispatching and peak shaving | 400 GW | 649 TWh | 7% |

### 5.2 Feasibility study for wind power targets realization

For analyzing the feasibility of wind power contribution to 10% of power demand, the electricity output from wind power should be calculated based on the installed capacity. Considering the wind power technology improving and wind farm management perfecting in the future, the annual operation hour of wind power will increase, which is 2000 hours in 2015, 2100 hours in 2020 and 2200 hours in 2030. In three scenarios, the electricity output from wind power will reach 473 TWh to 869 TWh (see Figure 8)

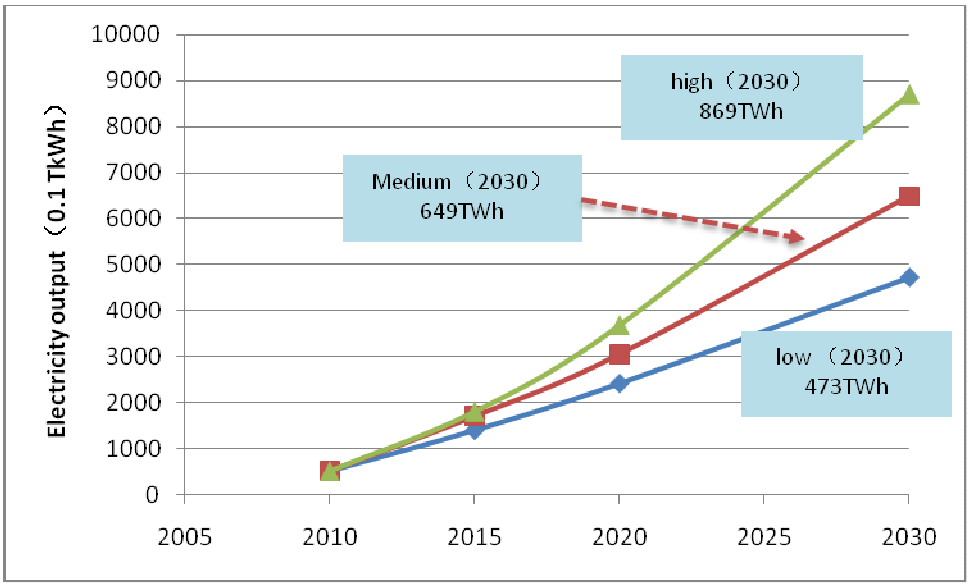



Figure 8: Electricity output of wind power in different scenario in 2030

It is necessary to confirm the total electricity demand in the future for calculating the wind power penetration in power sector. Based on the results from China Engineering Academy, the total electricity demand will reach 8086.6 TWh to 10403.4 TWh, which also including three scenarios(Seen Figure 9).

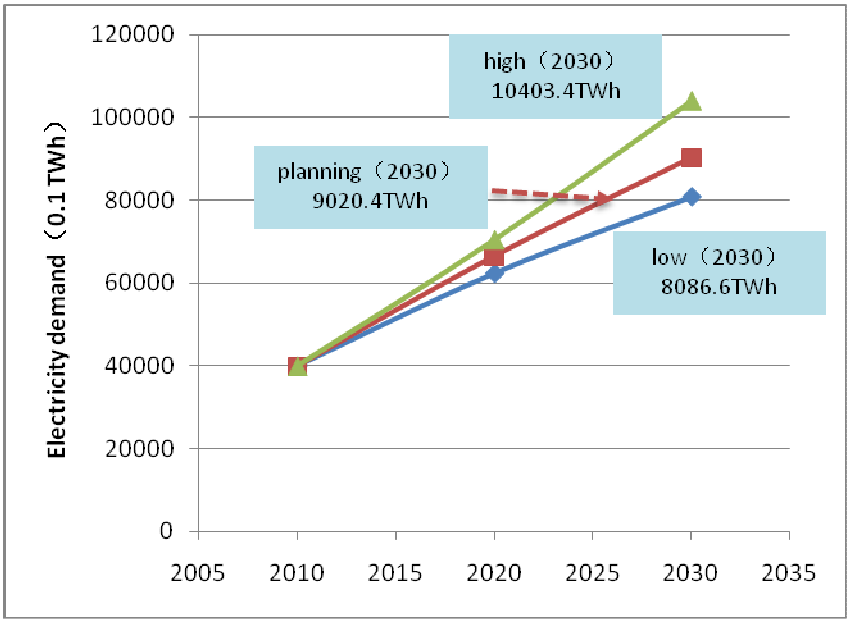


Figure 9 Total electricity demand in differnet scenario in 2030

According to Figure 8 and Figure 9, we calculate the wind power penetration in different scenario(Seen Figure 10). The conclusion is as followed:

