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Biomass power generation in China: Status, policies and recommendations

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Abstract

Benefiting from the large stock of raw materials and the support of policies, China's biomass utilization get rapid development in recent years. In particular, the Chinese government advocates the transformation of energy utilization from coal power to renewable energy power generation, of which biomass power generation will be play an important role. Therefore, it is necessary to get the actual situation of China's biomass power generation industry at present. The latest storage and distribution of biomass resources data in China is collected and the technological development of biomass power plants in China is described in this paper. The installed capacity and power generation of biomass power generation in China are illustrated since 2012. This paper also counts policies related to biomass power generation since 2006 and analyzes future policy trends. Some recommendations with practical problems are put forward in this paper.

Keywords

China; Biomass; Power generation; Installed capacity; Policy

1. Introduction

Biomass energy is the fourth largest energy source, followed by coal, oil, and natural gas[1]. From the perspective of the life cycle, biomass power generation can achieve almost zero CO_2 emissions. Therefore, as a clean and renewable energy source, biomass energy has great potential to solve the problem of energy shortage, help improve the ecological environment, and maintain ecological balance[2], [3]. Nowadays, biomass energy utilization is getting more and more attention and many countries and regions encourage using biomass energy through legislation[4]. Among the utilization methods of biomass energy, biomass power generation is one of the most common and effective ways to utilize biomass.

The world's biomass power generation originated from the outbreak of the global oil crisis in the 1970s, and Denmark began to generate electricity adopt straws. According to the latest International Energy Agency market forecast results, between 2018 and 2023, biomass energy will lead the continued growth of renewable energy, accounting for 40% of global energy consumption growth. By 2040, renewable energy will account for 17%–22% of the primary energy, and it will be the main contributor to global power demand. The installed capacity of biomass power generation all over the world has continued to rise since the beginning of the 21st century. Since the 1970s, almost all countries in the world have paid great attention to the development and utilization of biomass energy. Many short-term and long-term policies were issued to encourage the research and utilization of biomass energy[5]. In 2018, the International Energy Agency (IEA) proposed that biomass energy is an unnoticed "giant" and mentioned that it will be an important part of new energy in the next five years. According to the latest data released by International Renewable Energy Agency (IRENA)[6], the global biomass installed capacity exceed 120 GW. The total global biomass installed capacity from 2012 to 2020 is shown in Fig. 1.

Biomass power generation is the most popular way of biomass energy utilization. More than 80% of biomass raw materials are used for power generation in China according to the China Renewable Energy Industry Development Report 2021. In previous studies, some scholars

have studied biomass power industry in China in different area. Dennis Y.C. Leung reviewed the biomass gasification power generation technologies in China in 2004[7]. Q. Zhang analyzed the policies of biomass power generation in China before 2013, the results show that the biomass power generation development polices had lots problems such as goal being too large, tax policies not being easy to implement at that time[8]. Z. Zhao assessed the internal and external environment of the biomass power generation industry in China based on the strengths, weaknesses, opportunities, and threats (SWOT) method[9]. P. Yan calculated the gross biomass energy (BE) reserves in China and the research results shown the gross BE in China was about as 535.91 EJ[10]. X. Chen estimated the economic potential of biomass supply from crop residues in China adopting a mathematical programming model. The results indicates that China can potentially produce about 174.4–248.6 million dry metric tons of crop residues per year when biomass prices are larger than $100 per metric ton[11]. J. Liu reviewed the situation, problems of China's biomass power generation industry in 2014 and offered several suggestions in cost, strategic planning and policy[12].

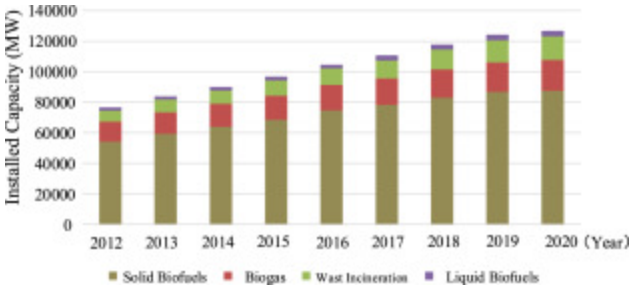

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Fig. 1. Total biomass installed capacity from 2012 to 2020 globally.

