



# Review of renewable energy industry in Beijing: Development status, obstacles and proposals



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## ABSTRACT

Beijing is the capital of China, serving as the center of China's politics, culture and education. The exploitation and utilization of renewable energy has become an important developmental carrier for Beijing, which is also a key channel for optimizing energy consumption structure, building a high-efficiency and low-carbon energy system, relieving the environmental pressure and ensuring the energy secure of Beijing. In this paper, Beijing's renewable energy industry was analyzed. First, Beijing's renewable energy resources, which include biomass energy, solar energy, geothermal energy, wind energy and hydro energy, were introduced from two aspects of energy resource distribution and energy resource utilization. Second, the development status of Beijing's renewable energy industry (including biomass, solar and wind energy industry) was expounded. Then, the obstacles of Beijing's renewable energy industry were analyzed. Finally, some proposals for the healthy development of Beijing's renewable energy industry were put forward, which will contribute to build a clean, safe, efficient and low-carbon energy system for Beijing.

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## 1. Introduction

Energy is a necessity for the survival and development of a city, which is also the basic guarantee for the normal operation of a city [1]. The level and quality of energy supply in a city play a vital role in its economy development, people's living standards enhancement and ecological environment improvement [2,3]. Beijing city is the capital of China, serving as the nation's political, cultural, and educational center. Along with the development of social economy and people's living standard, the demand for energy continues to rise in Beijing. In 2012, the total energy consumption in Beijing has reached to 71.777 million tons of standard coal equivalent (tce), which is 2.5 times that in 1990 [4]. Currently, Beijing is facing a serious shortage of energy resources, and the energy external dependency degree is very high [5]. At the same time, Beijing's air pollution is becoming more serious with the rapid development of economy and urbanization, and the hazy weather days reached an amount of 124 days in 2012, which is the highest in the past ten years [6].

The energy utilization in Beijing city is facing the dual pressures from economic growth and environmental protection. Compared with the developed countries or cities, Beijing's energy consumption structure and pattern is relatively backward. Exploiting renewable energy resources instead of traditional fossil fuels can reduce pollutant emissions and optimize energy consumption structure, which can also solve the bottleneck in the process of economic development to some extent [7,8]. The renewable energy resources reserves, which include biomass energy, solar energy, geothermal energy, wind energy and small hydropower, amount to 38.6 million tce in Beijing, and the availability accounts for 18.65% [9]. At the end of 2012, the "12th Five-Year Development Plan of Beijing's Renewable Energy" was issued, which stated that the utilization volume of Beijing's renewable energy will increase to 5.5 million tce by 2015, which will account for 6% in total energy consumption. Therefore, exploiting and utilizing renewable energy resources have important strategic significance to promoting economic development and preserving the ecological environment.

In this paper, the renewable energy industry of Beijing city is studied. The paper is organized as follows: Section 2 provides an overview of Beijing's renewable energy resources; the

development status and obstacles of Beijing's renewable energy industry are analyzed in Section 3 and Section 4, respectively; some proposals for the coordinated and healthy development of Beijing's renewable energy industry are put forward in Section 5; Section 6 concludes this paper.

## 2. Overview of Beijing's renewable energy resources

### 2.1. The distribution of Beijing's renewable energy resources

There are several kinds of renewable energy resources in Beijing city, namely biomass energy, solar energy, wind energy, geothermal energy and small hydropower. However, the reserves of these renewable energy resources are relatively less compared with that of other great resource provinces, such as Hebei and Inner Mongolia provinces [10]. According to the preliminary surveys, Beijing's renewable energy resources reserve amount equals to 38.6 million tce, and the availability accounts for 18.65% under current technological development level [11,12]. Among these renewable energy resources, the availability of biomass energy accounts for the highest proportion, which is 39.5%, followed by solar energy (31.9%), geothermal energy (27%), wind energy (1.2%), and small hydropower (0.4%), respectively [12]. The amount and availability of renewable energy resources in Beijing city are listed in Table 1.

**Table 1**

The amount and availability of Beijing's renewable energy resources [11,12].

|                            | Amounts (10 <sup>4</sup> tce) | Proportion (%) |
|----------------------------|-------------------------------|----------------|
| Renewable energy resources | 3860                          |                |
| Availability               | 720                           | 100            |
| Biomass energy             | 284.4                         | 39.5           |
| Solar energy               | 229.68                        | 31.9           |
| Geothermal energy          | 194.4                         | 27             |
| Wind energy                | 8.64                          | 1.2            |
| Small hydropower           | 2.88                          | 0.4            |

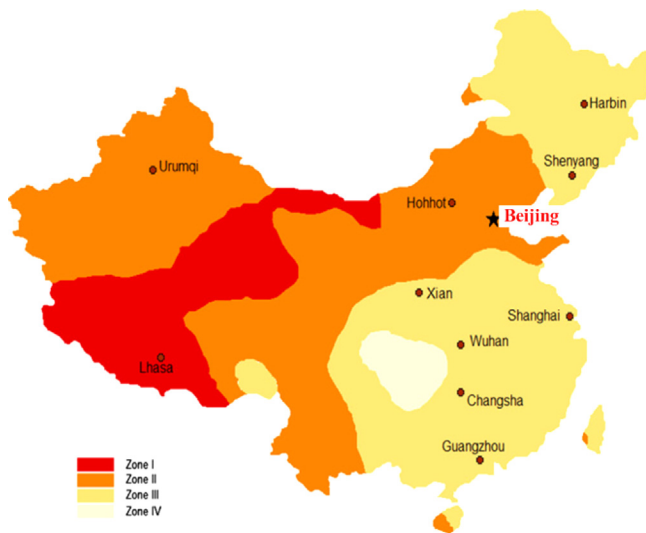


Fig. 1. Solar energy resource distribution in China [17].

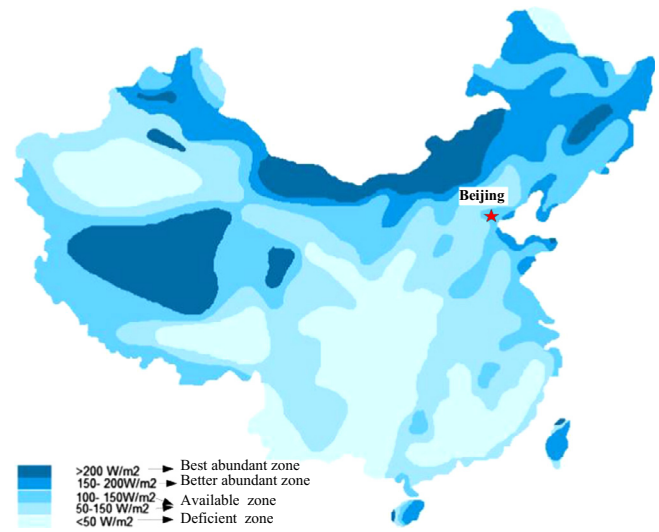


Fig. 2. Distribution of China's wind energy resource [15].

### 2.1.1. Biomass energy

Beijing's biomass energy resource is relatively rich, which mainly distributes in the suburbs, and the biomass energy type mainly includes agricultural waste, forestry waste, fecal residue and waste water, and household garbage. The annual production of agricultural straw amounts to 5.2 million tons, and the useable volume accounts for 80.2%, which equals to 1.79 million tce. The total production of living garbage in Beijing amounts to 4.7 million tons per year, the heat value of which can reach an average of 100 kcal/kg [11]. The biomass resources in the new urban districts and biological conservation areas account for over 80% of the total biomass resources in Beijing [13].

### 2.1.2. Solar energy

The solar energy resource in Beijing is relatively abundant. Beijing can receive a radiation of 5227.14 MJ/m<sup>2</sup> yr and 2600 h of sunshine, both of which are higher than national average level (5000 MJ/m<sup>2</sup> yr and 2200 h) [14,15]. The solar energy resource distribution in China is divided into four zones, which is shown in Fig. 1, and Beijing is located in Zones II [16]. Beijing annual radiation volume in the north and south areas is higher than that in the central area, especially, the radiations of Shangdianzi-Hetangkou area and Yanqing basin are dominant.

### 2.1.3. Geothermal energy

Beijing has a large potential in terms of geothermal heat. According to preliminary survey, the annual available geothermal energy resource can reach to 3.5 million tce, and the exploitable industrial waste heat resource is around 0.6 billion tce, which are mainly distributed in Yanqing, Haidian, Daxing, Changping and Shunyi districts [18]. In the whole, Beijing's geothermal energy resource is relatively rich with more than 20 billion m<sup>3</sup> of annual exploitable area. The geothermal energy resource with high level exploration, low embedded depth and satisfactory exploitation value mainly locates in Xiaotangshan geothermal field, Liangxiang geothermal field and Lisui geothermal field.

### 2.1.4. Wind energy

Beijing is an inland city with its three sides surrounded by the mountains connecting to Taihang Mountain in the south and Yanshan Mountain in the north, which causes the small wind amount and low wind speed. Moreover, Beijing's offshore wind resource is next to nothing. Although China's wind energy resource

is quite rich which ranks first in the world in terms of resource reserve, Beijing is located in wind energy distribution zone III, namely available zone, just as shown in Fig. 2. Beijing's wind resource reserve approximately equals to 4.6 billion kilowatt [18], and the availability under current exploitable technology only accounts for 0.45 billion kilowatt, which is mainly distributed in the north and northwest part such as Yanqing, Miyun and Mentougou [18].