- In 2030, the wind power penetration in electricity demand will reach 4.55% to 10.75%

- If the electricity demand of China develops with lower speed and the wind power develops with higher speed, we will realize the wind power contribution to 10% of power demand in 2030. In this scenario, the wind power penetration will be 10.5%. But it is a very optimistic scenario for wind power development.

- In general, the wind power developing will be confined by the power grid integration. At the same time, with economical development, the electricity demand maybe exceeds the lower forecasting. So the wind power penetration will be lower than 10%. If wind power hope to play an important role in power sector in the future, it will face the more challenge.

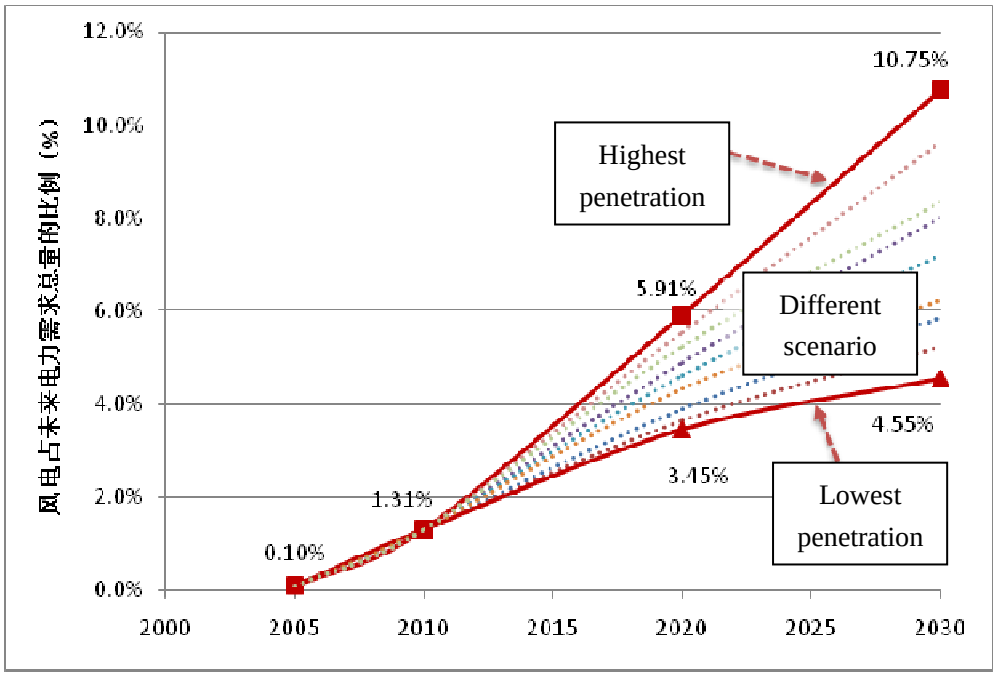


Figure 10 : Wind power penetration in power demand of different scenario in 2030

### 5.3 Wind power location

In the previous chapter, China's wind resource and its geographic distribution are introduced. Considering the future power demand in different areas, grid construction planning and economic analysis of long-distance transmission, the national wind power distribution is designed as follows.

Table5: 2030 Wind power location of each province

| Regions | 2020 (middle) | 2030 (low) | 2030(middle) | 2030 (high) |
|---|---|---|---|---|
| **National** | **15,000** | **22,000** | **30,000** | **40,000** |
| **North** | **5,230** | **6,700** | **9,500** | **15,800** |
| Beijing | 10 | 20 | 20 | 20 |
| Tianjin | 20 | 40 | 40 | 40 |
| Hebei | 1,500 | 1,800 | 2,100 | 2,400 |
| Shanxi | 200 | 340 | 340 | 340 |
| Inner Mongolia | 3,500 | 4,500 | 7,000 | 13,000 |
| **Northeast** | **2,300** | **2,700** | **4,000** | **4,300** |
| Liaoning | 600 | 800 | 1,000 | 1,300 |
| Jilin | 900 | 1,000 | 1,500 | 1,500 |
| Heilongjiang | 800 | 900 | 1,500 | 1,500 |
| **East** | **2,500** | **3,500** | **5,000** | **5,300** |
| Shanghai | 200 | 400 | 400 | 400 |
| Jiangsu | 1,300 | 1,500 | 1,700 | 1,700 |
| Zhejiang | 300 | 500 | 600 | 700 |
| Anhui | 50 | 100 | 100 | 100 |