However, as a rapidly developing industry, biomass power generation still faces many challenges, it is necessary to describe the present status of biomass power generation in China comprehensively and then to provide more timely recommendations.

2. Data sources

The statistical data related to biomass power generation capacity and power generation in China mainly come from the China Electricity Council, which has released the statistics data of biomass power generation capacity and power generation data since 2012. Other related data come from different departments such as the Chinese government, enterprises, and industry associations. We collect a large amount of data, some of which is unreliable. Only reliable data with clear conclusions is adopted in this paper. In this study, we selected data with credible records since 2012. However, some data is incomplete and only from the year

with a credible source. The source of policy documents is mainly from Chinese government ministries and commissions. In particular, the Chinese government issued the first law related to biomass power generation since 2006. Therefore, we collect policies from 2006 to 2021.

3. Biomass resources storage and distribution

China is rich in biomass resources, biomass resources in China are mainly crops and its residues, forestry residue and wastes including urban wastes, industrial organic waste, etc. The statistic result is shown in Fig.2.

The annual production of major biomass resources in China was about 3.494 billion tons in 2020. The theoretical crops straw resources in China were about 829 million tons, and the collectible resources were about 694 million tons, of which energy utilization amount was 88.215 million tons and the energy utilization rate was 10.6%. The total amount of animal manure in China was about 1.868 billion tons (excluding cleaning wastewater), of which energy utilization amount was 211 million tons and the energy utilization rate was 11.3%. The total amount of forestry residues available in China was 350 million tons, of which energy utilization was 9.604 million tons and the energy utilization rate was 2.7%. Urban waste is mainly household waste and waste grease, the total amount of urban waste was 310 million tons, of which the amount of waste incineration was 143 million tons and the energy utilization rate was 46.1%. The industrial organic waste include sewage and sludge, the total amount of industrial organic waste was about 25.05 million tons, of which the energy utilization is about 1.67 million tons and the energy utilization rate was 6.7%[13].

As Fig.2 illustrated, the total resource of animal manure is the largest, but the highest energy utilization rate is urban waste.

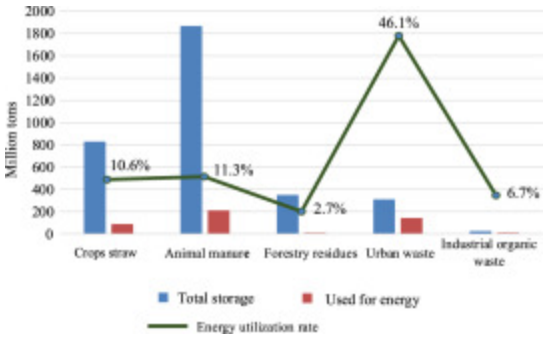

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Fig. 2. Biomass energy storage in China.

The biomass resources distribution in China is shown in Fig.3. The crop straw resources mainly distribute in grain-producing provinces of China, and the top five in total resources are Heilongjiang, Henan, Jilin, Sichuan, and Hunan, accounting for 59.9% of the national total. Animal manure resources are concentrated in animal husbandry area, and the top five in total resources are Shandong, Henan, Sichuan, Hebei, and Jiangsu, accounting for 37.7% of the national total. Forestry residue resources are concentrated in the mountainous areas of south China. The top five resources in total are Guangxi, Yunnan, Fujian, Guangdong, and Hunan, accounting for 39.9% of the national total. Urban waste resources are concentrated in the densely populated areas in the eastern China, and the top five in terms of total resources are Guangdong, Shandong, Jiangsu, Zhejiang, and Henan, accounting for 36.5% of the national total. Industrial organic waste resources are concentrated in areas with a high degree of industrialization. The top five resources in total are Beijing, Guangdong, Zhejiang, Jiangsu, and Shandong, accounting for 44.3% of the national total.