### 2.1.5. Hydro energy

Beijing's hydro energy resource reserve is relatively lower than other cities. According to the national hydro energy resources census, the technically and economically exploitable capacity of Beijing's hydro energy approximately amounts to 0.585 and 0.414 GW, which only accounts for 0.108% and 0.103% of the national level, respectively [19]. Beijing's hydro energy resource is mainly distributed in Chaobai river, Juma river and Jingmi water diversion canal.

Throughout Beijing's renewable energy sources, it can be seen that Beijing is relatively rich in solar, geothermal and biomass energy sources, and there is certain wind energy resource, but the hydro energy resource is scarce.

## 2.2. The utilization of Beijing's renewable energy resources

In recent years, Beijing is strengthening the adjustment and optimization of energy structure, which is gradually built with electricity in the first place, and coal, gas, oil, new energy and renewable energy as a supplement. Beijing has a relatively abundant renewable energy source reserve, and the availability is large. Ensuring the secure and reliable supply of different energy types, Beijing has intensified efforts to develop and utilize the renewable energy. The "Development Planning of Beijing's New Energy and Renewable Energy during the 12th Five-Year Plan period" points out that the proportion of new energy and renewable energy in the total energy consumption will reach around 6% [18]. This will promote the utilization and development of Beijing's renewable energy. At the end of the 11th five-year plan period, namely the year of 2010, the total utilization quantity of renewable energy in Beijing was 2.23 million tce, accounting for 3.2% in the total energy consumption, which is 2.7 times that in 2005.

### 2.2.1. The utilization of biomass energy

Biomass energy is one of the main energy types in our daily life, and it has got a widespread use in suburbs of Beijing in ways of generating biogas and biomass power generation. At the end of the *11th five-year plan period*, the biomass energy utilization reached to 0.36 million tce, of which the cumulative biomass power installed capacity amounted to 32.7 MW, biogas utilization amounted to 18 million m<sup>3</sup>, and the production amount of biomass fuel approximate to 0.2 million tce [18].

With respect to biomass power generation, several counties have established biomass power cogeneration plants which employ the straws to generate electricity and heat. Meanwhile, four waste incineration power plants namely Gaoantun, Nangongshan, Liulitun and Asuwei, have been constructed in different parts of the suburb with the total capacity of 100 MW, all of which have been put into use in 2010. In the suburban districts such as Yanqing, Miyun and Pinggu district, the biomass compression particle and block fuel have been used as a substitution of fossil fuels. In Pinggu district, a 25 MW biomass power plant has been built which takes the peach twig as the power generation fuel [20]. Some achievements have been obtained by the Chinese Academy of Agricultural Mechanization Sciences (CAAMS) in terms of biomass energy technology, such as the feeding system technology of agriculture and forestry biomass direct combustion power plant, collection and storage technology of agriculture and forestry biomass, etc.

With respect to biogas utilization, a centralized collection, processing and utilization of livestock and poultry manure have been achieved to produce biogas in Beijing's suburban districts. Beijing has possessed the technical strength in developing medium- and large-scale biogas engineering projects. In the future, the livestock farms aim at large and intensive scale, which will also provide resource potential for the large-scale biogas engineering projects development.

### 2.2.2. The utilization of solar energy

Solar water heater is the main utilization form of Beijing's solar energy. In Beijing, there are 270–300 days per year which satisfy the lighting condition for the solar energy utilization, the energy-saving effect of which is remarkable. Therefore, Beijing is a city that is very suitable for the installation of solar thermal systems [21]. At the end of the *11th five-year plan period*, the total utilization amount of solar energy was about 0.98 million tce. Of which, the cumulative installation area of solar water heaters has reached more than 6 million square meter, and the total area of solar building has approximated 0.3 million square meters. Meanwhile, the cumulative installed capacity of photovoltaic power generation amounted to 2.3 MW, and the number of solar lights was more than 0.13 million [18]. According to the survey, the solar water heater only has 7% of popularizing rate in Beijing's urban area, and the popularizing rate in the suburb and rural town is 30% and 85%, respectively. The popularizing rate of solar heat utilization is low in Beijing, and the utilization potential remains to be further developed.

In addition to solar water heaters, other utilization types of solar energy are still in an infantile stage. In order to promote the development of solar thermal and photovoltaic technologies, a number of demonstration projects such as solar photovoltaic power plants, rural solar heating buildings and solar greenhouse, have been built by Beijing municipal government and enterprises. In May 2009, the first megawatt solar thermal power plant, namely Yanqing-Badaling experimental solar thermal power plant was approved, which is China's first solar thermal power generation demonstration project. Meanwhile, the related technology researches are keeping pace with the times, and Beijing Institute of

Automation Technology (BIAT) has obtained some beneficial achievements in these areas.

During the *11th five-year plan period*, the average annual growth of solar energy utilization in Beijing is 15.7%, which is two times of that in 2006. The accumulated installation area of solar water heaters has increased to more than 6 million m<sup>2</sup>, and the solar heating area combined with the buildings amounts to about 0.3 m<sup>2</sup>. The accumulated installed capacity of photovoltaic power generation is about 2.3 MW. Beijing has been making great efforts to promote the wide application of solar energy.

### 2.2.3. The utilization of geothermal energy

Since the early 1970s, the geothermal energy in Beijing has been widely used. The geothermal water has been used for winter heating, bath care, greenhouse cultivation, boiler feed water, industrial utilization and aquaculture, which has achieved remarkable economic benefits. There are hotels, guest houses, publishing houses, printing houses, textile mills, dyeing factories, nursing homes and other more than 60 units to use geothermal water for heating. Currently, the total area of buildings which use the geothermal heating instead of coal-fired heating has reached 2 million m<sup>3</sup>. There are more than 50 geothermal common bathing pools, which can serve for 50 thousand people every day.

In the aspect of industry, the geothermal water is mainly used in the workshop air-conditioning system, textile printing and dyeing machinery. Miyun Bronze Bull garment factory has used the thermodynamic heating system, i.e. use the geothermal water for heating. Some other industries use the geothermal water for washing, cleaning and producing.

In addition, with the application of heat pump technology, Beijing has issued some relevant policies for supporting the orderly development of heat pump technology, which propose to develop the reclaimed water source heat pump, ground source heat pump and groundwater source heat pump with certain subsidies.

### 2.2.4. The utilization of wind energy

Beijing's wind energy is mainly used for generating electricity. Beijing's wind power plants are concentrated in the south bank of the Guanting reservoir in Yanqing county, where the average wind velocity reaches to 7.11 m/s at 70 m height above ground level, and the average wind power density approximates 422 W/m<sup>2</sup> with 2000 effective hours. During the *11th five-year plan period*, the Guanting wind farm with 43 units of 1.5 MW direct wind generators and 64.5 MW of installed capacity was built and connected to the grid, which fills the gap of wind energy utilization in Beijing. The Guanting wind farm adopted the fans with own intellectual property right and free of gear box as well as lubricating oil, which can greatly reduce the energy consumption and pollution. According to the estimation, the Guanting wind farm can generate 0.1 billion kW h of green electricity every year, which can meet the electricity demand of 0.3 million families and reduce 0.1 million tons emission of CO<sub>2</sub> and 50 thousand tons consumption of coal [22]. By the end of *11th five-year plan period*, the installed capacity of Beijing's wind power has increased to 150 MW, and the cumulative electricity generation has reached 0.48 billion kW h.

### 2.2.5. The utilization of hydro energy

Although the hydro energy resource in Beijing is scarce, the small hydropower has also developed to a certain extent in recent years. By the end of *11th five-year plan period*, there are 50 hydropower stations in Beijing with a total installed capacity of 250 MW. In recent years, affected by the water resource scarcity and generating unit aging, there are only 22 stations that still run with a total installed capacity of 224 MW. The average



**Table 2**

Development planning and policies of Beijing's new and renewable energy.