| | | | | |
|---|---|---|---|---|
| Fujian | 200 | 300 | 600 | 800 |
| Jiangxi | 50 | 100 | 100 | 100 |
| Shandong | 400 | 600 | 1,500 | 1,500 |
| **Central south** | **930** | **2,000** | **2,200** | **2,400** |
| Henan | 100 | 150 | 150 | 150 |
| Hubei | 50 | 100 | 100 | 100 |
| Hainan | 80 | 150 | 150 | 150 |
| Guangdong | 400 | 1,000 | 1,000 | 1,000 |
| Guangxi | 200 | 400 | 600 | 800 |
| Hainan | 100 | 200 | 200 | 200 |
| **Southwest** | **160** | **300** | **300** | **600** |
| Chongqing | 8 | 20 | 20 | 20 |
| Sichuan | 20 | 40 | 40 | 40 |
| Guizhou | 30 | 30 | 30 | 30 |
| Yunnan | 100 | 200 | 200 | 500 |
| Tibet | 2 | 10 | 10 | 10 |
| **Northwest** | **3,880** | **6,800** | **9,000** | **11,600** |
| Shanxi | 100 | 300 | 300 | 300 |
| Gansu | 2,000 | 3,000 | 4,500 | 6,000 |
| Qinghai | 80 | 600 | 800 | 800 |
| Ningxia | 100 | 300 | 400 | 500 |
| Xinjiang | 1,600 | 2,600 | 3,000 | 4,000 |

Source：The author’s analysis

### 5.3 Wind power investment

At present, the cost of wind power is significantly higher than that of conventional energy. But according the future development trend, with the higher demands on the resources and the environmental protection, coal and gas costs will increase, while wind power cost will gradually decrease with improved technology. By the end of 2009, domestic wind turbine price has already declined to less than 5,000 RMB / kW. As the wind power industry is now more and more mature, the price is expected to reduce by 10% by 2015, and will reduce by 10% per decade. Till the year 2030, the price of wind turbine will be around 3,850 RMB / kW, the investment costs about 3,000 RMB / kW and the unit operating cost about 0.125 RMB / kWh.

Taking the numbers above as standards, China’s total wind industry investment in the future is calculated in details in the following Table 6, mainly including turbine manufacturing investment, other wind power industry investment and supporting services investment. By 2030, the total wind power industry investment in the high scenario may reach 2.84 trillion RMB, 2.13 trillion RMB in the intermediate scenario and 1.57 trillion RMB in the low scenario.

In the three types of investment, wind turbine manufacturing is still the main part. With the realization of rapid wind power development, the investment may goes up to 1.5 trillion RMB.

Table 6: 2030 wind power investments

| Year | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Low scenario | Wind turbine manufacturing investment (100 million RMB) | 1,650 | 3712.5 | 5,280 | 8,470 |
| | Other wind power industry investment (100 million RMB) | 900 | 2,250 | 3,600 | 6,600 |
| | Supporting services investment (100 million RMB) | 65 | 176 | 303 | 591 |
| | Total wind power industry investment (100 million RMB) | 2,615 | 6,139 | 9,183 | 15,661 |
| Intermediate scenario | Wind turbine manufacturing investment (100 million RMB) | 1,650 | 4,455 | 6,600 | 11,550 |
| | Other wind power industry investment (100 million RMB) | 900 | 2,700 | 4,500 | 9,000 |
| | Supporting services investment (100 million RMB) | 65 | 210 | 378 | 804 |
| | Total wind power industry investment (100 million RMB) | 2,615 | 7,365 | 11,478 | 21,354 |
| High scenario | Wind turbine manufacturing investment (100 million RMB) | 1,650 | 4702.5 | 7,920 | 15,400 |
| | Other wind power industry investment (100 million RMB) | 900 | 2,850 | 5,400 | 12,000 |
| | Supporting services investment (100 million RMB) | 65 | 220 | 444 | 1,060 |
| | Total wind power industry investment (100 million RMB) | 2,615 | 7,773 | 13,764 | 28,460 |