As shown in Fig.3, China's biomass resources are mainly concentrated in the southeast, and the resources in the northwest are relatively poor. For the crop straw, its distribution is scattered and the collection is difficult and costly. Forestry residues resources mainly distribute in several major forest areas in the southwest. The low density of forestry resources and poor traffic conditions affect the application of forestry biomass resources. The animal manure, urban waste and industrial organic waste resources concentrate on the central and eastern developed regions. The main problems of biomass power plants construction in these areas are difficult land acquisition and high construction costs.

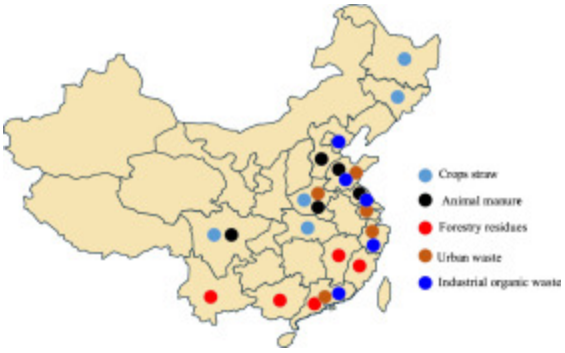

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Fig. 3. Biomass resources distribution in China.

4. Biomass power generation projects in China

The investment of biomass power generation in China continues to grow since 2006, with data showing that the scale of investment will exceed 150.2 billion CNY in 2019. China's

investment in biomass power generation exceed 160 billion CNY, and 1353 biomass power generation projects have been put into operation by 2020. The number of biomass power generation projects that have been put into operation from 2016 to 2020 are shown in Fig.4.

According to the materials applied in power generation, the biomass power generation technologies include agroforestry residue power, biogas power, waste incineration power, biomass–coal co-firing power, and biomass gasification power. The last two technologies has very little application in China[14]. Although the power generation equipment of biomass power plants is similar to coal-fired power generation equipment, due to the difference in biomass combustion process and coal combustion products, the technical requirements for the boilers used are also different. At present, the most commonly used biomass power generation boilers are mainly layer-fired boilers and circulating fluidized bed (CFB) boilers [15], [16]. Although biomass power plant construction capacity is increasing in China, it is still in its primary stage at the technical level. The domestic equipment such as incineration boiler and fuel conveying system are low conversion efficiency and high consumption. The high-performance core equipment needs to be imported. This situation led to high construction costs.

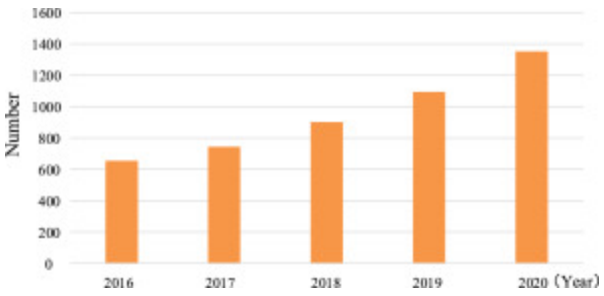

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Fig. 4. Number of biomass power generation projects in operation.

5. Biomass installed capacity and power generation

The data in this part are come from the annual operation data released by the China Electricity Council. The installed capacity and power generation of biomass in China from 2012 to 2020 are shown in Fig. 5, Fig. 6, respectively.