| Planning or policy  | Issue date | Main focus  |
|---|------------|---|
| Beijing's energy development and energy-saving planning during the 11th Five-Year Plan Period         | Dec. 2006  | <ul style="list-style-type: none"> <li>• Ensure energy security: strengthen the construction of electric power, natural gas, coal and oil; develop security pre-warning mechanism and emergency system related to the electric power, natural gas, coal and oil</li> <li>• Optimize energy structure: strive to develop electric power and natural gas; control the total amount of coal consumption; accelerate the development and utilization of new and renewable energy industry</li> <li>• Balance urban and rural energy development: improve the rural electric power grid system; increase the supply level of natural gas; improve the rural heating capacity</li> <li>• Give great impetus to building energy efficiency</li> <li>• Strengthen energy conservation in the field of transportation</li> </ul>   |
| Action planning on “Green Beijing” (2010–2012)  | Mar. 2009  | <ul style="list-style-type: none"> <li>• Promote the industrial upgrading and create the green production system: cultivate new energy as well as energy conservation and environmental protection industry; develop urban green agriculture; implementing cleaner production</li> <li>• Creating green consumption system: forge green government affairs; advocate green business; create a low-carbon and green life</li> <li>• Promote the carrying capacity of green development: popularize new and renewable energy; promote the utilization of clean energy</li> <li>• Popularize green building and transportation: promote the building energy-saving reform and the new energy environment-friendly cars</li> <li>• Comprehensively utilizing the waste resources, such as municipal refuse, crop straw and livestock and poultry manure</li> <li>• Control atmospheric pollution: strictly control boiler exhaust emissions; strengthen pollution control of industrial waste gas and dust pollution</li> </ul> |
| Implementation planning of vitalizing and developing Beijing's new energy industry                    | Oct. 2009  | <ul style="list-style-type: none"> <li>• Consolidate the dominance of R&amp;D and high-end manufacturing in the field of PV industry and solar thermal industry</li> <li>• Improve the integration capability of wind power equipment manufacturing system</li> <li>• Enlarge the industrial scale of high-end technical service of nuclear power</li> <li>• Promote the development of new-energy automobile industry</li> <li>• Improve the capability of key technology R&amp;D and engineering services of geothermal energy</li> <li>• Upgrade the clean and effective utilization technology of biomass energy</li> </ul>   |
| Guidance on speeding up the utilization and promoting industry development of solar energy in Beijing | Dec. 2009  | <ul style="list-style-type: none"> <li>• Implement “Golden Sunshine” project and build a first-class sunshine city: promote the 20 MW photovoltaic roof engineering; construct 50MW light energy demonstration accessing-grid power station; speed up the implementation of sunshine campus project; promote solar-based hot water project</li> <li>• Further support the science and technology innovation and implement the revitalization plan of science and technology related to solar energy</li> <li>• Build high-end base and foster competitive industry: build high-end solar energy industry base; foster the competitive industries in the field of PV and solar energy photo-thermal utilization</li> <li>• Build four supporting systems and construct a benign development mechanism: strengthen the construction of policy support system; improve the standard specification system; improve the planning and security system; enrich the propaganda and training system</li> </ul>                       |
| Development planning of Beijing's new and renewable energy during the 12th Five-Year Plan Period      | Nov. 2011  | <ul style="list-style-type: none"> <li>• Build high-end demonstration projects: promote the construction of new energy project; build national green energy demonstration project; achieve the comprehensive utilization of new energy in high-end functional district</li> <li>• Encourage innovation and promote development of new and renewable energy industry: consolidate the new energy technology innovation advantage; speed up the construction of new energy R&amp;D center; enlarge new energy industry base</li> <li>• Improve the development mechanism and guarantee the planning implementation</li> </ul>   |

annual power generation of these operating units amounts to 40 million kW h, which is only 10% of designed power generation capacity [18].

### 3. Development status of Beijing's renewable energy industry

During the 11th five-year plan period, the exploitation and utilization of new energy and renewable energy developed fast in Beijing, and the industry scales were expanding. Especially, the successful hosting of Beijing Olympic Games not only realizes the promise of “Green Olympic”, but also greatly promotes the

renewable energy development, which provides favorable treatment to the structural improvement and sustainable development of Beijing's energy [23]. It cannot be denied that these achievements largely benefit from the related new and renewable energy policies and regulations. In the past few years, several development planning and policies related to Beijing's new and renewable energy industry have been issued, which are listed in Table 2.

From Table 2, it can be seen that the development planning and policies of Beijing's new and renewable energy cover several new and renewable energy types, such as solar energy, biomass energy, and wind energy. In particular, there is a specific policy that

**Table 3**  
Beijing renewable energy projects during the 11th five-year plan period [24].

| Projects  | Scale                      | Power generation (10 <sup>4</sup> kW h) | Standard coal equivalent (10 <sup>4</sup> t) |
|---|----------------------------|---|--|
| 1 Power generation                                | (10 <sup>4</sup> kW)       |   |  |
| (1) Wind farm                                     | 10                         | 20000                                   | 6.5  |
| (2) PV power plant                                | 0.3                        | 450                                     | 0.2  |
| (3) Livestock and poultry farm biogas power plant | 3                          | 16500                                   | 5.4  |
| (4) Landfill gas recovery power plant             | 1                          | 7200                                    | 2.3  |
| (5) Trash-fired power plant                       | 10                         | 72000                                   | 23.4   |
| (6) Solid biomass power plant                     | 12                         | 72000                                   | 23.4   |
| (7) Small hydropower transformation               | 5                          | 8675                                    | 2.8  |
| <b>Sum</b>  |                            | <b>196825</b>                           | <b>64</b>                                    |
| 2 Heating   |                            |   |  |
| (1) Geothermal heating                            | 5 million m <sup>2</sup>   |   | 10   |
| (2) Heat pump                                     | 30 million m <sup>2</sup>  |   | 56   |
| (3) Solar water heaters                           | 5.4 million m <sup>2</sup> |   | 64.8   |
| (4) Biomass pellet fuel                           | 0.1 billion t              |   | 4.6  |
| <b>Sum</b>  |                            |   | <b>135.4</b>                                 |
| 3 Biological liquid fuel                          |                            |   |  |
| (1) Biodiesel derived by gutter oil               | 5000 t                     |   | 0.7  |
| <b>Sum</b>  |                            |   | <b>200.1</b>                                 |

**Table 4**  
Main equipment produced by biogas companies in Beijing.

| Company name                                      | Produced equipment   | Annual output | Annual revenue     |
|---|--|---------------|--------------------|
| Beijing JunBo new energy operation center         | Biogas digester<br>5 kW–100 kW biogas power generation equipment           | 10000<br>1200 | 7–10 million yuan  |
| Qingda industrial technology development Co., Ltd | Biomass gasification machine<br>Solar energy-combined straw biogas machine | 15000<br>5000 | 15–20 million yuan |

focuses on Beijing's solar energy industry development, namely "Guidance on speeding up the utilization and promoting industry development of solar energy in Beijing". These planning and policies promote the development of Beijing's new and renewable energy industry to some extent. Currently, a diversified energy supplying system is gradually forming in Beijing, and the share of renewable energy in the total energy consumption is increasing. During the 11th five-year plan period, a series of renewable energy projects related to biomass, solar and wind energy industry were carried out with a total investment of 9.796 billion yuan. All these projects are equivalent to 2.001 million tce, the details of which are listed in Table 3 [24].

Beijing who relies on its strong R&D strength in the field of new energy and renewable energy has built several R&D institutions, such as national key laboratories, national engineering laboratories and national engineering research centers. Meanwhile, Beijing is the first city in China to establish New Energy Industrial Technology Innovation Alliance (NEITIA) which is comprised of solar photovoltaic, solar-thermal, wind energy, biomass energy and so on. Nowadays, Beijing has initially formed an innovative pattern of enterprises, R&D institutions and industry alliance. Considering the development focus and trend of different renewable energy types in Beijing, the biomass, solar and wind energy industry will be detailed discussed in the following.

### 3.1. Development status of biomass energy industry

The biomass energy industry has been developed since 1970s. In recent years, great progress has been achieved for the utilization of biomass energy. Nowadays, there are several biomass energy-related demonstration projects and large- and medium-size enterprises in Beijing. Beijing has built several advanced biomass energy demonstration projects, such as biogas installation at Liu Mingyuan village, large-scale biogas power generation project at De Qingyuan

village, and landfill gas power generation project at A Suwei village. Meanwhile, there are many enterprises specialized in the technology R&D and equipment manufacturing related to biomass energy industry, such as Beijing JunBo new energy operation center and GuoNeng Biomass Power Group. The rapid development of biomass energy industry has improved the living environment in suburban district and the rural residents' energy-using conditions. During the 11th five-year plan period, the biomass industry has gained much improvement with average growth of 66.7% in terms of biomass energy utilization [18].

#### 3.1.1. Biogas industry

In recent years, the biogas industry in Beijing has achieved certain development, especially in the field of household biogas and large- and medium-size biogas engineering. The biogas industry has developed from simply biomass energy utilization to the multi-level comprehensive utilization of waste disposal and other biomass energy types. Currently, Beijing's biogas industry has gradually combined with breeding industry and planting industry, which has become an important way to develop green ecological agriculture and consolidate ecological construction gains.

At the end of 11th five-year plan period, there were more than 130 large- and medium-size biogas projects, and the annual biogas production reached more than 16 million m<sup>3</sup>, which can meet the demand of about 40 thousand households. The industrialized production of household biogas digester has obtained widespread development in Beijing, and a dozens of enterprises can produce the glass fiber reinforced plastics biogas reaction tank and cementing material methane tank, such as Beijing Zhongke international energy and environmental protection technology co., LTD. Meanwhile, there are several large- and medium-size enterprises engaging in the technology R&D, equipment design and fabrication related to biomass particles forming fuels.

**Table 5**  
Owned technology and equipment of mainstream solar water heater enterprises in Beijing.

| Company name                              | Main technology and equipment   | Annual output   | Annual revenue       |
|---|---|---|----------------------|
| Beijing Tsinghua sunshine energy co., LTD | Sailed brand all-glass evacuated solar collector tubes<br>Advanced separate solar hot water system  | 12 million<br>0.3 million                                 | About 1 billion yuan |
| Beijing Tianpu solar energy co., LTD      | Automatic production line technology<br>Hot water tank<br>Circular vent line with molecular pump technology<br>Ribbed and straight-through spiral solar vacuum tubes<br>Heat- stored and straight-through glass evacuated solar collector tubes<br>Meihua energy-gathered solar collector tubes | —<br>25000<br>—<br>20 million<br>30 million<br>35 million | About 5 billion yuan |

On the whole, the scales of current companies utilizing the biomass energy to produce biogas in Beijing are small. Although many companies turn to the research of utilizing biomass to generate biogas, the concentration of R&D institutions is low and the related technology is backward. For instance, although Beijing *JunBo* new energy operation center and *Qingda* industrial technology development Co., Ltd have their own unique technologies and related R&D equipment (just as listed in Table 4), their investment scales are too small to achieve economies of scale.