### 5.4 Energy benefit

The energy benefit of wind power is very clear and is calculated comparing to the consumption of coal for power generation. The coal consumption for power supply decreases 18gce/kWh during the ninth Five-Year Plan period and 15gce/kWh during the eleventh Five-Year Plan period. Accordingly, it is estimated that the coal consumption may fall by 10gce/kWh during the twelfth Five-Year Plan period and will decline to 0.32kgce/kWh by 2020 and 0.3kgce/kWh by 2030. In this respect, the alternative energy efficiency of wind power is proposed and three scenarios are put forward: the energy efficiency is 254 million tce in the high scenario, 193 million tce in medium scenario and142 million tce in low scenario.

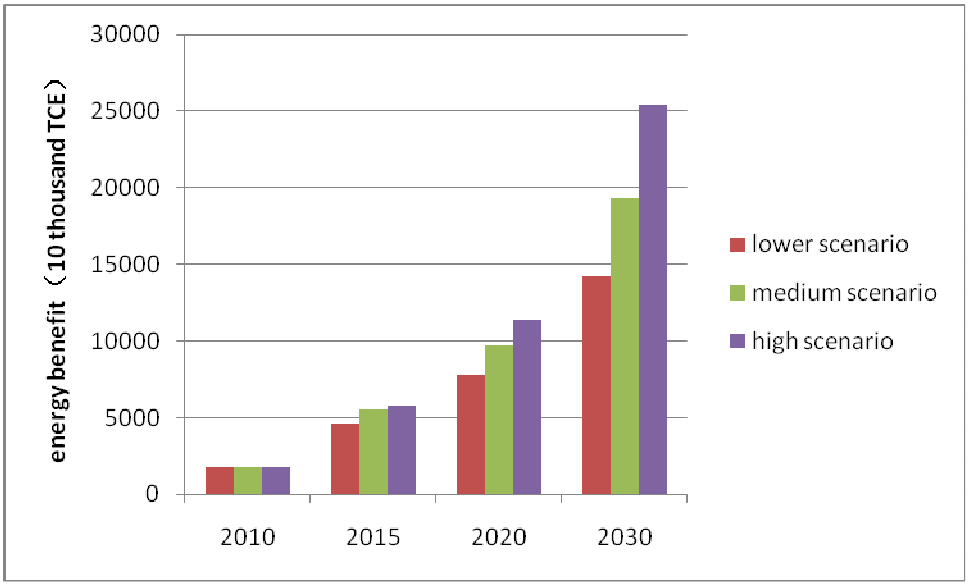



Figure9: Wind power alternative energy benefit by 2030

### 5.5 Environmental benefits

Wind power's environmental benefits are considered as reducing the emission of damage air from the coal-fired generation power, including $SO_2$, $NO_X$, TSP and $CO_2$.

The environmental benefits brought by wind power generation are shown in the following Table 7. It can be told from the table that the reduction of $CO_2$ emission is most obvious, reaching 861 million tons in the active scenario, in which the emission of $SO_2$ is 590 000 tons, $NO_X$ 550,000 tons and TSP 30 tons.

Table7: 2030 environmental benefits from wind power in three scenarios

| Year | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Low scenario | TSP (10 thousand tons) | 2 | 5 | 9 | 17 |
| | $SO_2$ (10 thousand tons) | 4 | 10 | 17 | 33 |
| | NOx (10 thousand tons) | 3 | 9 | 16 | 31 |
| | $CO_2$ (10 thousand tons) | 5,282 | 14,321 | 24,636 | 48,043 |
| General scenario | TSP (10 thousand tons) | 2 | 6 | 11 | 23 |
| | $SO_2$ (10 thousand tons) | 4 | 12 | 21 | 45 |
| | NOx (10 thousand tons) | 3 | 11 | 20 | 42 |
| | $CO_2$ (10 thousand tons) | 5,282 | 17,064 | 30,715 | 65,360 |
| Active scenario | TSP (10 thousand tons) | 2 | 6 | 13 | 30 |
| | $SO_2$ (10 thousand tons) | 4 | 12 | 25 | 59 |
| | NOx (10 thousand tons) | 3 | 11 | 23 | 55 |
| | $CO_2$ (10 thousand tons) | 5,282 | 17,876 | 36,047 | 86,142 |

### 5.6 Social benefits

Wind power's social benefit is mostly the increase of employment. According to its contribution to GDP, every added MW installed capacity could create 20 job positions, including equipment manufacturing, components supply, raw material production, development, construction of wind farms as well as indirect employment. In recent years, the optimization of production process causes a decline in manpower and accordingly, the job positions reduce to 15. In this respect, by 2030, the annual job positions provided by wind power development are as high as 6.13 million in the high scenario, 4.6 million in the intermediate scenario and 3.37 million in the low scenario.