As shown in Fig.5, the cumulative installed capacity of biomass power generation in China has been increasing in the past decade. The annual newly installed capacity has also been on the rise. The new installed capacity of 6280 MW in 2019 represented the fastest growth in recent years. Owing to the COVID-19 pandemic, the new installed capacity in 2020 has

slightly decreased compared with that in 2019. However, it still reached 5430 MW. The five-year plans for biomass energy development issued by the National Energy Administration in 2012 and 2016 also stimulated the development of the biomass energy industry, leading to a rapid increase in newly installed capacity in 2013 and 2019. With the increase in the installed capacity and the continuous growth of the project number, biomass power generation continues to grow. By 2019, biomass power generation reached 111,100 GWh, a year-on-year increase of 22.49%. In 2020, biomass power generation reached 132,600 GWh, a year-on-year increase of 19.35%, as shown in Fig. 6.

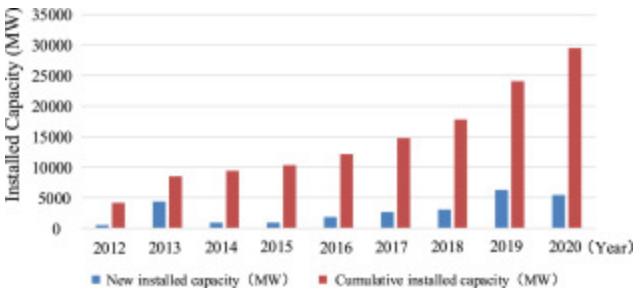

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Fig. 5. Biomass installed capacity in China from 2012 to 2020.

The share of biomass power generation and installed capacity among all renewable energy sources is shown in Fig. 7. The cumulative installed capacity of biomass power and the share of renewable power generation increased by 2.84% and 5.45%, respectively. It increased by 0.71% and 2.21%, respectively, when compared to 2014.

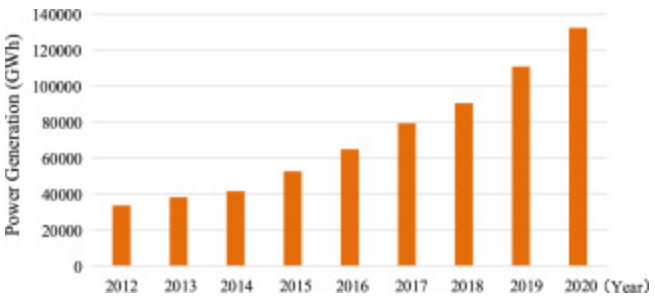

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Fig. 6. Biomass electricity generation from 2012 to 2020.

By 2040, China plans to reduce coal's share of energy from 57% to 35% while increasing the share of biomass [17]. The increase in biomass power generation reflects that biomass power generation has gradually become a new pillar of renewable energy utilization.

The different types of biomass installed capacity and power generation in China from 2014 to 2019 are shown in Fig. 8, Fig. 9, respectively.

As shown in Fig. 8, Fig. 9, the installed capacity and power generation of agroforestry demonstrate a steady growth trend. Since 2017, waste incineration power generation has grown considerably faster than agricultural and forestry biomass power generation and has achieved rapid growth in the past three years. Due to the troublesome collection of raw materials and the heavy maintenance work, the installed capacity and power generation of biogas is lower to than other resources.

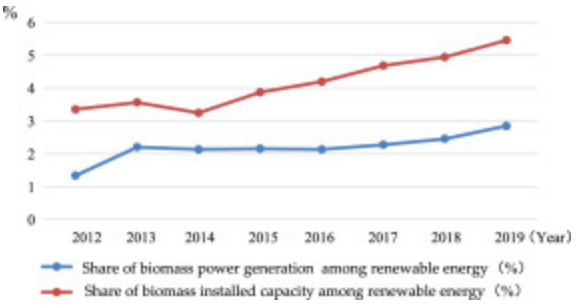

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Fig. 7. Share of biomass power generation and installed capacity among renewable energy.

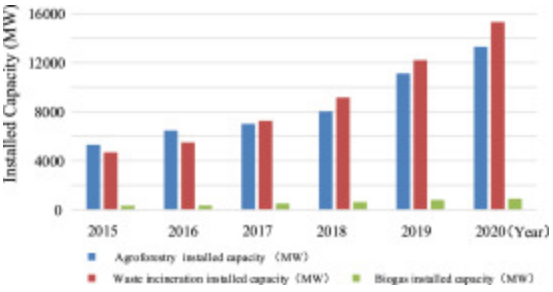

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Fig. 8. Installed capacity of different types of biomass.