Due to the security and stability issues, the related biogas industries fail to provide competent technical supports and services, so the biogas utilization in rural areas is very low. Because the related technologies and equipment are expensive, the rich biomass energy resources in rural areas have not been explored effectively. In a word, the development impetus scarcity and scale development failure are still major obstacles to the popularization of biomass energy industry in Beijing.

### 3.1.2. Biomass power generation industry

The biomass power generation industry in Beijing is still at an early development stage. There are only several scaled biomass power generation projects, including *Liumingying* village Biogas power cogeneration projects, *Deqingyuan* large-scale biogas power generation projects and *Anshuwei* landfill gas power generation plants. At the end of 11th five-year plan period, the biomass power generation amounted to about 16 million kW h, only accounting for 0.7% of national biomass power generation.

In terms of biomass power generation *GuoNeng* Biomass Power Group which headquartered in Beijing has achieved a fair expansion in size, and has become the representative in this field in Beijing. This company has adopted the advanced international direct combustion biomass power generation technology to develop the abundant biomass resources in China and to construct biomass power generation projects. It also extends the industrial chain with the production and processing of biomass fuel and the recycling of grey powder. At present, *GuoNeng* Biomass Power Group has already become the biggest professional company in terms of biomass generation in the world. There are about 40 biomass power generation projects, and the total installed capacity amounts to 1000 MW with 9.2 billion kW h of electricity generation as well as 6.9 million ton of CO<sub>2</sub> emission reduction. At the end of 2013, these projects consumed 30 million tons of bio-residue, and increase farmers' income as much as 8 billion yuan. However, the major technologies of *GuoNeng* Biomass Power Group are introduced from abroad and lack of independent innovation. In addition, it has high production cost and operational risk. Both the lagging policies of promoting the development of biomass power generation industry and the mismatch between the subsidy policy and the actual development make the development of biomass power generation industry more slowly.

### 3.2. Development status of solar energy industry

In recent years, some progresses have been achieved in the field of the utilization and popularization of solar energy industry in Beijing. Taking a group of solar energy utilization projects such as “Sunshine Double Hundred” and “Golden Sun” Program as a breakthrough point, the utilization scale and technology level of Beijing's solar energy have been significantly improved. During the 11th five-year plan period, Beijing's solar energy has been developed rapidly with an average annual growth of 15.7% [18]. There are also significant advantages in the field of solar-thermal power generation technology and amorphous silicon (a-Si) thin film solar cells production technology in Beijing.

#### 3.2.1. Solar thermal industry

With regard to solar thermal application, Beijing is one of three major production bases of solar water heaters. In Beijing, there are about 20 enterprises the output value of which exceed 0.1 billion yuan, such as *QingHua* Sun, Beijing *TianPu*, et al. The total export volume amounted more than 65 million U.S. dollar. At the end of 11th five-year plan period, the solar water heaters holdings were about 15 million m<sup>2</sup>, which accounts for about 8% of the national solar water heaters holdings. The solar water heaters have been also exported to many countries and regions, including Europe, America, Africa and Southeast Asia, which has international market share of 0.1 billion m<sup>2</sup>.

At present, there are hundreds of manufacturers in Beijing, mainly located in suburbs of Daxing, Miyun, Huairou, Mentougou and other districts. The mainstream manufacturers include *QingHua* Sun, Beijing *TianPu*, Beijing *ShenGuang*, and Beijing *Sunp*. Because of the lower barrier to entry in solar water heater industry, Beijing's solar water heater industry is in a chaotic situation currently. There are many brands of solar water heaters circulating in Beijing market, but the concentration ratio is low. Of which, the medium and small brands take a large market share (about 60%), and the other larger brands only account for 40% market share. The owned technology and equipment of the mainstream solar water heater enterprises are listed in Table 5.

Beijing's solar water heater has a low penetration, even in rural areas. The main reasons are as follows: (1) the solar energy heating is not as fast as the electrical heating; (2) the stability and convenience of solar water heater are poor because its availability is directly affected by the weather; (3) the solar water heater companies cannot provide a satisfactory after-sales service; and (4) the acquisition cost of solar water heater is high for consumers, and the substantial subsidies which have economic incentives are lack. In addition, the solar water heaters installed in the urban buildings and balconies are still relatively few. Both the unsolved technique security and high cost issues greatly hinder the urban consumers' enthusiasm to use solar water heater, which lead Beijing urban areas have a very low penetration of solar water heaters. On the whole, Beijing's solar thermal industry develops insufficiently.

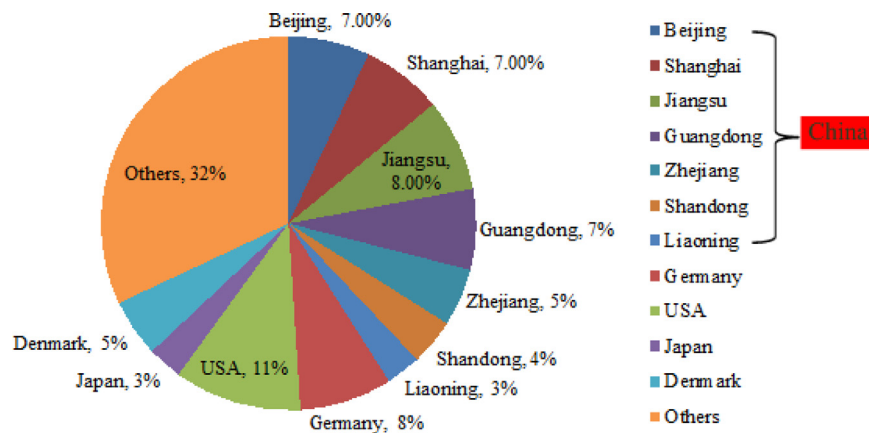


Fig. 3. The geographical distribution of wind power patent application in China and other countries.

### 3.2.2. Solar power generation industry

The solar power generation industry in Beijing began to develop from past few years, which is currently still in the initial developing phase with a huge developing space. In May 2009, the experimental solar thermal power plant in Yanqing county was approved, which is the first solar thermal power demonstration project in China, remarking that Beijing obtained a new breakthrough in the field of solar energy utilization. In December 2010, the 20 MW *Gold Sun* photovoltaic roof project in Yizhuang town (located in Daxing district, Beijing) was approved as the centralized application demonstration area of solar photovoltaic power generation of China, the total investment of which amounted to 0.46 billion yuan. Currently, some solar photovoltaic power has realized the combination with building in Beijing, which the solar photovoltaic power generation equipment has been installed on the building roof.

Although Beijing started late on solar power generation, it has hold some key technologies for solar power generation benefiting from its science and technology advantages. Some institutes and enterprises are investing in research and development related to solar power generation, which promote the development of Beijing's solar power generation industry. Beijing Institute of Automation Technology and Beijing Remote Power Renewable Energy Technology Co., Ltd. have shaped in the study of solar power generation. Beijing Institute of Automation Technology is one of the new science and technology enterprises in possession of process automation technology, digital signal processing technology and mechatronics technology, which combines the scientific researching, designing, developing, producing, testing and technical services, and its products mainly include wind-solar complementary inverter, grid-connected photovoltaic power plants; solar lighting products; electric converter products. The main products of Beijing Remote Power Renewable Energy Technology Co., Ltd. are solar intelligent controllers, PV grid-tied inverter and solar LED products. At the same time, it also provides a variety of application systems and engineering services, which includes solar street lighting system, solar independent power plant, solar telecommunications power system, wind-solar complementary power generation system, solar grid-tied power generation system, BIPV power generation system, solar landscape lights, solar advertising light boxes, solar traffic lights and signs. The annual revenue of Beijing Remote Power Renewable Energy Technology Co., Ltd. is 65–90 million yuan, and many products have been exported to 90 countries and regions of the world, the annual export value of which amounts to 7–10 million yuan. These companies promote the development of Beijing's solar power industry to some extent, but the solar power development is still in its infancy.

### 3.3. Development status of wind energy industry

Adopting wind to generate electricity is the main form of wind energy utilization in Beijing. Beijing takes obvious advantages of key technology innovation in the field of large-scale wind power, which has formed a relatively complete industrial chain. Beijing not only has significant advantages in the integration capabilities of fan system, but also the manufacturing levels of wind power machines and blades as well as turbine control systems takes the top in China. Beijing's wind energy industry mainly concentrates in the field of technology development and equipment manufacturing. The application quantity for patent of wind power in Beijing shows a rising trend, which is consistent with that of China. Fig. 3 shows the geographical distribution of patent application in China and other developed countries. We can see that the patent application of Beijing accounts for 7% in the total amount of the world, behind Jiangsu and Shanghai. Beijing has more advantages of high-level and new technique exploitation of wind power compared with other cities.

There are many enterprises engaging in wind power equipment R&D and manufacturing, of which *Sinovel Wind Group Co., Ltd.* and *Goldwind* are representative enterprises in Beijing's wind power industry. *Sinovel Wind Group Co., Ltd.*, headquartered in China's silicon valley, is China's first specialized high-tech enterprise engaged in independent development, design, manufacturing and sale of large-scale onshore, offshore and intertidal series of wind turbines which are adaptable to a global variety of wind resources and environmental conditions, and the first in China to have independently developed the global advanced 5 MW and 6 MW series wind turbines [25]. It has formed a complete industrial chain, and the cumulated installed wind power capacity ranks first in China. At the end of 2013, the accumulated wind power installed capacity of *Sinovel Wind Group Co., Ltd.* was about 15,000 MW, and the offshore wind power installed capacity amounted to 170 MW, which accounts for 39.7% in the domestic market. The revenue amounted to approximately 4 billion yuan at 2013.