Table8: 2030 social benefits of wind power in three scenarios

| Year | | 2010 | 2015 | 2020 | 2030 |
|---|---|---|---|---|---|
| Low scenario | Average annual number of new job positions (10,000) | 16 | 18 | 16 | 15 |
| | Total job positions (10,000) | 61 | 152 | 208 | 337 |
| Intermediate scenario | Average annual number of new job positions (10,000) | 16 | 24 | 21 | 23 |
| | Total job positions (10,000) | 61 | 183 | 260 | 460 |
| High scenario | Average annual number of new job positions (10,000) | 16 | 26 | 29 | 34 |
| | Total job positions (10,000) | 61 | 193 | 312 | 613 |

### 5.7 Policy subsidies

At present, China's wind generated electricity tariff is classified into four kings of tariffs: 0.51 RMB / kWh, 0.54 RMB / kWh, 0.58 RMB / kWh and 0.61 RMB / kWh. And the part higher than coal-fired generated electricity is shared by the country, which is called wind power tariff subsidies.

The policy subsidies for wind power development are calculated in Table 9 (based on the intermediate scenario). It can be told that the subsidy may reach 72.7 billion RMB by 2020 and 163.4 billion by 2030.

Table9: Electricity tariff subsidies for Wind power

| Regions | 2015 | 2020 | 2030 |
|---|---|---|---|
| **National** | **342.9** | **726.7** | **1633.9** |
| **North** | **146.5** | **261.5** | **506.7** |
| Beijing | 0.2 | 0.4 | 1.0 |
| Tianjin | 0.2 | 1.0 | 2.1 |
| Hebei | 35.5 | 53.9 | 90.2 |

| | | | |
|---|---|---|---|
| Shanxi | 2.7 | 11.2 | 21.6 |
| Inner Mongolia | 83.7 | 152.3 | 343.8 |
| **Northeast** | **45.0** | **112.7** | **222.6** |
| Liaoning | 14.8 | 31.4 | 57.0 |
| Jilin | 17.3 | 40.8 | 79.8 |
| Heilongjiang | 12.8 | 40.5 | 85.8 |
| **East** | **39.5** | **102.2** | **226.8** |
| Shanghai | 1.7 | 6.9 | 15.3 |
| Jiangsu | 22.6 | 53.1 | 76.0 |
| Zhejiang | 3.5 | 10.6 | 23.1 |
| Anhui | 0.4 | 2.2 | 4.9 |
| Fujian | 4.2 | 8.7 | 27.6 |
| Jiangxi | 0.2 | 1.8 | 4.3 |
| Shandong | 6.9 | 18.8 | 75.6 |
| **Central south** | **9.6** | **31.8** | **80.8** |
| Henan | 0.9 | 4.7 | 7.9 |
| Hubei | 0.8 | 2.0 | 4.4 |
| Hunan | 0.7 | 2.9 | 6.1 |
| Guangdong | 4.1 | 11.1 | 29.8 |
| Guangxi | 1.5 | 7.7 | 25.4 |
| Hainan | 1.6 | 3.4 | 7.2 |
| **Southwest** | **2.6** | **9.1** | **19.0** |
| Chongqing | 0.2 | 0.4 | 1.0 |
| Sichuan | 0.2 | 0.9 | 2.0 |
| Guizhou | 0.3 | 1.7 | 2.0 |
| Yunnan | 1.9 | 5.8 | 12.8 |
| Tibet | 0.0 | 0.2 | 1.3 |
| **Northwest** | **99.8** | **209.3** | **578.0** |
| Shanxi | 2.6 | 5.6 | 18.1 |
| Gansu | 63.5 | 108.2 | 278.9 |
| Qinghai | 2.5 | 5.4 | 56.6 |
| Ningxia | 0.6 | 3.8 | 24.4 |
| Xinjiang | 30.5 | 86.3 | 200.0 |