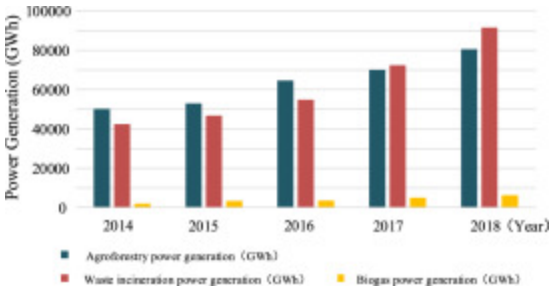

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Fig. 9. Power generation of different types of biomass.

6. Policies related biomass power generation

Biomass energy is an industry that has not sufficient market competition. Therefore, policy play an important role in the development of biomass energy industry. From 2006 to 2021, there are 62 national-level regulations and policies related to biomass power generation, and the number of policies issued each year is shown in Fig. 10.

In terms of China's economic development plan, there is an economic planning cycle every five years. Fig. 10 illustrate that the number of policies related to biomass power generation shows an increasing trend from the 11th to the 13th five-year plan.

In China's national-level policy system, the National People's Congress is the highest legislature, issuing laws of the highest level and involving the most fundamental and important issues. The next level is State Council, and the policies from State Council are relatively macro-level and mostly are guiding policies. Further down are Ministry, such as the National Development and Reform Commission, the National Energy Administration, and the Ministry of Finance, which are responsible for issuing policies in specific areas. The number of policies issued by different departments in different economic cycle is shown in Fig. 11.

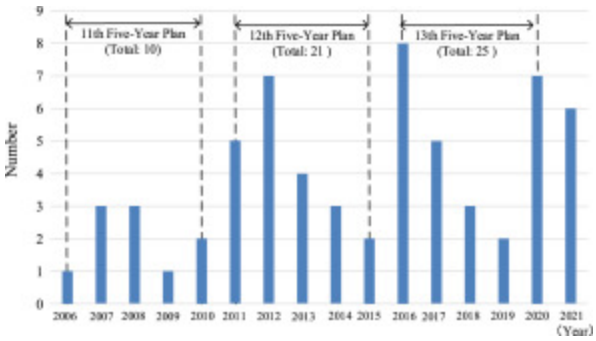

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Fig. 10. National policies issued from 2006 to 2021.

It can be seen from Fig. 11 that the National People's Congress only issued two laws during the 11th Five-Year Plan period, namely the "Renewable Energy Law" in January 2006 and the "Circular Economy Promotion Law" in January 2009. These two laws determine the legal position of renewable energy in China, indicating that China supports the development of renewable energy in national level. The State Council issued 8 regulations related to biomass power generation in 12th Five-Year Plan but only 1 in 13th Five-Year Plan. However, compared with 8 regulations in the 12th Five-Year Plan, Ministries issued 24 in the 13th Five-Year Plan. The policies are becoming more and more detailed.

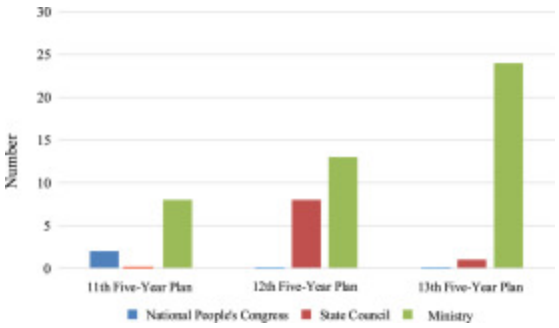

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Fig. 11. Number of policies issued by different departments.

Among these policies about biomass power generation, some were issued only for biomass power generation, some were involved in renewable energy-related policies, and some were involved in energy-related policies. The number of policies for different economic cycles in this regard is shown in Fig. 12.