In addition, *Goldwind* is an international, multi-faceted wind power company based out of Beijing, and is the largest manufacturer of wind turbines in China. At 2013, *Goldwind's* revenue amounted to more than 12 billion yuan with 3363.75 MW of total sale orders, and it captured 23.3% of the national new additions in wind installed capacity, namely 3750.25 MW. At this year, the newly added overseas orders were 314.75 MW covering six continents, and the export revenue was about 1.4 billion yuan. The large development scale, solid strength and proven technique of these wind turbine equipment manufactures promote the further



development of Beijing's wind power industry. However, the high generation cost, intermittent and anti-peaking characteristics of wind power make the grid reluctant to purchase wind electricity, which makes the utilization of Beijing's wind energy is low.

#### 4. The obstacles of Beijing's renewable energy industry development

In the past few years, Beijing has gained some achievements in renewable energy exploitation and utilization, and its renewable energy industry has made certain progress. However, there are still some obstacles which hinder the rapid, healthy and sustainable development of Beijing's renewable energy industry.

##### 4.1. The utilization level of renewable energy resources is low, and energy structure need be further optimized

In 2011, the renewable energy consumption amounted to 2.8 million tce, which accounted for 38.89% of the availability of Beijing's renewable energy resources [26,27]. At the same year, Beijing's renewable energy consumption only shared 4% of its total energy consumption (equal to 69.95 million tce). The renewable energy consumption only accounts for a very small proportion in the total energy consumption. Therefore, the exploitation and utilization of renewable energy resources in Beijing are still low, which has a lot of development room. Meanwhile, Beijing's energy structure has been optimized to some extent in the past few years. Beijing's coal consumption has decreased from 44.1% in 2004 to 26.4% in 2011, and the proportion of renewable energy consumption has increased from 1% to 4%.

Exploiting and utilizing renewable energy resources can cut down Beijing's consumption on traditional energy resources such as coal and oil, which can relieve the pressures of traditional energy resources shortage as well as environmental pollutant and largely meet the increasing energy demand due to the rapid economic development. Currently, compared with other renewable energy types such as wind and biomass energy, the solar energy develops relatively fast in Beijing. The wind power develops very slowly, and the purchase of wind power from other provinces is small; the biomass energy, such as animal waste and household garbage, is mainly used for biogas production. Generally speaking, Beijing's renewable energy utilization, especially the dominant renewable energy types, is still low, which has some room for improvement. The distribution of energy consumption in Beijing is uneven. The urban energy demand is large, which needs to be met from outside; while the energy demand in rural area is not very large, and the solar and biomass energy reserves are relatively rich, so part of its energy demand can be met mainly from inside. However, the biomass, solar and other renewable energy types only accounts for 8.7% in the total rural energy consumption, which are mainly used for the daily life. Therefore, the exploitation and utilization of rural renewable energy resources need to be improved, and the industrial development should be vigorously promoted.

In recent years, Beijing's coal consumption has been greatly reduced, but the proportion in total energy consumption is still high. Although the proportion of high-quality energy consumption has increased, there is still some room for improvement, and the energy consumption structure needs to be further optimized. Compared with the reserves of renewable energy resources, the exploitation and utilization of Beijing's solar and biomass energy are still at low level. The industrial scales of renewable energy are small and the related technologies are immature. Beijing's renewable energy industry is still in its early development stage with some constraints and deficiencies. Beijing has more than 200 solar

thermal and photovoltaic enterprises, but they only take 8% of market share. The brand concentration is also very low, and the medium- and small- brand share approximately 60% of the whole market in total. Facing the fierce competition at home and abroad, the overall competitiveness of Beijing's solar energy industry is very weak, lagging far behind Jiangsu, Zhejiang and Shanghai. Moreover, the ancillary facility construction of Beijing's renewable energy industry is not in place. For example, the related infrastructure constructions of solar water heaters and photovoltaic power generation are not enough, and the electric power grid planning also lacks foresight. These cause that there are some difficulties for renewable energy power generation accessing to grid, which has severely hindered the further optimization of energy structure and renewable energy industry development.

##### 4.2. Lack effective cooperation with the surrounding regions

Beijing's renewable energy resources are relatively scarce compared to other renewable energy powerful provinces such as Inner Mongolia and Hubei province. Currently, Beijing is mainly focused on its own renewable energy resources. There are few cooperation projects related to renewable energy industry between Beijing and other provinces. Most of the renewable energy projects are constructed by Beijing's government or local enterprises. Obviously, that is not enough. Beijing should not only explore its own renewable energy resources, but also utilize surrounding provinces' renewable energy resources. However, Beijing lacks the effective cooperation with surrounding areas related to renewable energy exploitation and utilization.

In a long period, Beijing's energy consumption shows strong dependence on other domestic provinces or foreign countries. 100% of natural gas and petroleum consumption, 98% of coal consumption, 80% of product oil consumption and 65% of electricity consumption need to be provided from other regions. Nowadays, with the rapid economic development, the dependence of Beijing's energy consumption on others is increasing. Facing the traditional energy resources shortage, national energy conservation targets, heavy dependence on external energy supply and fast-growing energy demand, Beijing should make the best efforts to develop the renewable energy industry, which can reduce the dependence on traditional fossil fuel and ensure energy security.

Hebei province and Inner Mongolia have the utilization advantages of renewable energy. The solar and wind energy resources in Hebei province are abundant, and Inner Mongolia holds a strong advantage in the exploitation and utilization of wind energy resource. Hebei province is rich in wind energy with 74 million kilowatts of land wind energy resource reserve. The solar energy resource is also abundant with the total annual radiation of 5900 MJ/m<sup>2</sup> and annual average sunshine of 2800–3000 h. Meanwhile, Hebei province has the advantage of exploiting geothermal energy, which is rich in geothermal resources with 170.6tL tce of reserves [28]. Currently, Hebei province has only exploited about 20% of total geothermal energy reserves, so there is much room for geothermal resources exploitation and utilization. The technically exploitable wind energy resource at 10 m height above ground level in Inner Mongolia is about 101 GW, which ranks first in China [29]. The wind energy in Inner Mongolia has the advantages of high stability and good continuity. Meanwhile, the solar energy resource in Inner Mongolia is also rich with a radiation of 4599–7884 MJ/m<sup>2</sup> yr and 2600–3400 h of sunshine, which ranks second only after Tibet in China. Biomass resource in Inner Mongolia rural areas is also very rich [30,31].

Meanwhile, the feed-in tariff of wind power in Hebei and Inner Mongolia are lower than the national average, which shows a big advantage. Therefore, the cooperation in the field of renewable energy should be enhanced with these two provinces. If Beijing

strengthens the renewable energy cooperation with Hebei and Inner Mongolia, a part of its electricity demand can be met by transmitting the wind and solar power of Hebei and Inner Mongolia to Beijing. This will also promote renewable energy industry development of Hebei and Inner Mongolia. Meanwhile, the renewable energy industry development of surrounding provinces will also promote Beijing's renewable energy industry development.

#### 4.3. *Underachieve the technical and financial advantages*

Nowadays, the renewable energy industry development in Beijing is still in its early stage with a lot of technical constraints and deficiencies. In Beijing, the key technology R&D and promotion of renewable energy utilization are lacking, such as solar energy efficient conversion technology as well as electric heat integration application system, efficient biomass conversion species. Although there are national standards for the solar water heaters production, these standards have not been strictly executed, which result in disordered market environment, brand clutter and uneven product quality in China's solar water heater market. Meanwhile, the penetration of solar water heaters is low, lacking of new technologies, and the after-sales service is seriously lagging behind. Although there are many solar energy enterprises, they are difficult to form scale due to the weak solar energy utilization technology. Monocrystalline silicon cell is the main type of photovoltaic cells in Beijing. There are significant gaps between China and developed countries in terms of production cost, efficiency level, finished product ratio, production automation and process stability. The research on solar energy utilization should be strengthened.

Beijing has constructed a number of biomass energy projects, including biomass gasification and central gas supply projects, large- and medium-size biogas projects, and household biogas digesters. However, constrained by the technical factor, most of these projects have been shut down, and the remaining is only under low-efficiency operation. The normal working rate of biomass gasification and central gas supply project is only 60%, and the rate of normal usage of household biogas digesters is less than 50% [32]. Ground source heat pump industry is pretty good, and the application area of ground source heat pump system has been over 20 million m<sup>2</sup> in Beijing. However, due to the short technology-introduced time and inadequate experience, the geothermal resource has not been effectively utilized, and this industry is lack of competitiveness. Biomass power has good prospects in Beijing, but its generating cost is quick high which should worth noting. There need a lot of labor, equipment and time form the collection to the use of straw. Without the farm-style planting, the cost in China is bound to high. Moreover, different fuels have different efficiencies. So, the stability and utilization rate of biogas are worth considering.