It can be seen from Fig. 12 that during the 11th Five-Year Plan, only 3 polices were directly related to biomass power generation, while during the 13th Five-Year Plan, 12 were directly related. More and more attention was paid to biomass power generation at national level, and more targeted policies were issued to promote its development.

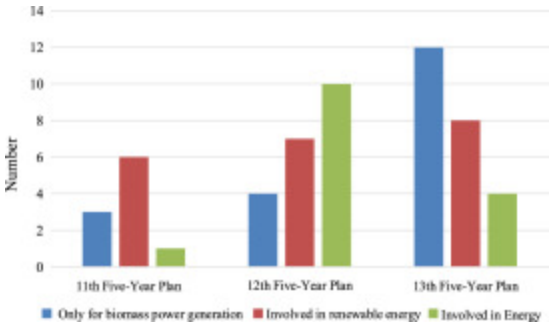

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Fig. 12. Number of policies related with different level.

Some of the policies related to biomass power generation are about finance. Some are related to the construction and operation of biomass power generation projects. In addition, there are some orientation policies that are issued by the National Development and Reform Commission. The number of policies for different economic cycles in this regard is shown in Fig. 13.

Fig. 13 shows that although specific financial, construction and operation policies increased in each economic cycle, the number of orientation policies is still the majority.

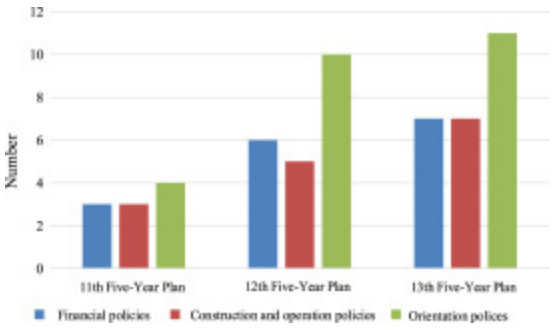

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Fig. 13. Number of policy with different direction.

From 2006 to 2021, there were 7 policies that have an important impact on the development of biomass power generation in China.

(1) In January 2006, the National People's Congress issued the "Renewable Energy Law"[18], which is the first time Chinese government issues a law on renewable energy.

(2) In December 2007, State Council issued the "Regulations on the Implementation of the Enterprise Income Tax Law"[19]. According to this law, biomass power generation enterprises are exempt from corporate income tax from the first to the third year, and half the corporate income tax from the fourth to the sixth year.

(3) In March 2008, National Development and Reform Commission issued the "11th Five-Year Plan for the Development of Renewable Energy"[20]. It pointed out that it is necessary to develop technologies for the clean and efficient utilization of biomass energy.

(4) In July 2010, National Development and Reform Commission issued the "Notice on Improving the Price Policies for Agroforestry Biomass Power Generation"[21]. It stipulated the price of Feed-in-Tariff for biomass power generation is 0.75 CNY per kWh, while the price of coal-fire power is about 0.4 CNY per kWh.

(5) In July 2012, National Energy Administration issued the "12th Five-Year Plan for Biomass Energy Development"[22], which proposed to comprehensively consider the characteristics of biomass resources, the biomass energy utilization technology and the market development to promote biomass power generation.

(6) In October 2016, National Energy Administration issued the "13th Five-Year Plan for Biomass Energy Development"[23], which proposed that biomass energy should be developed in a distributed way and the environmental protection should be considered in the process of biomass power generation.

(7) In August 2021, National Development and Reform Commission, Ministry of Finance, and National Energy Administration jointly issued the "2021 Biomass Power Generation Project Construction Work Plan"[24], which clarified that 2.5 billion RMB of financial subsidies from central and local government will be provided for biomass power generation in 2021.