Beijing is the capital of China, the talent competitiveness as well as scientific and technological innovation capacity of which rank first in the whole country. The enterprises located in Zhongguancun Science and Technology Park show strong high-tech power. Beijing also has many scientific research institutions (such as Chinese Academy of Sciences) and universities (such as Tsinghua University and Peking University). In the past few years, many national key laboratories and national engineering laboratory related to renewable energy industry have been built in Beijing, such as the national key laboratory of wind power equipment and control, national engineering laboratory of biomass power generation complete equipment, and national engineering laboratory of electric vehicles. There are many universities and research institutes in Beijing, and it can be said that Beijing has great technical advantage. Beijing should make full use of this

technical advantage to solve technical problems related to renewable energy industry development.

Beijing is an international metropolis, who has financial advantage. As the capital, Beijing can obtain the maximum funding support from the country. Currently, the greenhouse gas emission cost is relatively high. In order to fulfill the quantified greenhouse gas emission reduction obligations by the Kyoto Protocol, developed countries often cooperate with developing countries by means of the Clean Development Mechanism (CDM) [33]. Through CDM, the developing countries can obtain external capital and advanced technology, which can promote the related industry development. Beijing's population size is large, and energy efficiency in some energy sectors is low. Moreover, Beijing's renewable energy industry is still in its infancy, which can achieve emissions reduction at a lower cost. Therefore, Beijing has certain financial advantage. Until now, there are a few CDM projects between Beijing and developed countries. If Beijing actively cooperates with developed countries by means of international CDM projects, it can attract foreign investment and facilitate technology transfer, which can promote renewable energy industry development from technological and economic perspectives.

#### 4.4. *Ignore the positive external benefits, and lack effective economic policy and incentive mechanism*

The renewable energy power hardly discharges pollutants, the environmental benefit of which is remarkable. Moreover, the solar and wind energy power can save water resources. Due to wide distribution and reproducibility of renewable energy resources, the renewable energy utilization can reduce the energy transportation cost and energy losses during the transportation, and can also relieve the energy emergency and price fluctuation risk. The renewable energy industry is a capital-intensive and technology-intensive industry with a long industrial chain. Therefore, developing renewable energy industry can bring agglomeration economies and macroeconomic external benefits such as technological progress and fiscal revenue growth. Meanwhile, the renewable energy industry can also bring more employment opportunity. Therefore, compared with the traditional fossil fuels-based power generation types, the renewable energy power can bring some positive benefits, such as energy benefit, environmental benefit, macro-economic benefit and social benefit [34]. However, the positive benefits of renewable energy industry and renewable energy power have not been paying much attention in Beijing, even in China.

Currently, the renewable energy power pricing tends to be on the basis of economic cost without consideration of environmental and social benefits. When the renewable energy power is priced, the positive benefits have not been considered, which indicates the current renewable energy pricing mechanism is imperfect. In reality, the on-grid price of renewable energy power is higher than traditional power generation types in Beijing, which puts it at a price disadvantage. So, the grid company is reluctant to purchase renewable energy power, which hinders the development of renewable energy industry.

Renewable energy power has many positive external benefits, which have not been internalized. Among the renewable energy power types, the wind power has relatively more mature technology, but its' generating cost is still much higher than that of the conventional thermal power. The high power generating cost covers the economics of renewable energy power, which makes the renewable energy power types lose the ability to compete with conventional power generation types. However, Beijing has not issued effective economic policy or incentive mechanism to compensate for the positive external benefits of renewable energy power. If the positive external benefits of renewable energy power

can be internalized or be compensated, the competitiveness of renewable energy power will then be enhanced, which will promote the renewable energy power and renewable energy industry development.

Currently, there is only one specific policy focusing on renewable energy (namely solar energy) in Beijing (just as list in Table 2), but no specific policy focusing on biomass, wind and geothermal energy, which may result in the unbalanced development of Beijing's renewable energy industry. Meanwhile, Beijing lacks of financial support for renewable energy industry development and guidance mechanism for energy consumption. The mechanism design of renewable energy industrial compensation and cost-sharing principle are unsound. The rapid development of regional renewable energy tends to increase the total cost of energy consumption, and the compensation mechanism should be designed based on different renewable energy industries. The green energy consumption tends to increase the purchase expenditure of consumers. Industrial enterprises, service industries and residents are the major consumers of energy resources. However, under the economic consideration, the consumers are reluctant to purchase green energy. Meanwhile, the government does not design effective demand-side response incentive mechanism. These hinder the renewable energy consumption and renewable energy industry development.

Moreover, the consistency and stability of policies related to renewable energy industry are poor. The stable market demand of renewable energy industry with a reasonable size has not been formed, which influences the investing enthusiasm of investors. Beijing also lacks the effective investment and financing mechanisms, which greatly constrain the popularization and application of renewable energy technology. The operating cost of renewable energy technology utilization such as renewable energy power and solar water heater is low, but the initial investments are high. Therefore, to promote renewable energy industry development, the stable and effective investment and financing channels should be built, and the preferential policy aiming to reduce the renewable energy utilization cost should be implemented.

#### 4.5. Lack the renewable energy demonstration projects

Currently, Beijing's renewable energy utilization mainly focuses on residential, commercial and agricultural fields. In the past few year, the built renewable energy demonstration projects in Beijing includes Sunshine bathroom project (used for local resident), Guanting wind farm project (used for commerce), Liumingying villiage biogas power cogeneration project (used for commerce and agriculture), and so on. The comprehensive renewable energy application in industrial development zone is still at early and demonstration stage.

Although the major projects related to renewable energy application in some industrial parks have been determined, such as biomass briquettes fuel heat supply demonstration project in the key villages and towns, wind-solar power complementary demonstration project in Changping district, landfill gas power generation demonstration project in Six Mile village of Haidian district, they are still at in-depth knowledge and scheme discussing stage. Some implemented renewable energy projects are only restricted to monomer lighting system such as conventional solar street lamp and lawn lamp, while the large-scale renewable energy projects such as heat pump and ice storage engineering, centralized photovoltaic power generation, have not built specific application demonstration projects. Therefore, the promotion of renewable energy demonstration projects in Beijing needs to be advanced.

#### 4.6. Lack the propaganda and education on general public

Serving as the center of China's politics, culture and education, Beijing assembles a large number of highly-competent people at various aspects, and the comprehensive quality of residents is relatively high. The residents living in Beijing usually have good abilities of learning and accepting new things. Renewable energy application and industry are new things, and the cognition degree of general public on renewable energy exploitation and utilization is not well. For example, the local villagers in Cheerying village located in Haidian district of Beijing regard the biomass gas as a new flue for daily cooking, and they have few knowledge about it, so they worry about whether employing biomass gas for daily cooking is safe or not. Therefore, they are reluctant to change the cooking fuel from primary coal or liquefied natural gas to biomass gas.

The renewable energy industry becomes flourishing only from the past few years in Beijing, and its development history is not long. So, the atmosphere of general public actively participating in and supporting renewable energy industry development has not been formed. In the environment that China is striving to develop renewable energy industry, the people in Beijing gradually obtain certain knowledge about renewable energy. However, this is not enough. Meanwhile, there are few propaganda or advertisements on renewable energy by way of TV, newspaper, site activity and special website. The consciousness of whole society engaging in energy conservation and social responsibility sense of enterprises should be enhanced. Due to good abilities of learning and accepting new things, the general public can quickly understand the positive external benefits of renewable energy industry and actively participating in the promoting activities of renewable energy development if the propaganda as well as education on general public are been done.

### 5. Proposals for the coordinated and healthy development of Beijing's renewable energy industry

Although Beijing's renewable energy industry has achieved some progress in the past few year, there are still some urgent issues need to be solved. Based on the current development situation of renewable energy industry and the existing problems, some proposals are put forward in order to promote the coordinated and healthy development of renewable energy industry in Beijing.

#### 5.1. Promote the exploitation and utilization of renewable energy, and increase the share of renewable energy power in total energy consumption

Beijing's renewable energy resources are uneven. Solar energy resource reserve is the richest among all the renewable energy resource types in Beijing. The exploitation and utilization of solar energy has natural and social conditions. Specific suggestions are as follows: (1) Beijing should accelerate the solar PV power and MW-level solar-thermal power generation projects in Yanqing county (located in northwest Beijing) to promote the commercial operation of solar energy power; (2) further implement the *Golden Sunshine* projects to advance the exploitation and utilization of solar energy, aiming to become the high-end manufacturing and demonstration center of solar energy R&D, and finally make Beijing be a first-class sunshine city; (3) according to the principles of combining the policy supporting and market cultivating, Beijing should promote the construction of building-combined grid-connected photovoltaic power generation system, and escalate the application of solar energy power; (4) actively promote the solar



PV power in industrial park building, large garden, primary and secondary schools, public emergency buildings and abandoned mine; and (5) promote the solar thermal system application in industry, encourage the combination of solar thermal with other new energy types, and build the projects of solar hot water, solar heating in new rural dwellings and sunshine bathroom.

Biomass energy resource reserve is relatively rich, and the utilization level of biomass energy should be improved in Beijing. Specific suggestions are as follows: (1) make full use of the municipal solid waste, and the large-scale garbage-based energy utilization engineering such as landfill gas plant and garbage incineration power plant should be built; (2) the large-scale multi-village centralized biogas and straw-fueled centralized gas supply projects should be pushed forward, and the biomass-based combined heat and power generation key demonstration projects should also be built; (3) make full use of agricultural waste, forestry waste and kitchen waste, and construct the BMF (biomass molding fuel)-based heating demonstration project in the field of villages as well as towns heating and agriculture facilities such as nursery garden and greenhouses; and (4) under the background of new rural construction, accelerate the utilization of livestock manure, straw and firewood, and based on the large-scale livestock and poultry farm, construct the multi-regional and multi-village large- and medium-sized methane gas supply engineering in biological conservation area such as Yanqing, Daxing and Miyun county.