It can be seen from the development history of biomass power generation policy that the early policy was mostly general orientation policies, and there was few specific regulations with strong operability, which made it difficult to implement. In terms of financial subsidies, Feed-in-Tariff subsidies are majority. In recent years, policy is becoming more and more specific. In addition to the Feed-in-Tariff subsidy, there is special subsidy funds for construction projects.

7. Problems and recommendations

The problems of the biomass power generation industry in China include few financial subsidy channels, low technical level, immature industrial chain, unspecific policies, and

insufficient market competition, etc. These problems had been summarized in many literatures [7], [8], [9], [10], [11], [12], and this paper has not the plan to discuss them in detail. This paper focus on specific problems existing in the biomass power generation industry in China and proposes corresponding solutions recommendations.

For agroforestry biomass and biogas power generation, the biggest problem is the high cost of raw materials. The planting areas of raw materials such as straw are scattered and require a lot of labor. As a result, the cost of raw materials accounts for 60% of the total cost of the biomass power generation. At present, the fuel cost of agricultural and forestry biomass power generation in China is about 0.42∼0.45 CNY/kWh, while the price of Feed-in-Tariff is 0.75 CNY/kWh. In addition to labor, operation and depreciation costs, even if there is financial subsidy, it is a meager profit, and once the market fluctuates, it will lead to losses.

Ensuring a stable supply of raw materials is the key step to solve this problem. A large amount of straw is burned in rural China, which not only causes environmental pollution, but also consumes the raw materials for biomass power generation. The government can provide the straw disposal subsidies for farmers. It is not only increase the enthusiasm of farmers to collect straw, but also reduce the cost of purchasing raw materials for biomass power generation enterprises. The transportation cost of biomass raw materials is high due to the dispersion of raw material planting areas. Exempting expressway tolls for the transportation of biomass raw materials is an effective way to reduce transportation costs.

Compared with agroforestry biomass power generation, waste incineration power generation got rapid development in recent years. The main reason is that waste incineration power generation can not only have the Feed-in-Tariff subsidies for power generation, but also have waste treatment subsidies. However, the problem of waste incineration generation is that the waste classification has not been implemented in China at present, and resulting in a low utilization rate of waste raw materials.

The other resistance of waste incineration power generation is local residents in many cities resist the construction of waste incineration plants. Because concerns the waste incineration may emit toxic gases that is harmful to health, boycott had occurred in Hubei, Guangdong, Tianjin, and Hainan regardless of how advance the technology is. Therefore, it is necessary to carry out waste classification to increase the waste utilization rate and popularize the scientific knowledge to eliminate the misunderstanding of residents about waste incineration power generation.

China has launched the national carbon emission rights trading market (carbon market) in July 2021, and the initial allocation system of carbon emission rights will be improved

gradually. It is necessary to make full use of the zero-carbon merits of biomass energy and embrace the carbon market. At present, the carbon price in China's carbon market is about 49 CNY/ton but in the international market is above $47/ton. A biomass power plant with a capacity of 30 MW can reduce carbon dioxide emissions by nearly 150,000 tons a year and make a profit of 7.35 million CNY in the carbon trading market. Carbon market is a great chance to promote the profitability and market competitiveness of biomass power generation industry.

8. Conclusions

Biomass resources are very rich in China. At present, more than 1300 biomass power plants have been put into operation. The installed biomass capacity reached 29,520 MW and the power generation reached 13,260 GWh in 2020. However, there are also high labor costs and high transportation costs for raw material collection. The high cost of raw materials has become the biggest problem restricting the development of biomass power generation enterprises in China. In terms of policies, Chinese government not only legislates to support the development of biomass energy, but also continuously issues specific policies on financial subsidies, construction and operation, which have played an important role in the development of the biomass industry. However, policies does not match with the development of technology, and the subsidies are not comprehensive. In the development of China's biomass power generation industry, improving profitability and market competitiveness is the most important problem need to be solved. In addition to government financial subsidies and policy support, biomass power generation enterprises should pay more attention to the carbon market. The carbon market will be an important way to improve the profitability of biomass energy industry in the future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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