Based on the characteristics of geothermal energy resources endowment, Beijing should encouragingly develop reclaimed water heat pump, power plant circulating water heat pump and ground source heat pump, and moderately develop water source heat pump. Beijing should construct a batch of regional scaled and system integrated key demonstration projects: (1) construct a batch of heat pump building integrated engineering and heat pump heating (cooling) projects combined with other energy sources in key functional areas and high-tech parks; (2) substitute heat pump system for coal/oil-fired boiler in areas with suitable conditions to update the energy system; and (3) construct a batch of waste heat-based heating supply demonstration projects to reuse the waste heat resource. Meanwhile, Beijing should rationally develop and utilize deep-layer geothermal resource: (1) exploit the geothermal resources advantage of Fenghetian village (located in Daxing district, southeast Beijing), and construct the graded geothermal heating projects to realize the geothermal resources utilization pattern of “power generation-industrial utilization-heat supply-agricultural utilization”; and (2) plan the heat supply in Yanqing county (located in northwest Beijing) and implement the geothermal heating projects in western Beijing.

Based on the resource endowment, Beijing should further develop the wind energy resource and construct wind power projects. Specific suggestions are as follows: (1) promote the scale development of wind power orderly in Yanqing, Changping, Miyun and Fangshan, where the wind energy resource is relatively rich, and the wind power accessing grid condition is good; (2) encourage the exploitation and construction of distributed wind power; and (3) actively promote the project construction of Guanting wind farm III and wind-solar complementary power generation farm located in Qinghuiling, Changping district.

During the Twelfth Five-Year Plan Period, Beijing's energy consumption structure will be optimized with the characteristics of clean and low-carbon. Electric power, natural gas and renewable energy belong to high-quality or clean energy. In some developed countries such as England and United States, the share of high-quality energy in total energy consumption has exceeded 75%, while that in Beijing is just about 67%, which means there is still a certain gap compared with developed countries. For Beijing, largely improving the share of coal-fueled electric power

generation and nature gas in energy consumption structure will face with the energy supply risk and environmental pollution pressures. Therefore, striving to develop renewable energy power including wind power, solar PV power and biomass power is imperative development direction for Beijing's clean and low-carbon energy consumption.

## 5.2. Strengthen the inter-regional cooperation in the field of renewable energy industry

From the development history of renewable energy utilization in some developed cities such as Tokyo, London and New York, the renewable energy resource complementarity and coordinated development are necessary and helpful, which can drive and promote the renewable energy development of a region. Therefore, Beijing should enhance the cooperation with other provinces in the field of renewable energy industry.

Compared with the surrounding provinces such as Hebei and Inner Mongolia, Beijing's renewable energy resources are relatively scarce, so the renewable energy industry will not develop well if only rely on its own renewable energy resources. As mentioned above, Hebei and Inner Mongolia have abundant renewable energy resources. Beijing should strengthen the cooperation with these provinces and improve the renewable electricity trading network to facilitate the electricity purchase from surrounding regions. This can not only meet part of the increasing electricity demand in Beijing, but also drive the renewable energy industry development in these regions.

The demand for electricity is greater than the supply in Beijing, and the electricity shortage needs to be filled by means of purchasing from other provinces. A potential way for Beijing's electricity purchase from surrounding regions is to implement the renewable energy quota, such as the quota purchase of wind power from Inner Mongolia or Hebei province. It can not only ensure Beijing's electricity supply, but also drive the wind power industry development in surrounding regions. The electric power transmission network is critical to the smooth and prompt electricity transmission between different regions. Ensuring the sufficient electricity transmission capacity of power grid is very important for the sustainable cooperation between Beijing and surrounding provinces in the field of renewable energy power. With the electricity transmission volume increasing, the electricity transmission capacity may become not enough. Therefore, when strengthening the inter-regional cooperation between Beijing and Inner Mongolia/Hebei province in the field of renewable energy power, the electric power transmission network construction cannot be ignore, which should be enhanced. Currently, China is developing ultra-high voltage (UHV) power transmission network, and there are several UHV transmission lines passing by Beijing. So, Beijing should actively develop the construction of UHV power transmission network, which can improve the electricity transmission capacity between it and surrounding provinces.

Meanwhile, Beijing should make full use of its R&D and financial advantages to explore and enhance the cooperation with its surrounding regions in the field of renewable energy industry. A serial of R&D and financial supporting projects should be developed between Beijing and surrounding provinces. Currently, there are still some obstacles hindering the healthy development of wind power and solar PV power industry in Inner Mongolia/Hebei province, some of which are related to technological and financial issues. Beijing should provide the R&D technology and funds to cooperate with Inner Mongolia/Hebei province in the field of key equipment manufacturing and renewable energy power accessing grid to solve the practical problems faced by renewable energy industry. Beijing should take the opportunity of cooperation with surrounding provinces in terms of renewable



energy industry, and maximize its market value and promote its health and sustainable development.

### 5.3. Strengthen the scientific and technological innovation capacity

In the context of the global response to climate change and countries seizing renewable energy development opportunities, Beijing should take full advantages of sci-tech innovation resources as well as demonstration city, and strengthen the renewable energy core technology and product innovation to promote the renewable energy resources utilization and renewable energy industry development.

To break through the development bottlenecks of renewable energy industry such as cost, technology, equipment and talents, many countries have provided strong supports for the renewable energy industry, such as establishing national laboratories and research centers, providing technical guidance as well as R&D funding, and setting up a special national renewable energy agency. Beijing should take the market advantages of intensive technology resources and high-end application demonstration to implement the national renewable energy R&D innovation and industry base construction projects, then gradually form a benign development model of “R&D promoting application, application driving industry, and industry boosting R&D”, and finally become a high-end R&D, demonstration and manufacturing center. Based on the development status and advantages of renewable energy industry, Beijing should strengthen the independent innovation capacity and strive to make a breakthrough in terms of key technologies, core equipment and system integration.

For biomass energy industry, Beijing should upgrade the biomass energy application technology. Specific suggestions are as follows: (1) enhance the integration capabilities of large- and medium-sized biogas self-insulation and efficient heating systems, and carry out the design R&D of core technologies of biomass gasification tar; (2) carry out technical research on integrated utilization of unconventional biomass energy such as sludge and kitchen waste; (3) promote the key technology R&D and industrialization of large-scale efficient garbage incineration power generation and landfill gas utilization; and (4) strengthen the key technology R&D of biomass direct combustion technology and biomass liquid fuels.

For solar energy industry, Beijing should consolidate the R&D and high-end manufacturing advantages. With respect to solar thermal utilization, a number of core key technologies should made breakthrough including high-efficiency flat plate solar heat collection, solar hot water heat collection, and large-scale solar thermal storage. Meanwhile, the integration capability of megawatt tower- and trough-based solar power generation system should be enhanced. With respect to solar photovoltaic utilization, Beijing should (1) focus on the integration technologies of building photovoltaic systems, photovoltaic micro-grid systems, and large-scale grid-connected PV systems, and break the technology bottleneck of ultra-thin crystalline silicon cell industrialization; (2) promote the research on crystalline silicon solar cells and thin-film solar cell with low-cost, high-efficiency and long-life; (3) promote key equipment localization of multi-line slicers crystalline silicon cell; and (4) accelerate the R&D and industrialization of efficient energy storage battery.

For wind energy industry, Beijing should enhance the integration capability of wind power equipment manufacture system. Specific suggestions are as follows: (1) promote the industrialization of key manufacturing technology and electrical control technology of wind power machine with capacity of 3 MW and above; (2) accelerate the R&D and industrialization of large-scale wind turbine performance testing and evaluation system; and (3) focus on developing the central monitoring system, remote

monitoring systems, frequency control system and network control systems of wind farm.

For geothermal energy industry, Beijing should enhance the capacities of key technology R&D and engineering services. Specific suggestions are as follows: (1) strengthen the research on geothermal energy utilization technology, and promote the industrial development related to system integration, equipment manufacturing and operation maintenance; (2) actively promote the technology R&D of high EER (energy efficiency ratio) heat pump, geothermal energy conversion technology, and intelligent control system; (3) promote the development work of high efficiency new type heat pump heating and refrigeration system based on sewage source, reclaimed water source and power plant cooling water source; and (4) advance the development of geothermal energy service industry including utilization standard, technology consulting, system integration and operating maintenance.

Meanwhile, Beijing should (1) seize the opportunity of building the national independent innovation demonstration area in Chinese Silicon Valley (namely *Zhongguancun*) to promote the construction of renewable energy R&D and innovation projects; (2) build the technology innovation platform and undertake R&D projects to upgrade technology service level and promote the industrialization of scientific and technological achievements; and (3) actively promote the cooperation with enterprises, universities and research institutes, and build a number of national key laboratories and other state-level R&D platform in the field of photovoltaic and wind energy, new energy vehicles and smart grid.

### 5.4. Strengthen the fiscal and taxation policies and incentive mechanism

Through the implementation of fiscal and tax preferential policies for renewable energy enterprises, more capital can flow into renewable energy industry. Meanwhile, the fiscal and tax preferential policy can reduce the burden of renewable energy enterprises, which can guarantee the long-term development of renewable energy industry. Beijing should give full play to its geographical, economic and political advantages, and provide fiscal and taxation policies and incentive mechanism to promote the renewable energy industry development. Specific suggestions are as follows.

- (1) Increase financial input to renewable energy industry in the field of renewable energy R&D technology and industry promotion. Beijing should actively seek the national support, enhance the financial investment on the key core technology R&D and system integration capabilities of wind power, solar PV power and biomass power, and support the construction as well as demonstration projects of regional renewable energy system.
- (2) Give preferential policies including financial subsidy and tax preference. Financial subsidy and tax relief are very effective measures for promoting renewable energy industry development which have been adopted by many developed countries. Compared with developed countries, Beijing's finance and taxation subsidies, which include subsidy range and amount, need be enhanced. Beijing should take the measures of tax rate reduction, investment tax credit and deficit remedy to promote the commercialization of renewable energy industry. For the enterprises engaging in renewable energy technological development, the tax deduction and exemption can be provided; for the wind and solar power generation enterprises, the subsidy and preference related to feed-in tariff and power generating cost can be provided; for the loss-making renewable energy enterprises with good environmental benefit and

social benefit should be provided with loss compensation and commodity price allowance. Meanwhile, the management on financial subsidy and tax preference policies should be strengthened, and the information platform of renewable energy subsidy and tax preference should be built as soon as possible.

- (3) Promote the green tax reform. Raising the price of non-low-carbon energy is an effective method for promoting the production and supply of low-carbon energy. Therefore, carbon tax is also a feasible measure for renewable energy development. As the first carbon tax and carbon trading market pilot cities, Beijing should flexibly choose the tax targets as well as tax applying links and reasonably set the tax rate based on its actual development situation, and gradually include the carbon tax in the current tax system. The carbon emissions trading system should be gradually built. The basic management framework, transaction process and regulatory approach of voluntary emissions trading mechanism should be determined. The voluntary emissions trading activities of carbon market should be implemented by the appropriate means such as carbon audit and carbon finance.
- (4) Set up special funds to encourage the technology research and development of renewable energy. Learning from the operating experience of China's green energy development fund, Beijing should consider setting up renewable energy development fund. This fund can be managed by Beijing municipal government or the third-party companies/institutions with the supervision of Beijing municipal government. This fund can be gathered by various means, and used in the field of solar water heater, solar PV power, ground temperature-based heat pump, reclaimed water-based heat pump, and wind power.

##### *5.5. Improve the internalization mechanism of the external benefits of renewable energy power and the CDM coordination and transformation mechanism*

As mention above, the renewable energy power has many external benefits, such as environmental benefit, macro-economic benefit and social benefit. Although the renewable energy power has great advantages in both environmental protection and long-term sustainable energy supply, these external benefits have not been reflected in the electricity price due to their difficult measurement and short of attentions. The on-grid price of renewable energy power is much higher than that of conventional electricity generation types, which puts renewable energy power at a competitive disadvantage in the electricity market. Therefore, the external benefits of renewable energy power should be taken into consideration when the government prices the renewable energy power. Currently, there are some papers that perform the environmental benefit evaluation on renewable energy power, such as Ref. [34], while the evaluation on macro-economic benefit and social benefit are few. If there are inevitable difficulties in evaluating the external benefits of renewable energy power, the government can provide subsidies for renewable energy power.

There are disadvantages in initial investment cost for renewable energy power. It is difficult to make progress in renewable energy power market by simply relying on consumers' recognition on renewable electricity because the consumers are reluctant to pay higher electricity price to purchase the renewable energy power. Therefore, the implementation of low-cost fixed electricity price system can be regarded as a way of government's subsidy for renewable energy power. Reducing the renewable energy power price can stimulate consumers to purchase renewable energy power. Meanwhile, the compulsory acquisition policy of power grid company purchasing renewable energy power should be further made to promote the development of Beijing's renewable

energy power. The local government should rationalize the electricity pricing mechanism and improve the internalization mechanism of the external benefits of renewable energy power, which can enhance the economy of renewable energy power, stimulate renewable energy power consumption, and then promote the development of renewable energy industry.

The CDM project planning should be enhanced. The coordination working mechanism on CDM should be built, which aim to coordinate the project development and construction managed by the corresponding departments of Beijing municipal government. Under the guidance of National Development and Reform Commission (NDRC), Beijing should research the open solicitation mechanism of CDM projects, recruiting and selecting mechanism of intermediary agency, services and information platform of CDM projects. While safeguarding the effective exploitation of CDM resources, the market management of CDM projects should be standardized and strengthened. Meanwhile, the compiling work on "Promoting Beijing's CDM integrated planning" should be accelerated.

##### *5.6. Promote the construction of renewable energy demonstration projects, and strengthen the propaganda and education on general public*

Demonstration projects and engineering are important means of technological exploration and diffusion. In accordance with the national energy conservation and emissions reduction strategy, Beijing should (1) encourage and support the advanced and energy-saving renewable energy projects, and employ the pilot exercise to drive the renewable energy industry development; (2) promote the constructions of MW-scale solar PV power system, solar heating boiler, sewage-source heat pump concentrated heating system, geothermic cascaded direct-supply integrated utilization system, circulating fluidized bed trash burning boiler and solar heat pump air conditioning system according to local conditions in some potential industrial development zones; and (3) improve the application share of solar PV, solar thermal collector, renewable energy boiler and heat pump in Beijing's secondary industry. Meanwhile, renewable energy demonstration projects can be considered to build in the private houses and public buildings, and gradually form the scale, integration and complete sets application technologies of renewable energy in buildings to promote the renewable energy industry development.

Beijing should accelerate the cultivation and development of some specific renewable energy industry bases. The renewable energy industry bases dominated by solar energy, wind energy and smart grid industry as well as application demonstration in Yanqing county, Changping district and Tongzhou district should be built. The renewable energy industry bases characterized by solar thin-film battery in Pinggu district (located in northeast Beijing) should be built. Meanwhile, the advantages of solar cell production and high-end equipment manufacturing should be further enhanced, and the Beijing's new energy vehicles designing and manufacturing industry base should also be built.

Employing the term "Vast Territory and Abundant Resources" to describe national condition is the common educational concept in China in the past many years. While in the current national situation, this is not appropriate any more. In China, many issues have shown, such as energy resource shortage, more and more serious environmental pollution. The increasing consumption on traditional fossil fuels not only consumes the limited resources, but also produces environmental pollution, which cannot promote the sustainable development of the national economy and society. Therefore, guiding the residents to change their consumption concept and strengthening the energy saving and environmental protection propaganda are quiet important. Exploring renewable energy sources and developing renewable energy industry can

reduce the dependence of the society on traditional energy types especially the fossil fuels. For example, the renewable energy power can substitute for coal-fueled power and natural gas-fueled power, and the application of solar water heater can make the residents not go to the public bathroom, both of which can reduce the consumption on fossil fuels.

Therefore, the propaganda and education of using renewable energy on general public should be further enhanced. Beijing should enhance the public's awareness of energy conservation and green consumption by means of elementary and secondary education, vocational education, community advocacy training, which aims to improve the diligent and thrifty awareness and low-carbon energy consumption enthusiasm. Beijing municipal government should play the leadership role to strengthen the propaganda and education of energy as well as renewable energy scientific knowledge on general public, and propagandize the important role of energy conservation and renewable energy development in the sustainable economic and social development by way of newspapers, radio, TV and the internet.

## 6. Conclusions

Energy is the important material foundation of national economic and social development. As a kind of energy resources, renewable energy has the advantages of rich resources reserves and less environmental pollution. As the capital of China, Beijing has many renewable energy types, such as solar energy, geothermal energy, biomass energy and wind energy. Under the background of growing petrochemical resources' shortage and increasing environmental pollution, the exploitation and utilization of renewable energy has become the important carrier for the construction of "Humanities Beijing, High-tech Beijing and Green Beijing", which is also important for enhancing the innovation ability, cultivating the future economic support and achieving green sustainable development of Beijing city.

In the past few years, Beijing's renewable energy has developed fast, and the renewable energy industry has achieved certain development, namely the increasing industry types and expanding industry scales. However, there are still some obstacles hindering the healthy and sustainable development of Beijing's renewable energy industry. To promote the better development of Beijing's renewable energy industry, this paper firstly introduces the distribution as well as utilization of Beijing's renewable energy resources and the development status of Beijing's renewable energy industry. Then, the obstacles existing in the process of Beijing's renewable energy industry development are detailed analyzed, which are (1) the utilization level of renewable energy resources is low, and energy structure need be further optimized; (2) lack effective cooperation with the surrounding regions; (3) underachieve the technical and financial advantages; (4) ignore the positive external benefits, and lack effective economic policy and incentive mechanism; (5) lack the renewable energy demonstration projects; and (6) lack the propaganda and education on general public. Finally, some proposes are put forward for the coordinated and healthy development of Beijing's renewable energy industry. In the coming years, Beijing should (1) promote the exploitation and utilization of renewable energy, and increase the renewable energy power share of total energy consumption; (2) strengthen the inter-regional cooperation in the field of renewable energy industry; (3) strengthen the scientific and technological innovation capacity; (4) strengthen the fiscal and taxation policies and incentive mechanism; (5) improve the internalization mechanism of the external benefits of renewable energy power and the CDM coordination and transformation mechanism; and (6) promote the construction of renewable energy demonstration projects, and strengthen the propaganda and education on general public.

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