

## REVIEW ARTICLE

# Analysis on development trend of biomass energy distributed utilization

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## ABSTRACT

Distributed biomass energy technology has strong adaptability to the types of raw materials, flexible project scale, can meet the needs of special users, better economy in small scale, easier commercial development, in line with the characteristics of biomass resources and China's national conditions. The distributed utilization of biomass energy mainly includes biomass briquette fuel and biogas. The key technologies include biomass briquette fuel processing and combustion, large and medium-sized biogas engineering technology, biomass gasification pyrolysis and gas utilization. At present, China's distributed biomass energy technology is mainly in the stage of technological improvement and application demonstration. It is expected that by 2030, most of the key technologies will be basically mature and have the conditions for industrialization. The main development direction of China's distributed biomass energy industry is the replacement of traditional coal-fired gas, urban/rural clean energy supply, and rural ecological environmental protection. The pollution caused by burning coal/fuel oil, and at the same time centering on the national new urbanization strategy, provide sustainable clean energy for the construction of new rural areas, and improve the level of rural ecological and environmental protection. At present, the main bottleneck restricting the development of distributed biomass energy industry is economy and reliability. The state should increase investment in technological innovation and policy support, convert the environmental and social benefits of biomass energy into cost benefits, and promote biomass energy. The development of the industry can be distributed and utilized.

**Keywords:** Biomass; Distributed; Briquette fuel; Biogas; Route map

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## 1. Significance of distributed utilization of biomass energy

### 1.1 Distributed utilization conforms to the characteristics of biomass resources

Biomass resources have diverse sources, low energy density, and scattered distribution. These resource characteristics determine that local conditions and distributed utilization are the inevitable requirements for the development of the biomass energy industry. In terms of resource supply, it should be developed and utilized on the spot without long-distance transportation, which can effectively reduce transportation costs, and conform to the natural attributes of low density and scattered distribution of biomass resources; in terms of energy use, it should be used nearby and directly for end users, and excess energy can be used. In terms of management and operation, it should have the ability and conditions for independent operation, and if necessary, it can be connected to the Internet or complementary to fossil energy.

The scale of distributed biomass energy technology application is

very flexible, and it can meet different needs according to the actual local conditions. For example, small-scale power stations can be built, and it can also be used as residential gas, and even as fuel for heating and industrial furnaces. It is an effective way to truly realize the development and utilization of biomass energy according to local conditions. Moreover, from the perspective of industrialization, due to the strong adaptability of distributed biomass energy technology to the type and scale of raw materials, the project scale requirements are small, the capital threshold requirements are low, the investment return is high, and the adaptability to various user needs is good. There is a certain economy in scale, so distributed utilization of biomass energy is easier to commercialize than centralized utilization. In general, distributed biomass energy technology conforms to the characteristics of China's scattered biomass resources, is suitable for decentralized utilization and industrial applications, has strong adaptability and survivability, and has broad applications in the development of distributed biomass energy technology in China. prospect.

## **1.2 The distributed utilization of biomass energy is in line with the development status of China**

China's economic development is unbalanced, and the energy consumption structure of residents in different regions is quite different. On the one hand, there are still about 133 million rural families that use traditional biomass energy as the main energy for cooking or heating, and many rural areas in the central and western regions still use traditional biomass energy directly burned such as straw and firewood as the main energy for living; on the other hand, with the development of the rural economy and the improvement of living standards in the eastern coastal areas, the use of traditional biomass energy as living energy has been greatly reduced, and a large number of crop straws have been abandoned in the fields and burned on the spot, resulting in serious air pollution

China is vigorously promoting new urbanization and new rural construction, which requires a large amount of clean energy supply. Making full

use of abundant and cheap biomass resources in vast rural areas and accelerating the development of biomass industry is an effective way to solve the sustainable energy supply in rural areas in the future. As a clean energy sourced from agricultural and forestry by-products, biomass energy can provide living energy for rural urbanization, including heating, gas and electricity, forming a new supply model of self-produced and self-sold rural energy. Distributed biomass energy conversion technology is the most suitable industrialization direction for rural decentralized utilization. For example, using straw to provide heat, electricity, gas and other living energy for rural areas is an effective measure for new rural areas to get rid of coal-fired dependence.

## **2. Development status of distributed utilization of biomass energy**

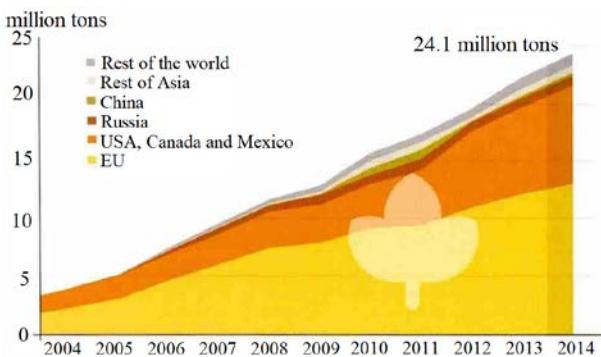
The main methods of distributed utilization of biomass energy are briquette fuel and biogas (biogas and gasification). Biomass briquette fuel and biogas are used in the same way as traditional fossil fuels. They are good substitutes for coal or natural gas, meet the requirements of sustainable development, and realize the transformation from low-grade fuels to high-grade, low-polluting fuels, and can be widely used. Used in various small hot water boilers, hot blast stoves, family heating stoves or fireplaces, it can not only solve the cooking and heating of urban and rural households, but also be used in small power generation and heating facilities, creating conditions for the adjustment of the energy structure of small and medium thermal power plants.

### **2.1 Status quo of distributed utilization of biomass energy abroad**

(1) Production and application of briquette fuel. The production of briquette fuels in Europe and most other regions is mainly based on woody biomass. At present, most of them are used in various small hot water boilers, hot blast stoves, home heating stoves or fireplaces, and some are used in small community cogeneration power stations to meet the heating needs of residents. In China's new urbanization plan, it is clearly stated that the re-

quirement for rural renewable energy to reach 13% after 10 years, in which the use of biomass briquette fuel to provide cooking and heating energy for rural and small-town households will be an important way.

Biomass solid particle fuel is not only supplied to power plants and heating companies through special means of transportation, but also sold in bags in the market, and has become the preferred living fuel for many households. In 2014, global wood pellet production reached 24.1 million tons, with the EU accounting for about 62% and North America about 34% (**Figure 1**). The largest producers are the United States (26% of total production), Germany (10%), Canada (8%), Sweden (6%) and Latvia (5%)<sup>[1]</sup>. EU countries consume the most wood pellets in the world, with 15 million tons in 2013.



**Figure 1.** Wood pellet fuel production<sup>[1]</sup>.

(2) Biogas production and application. Biogas refers to the gas converted from biomass, including biogas, syngas and hydrogen. At present, biogas has a large cost advantage, so biogas often refers specifically to biogas. According to the International Energy Agency, in 2012, there were more than 13,800 biogas plants in operation in Europe, with an installed capacity of 7.5 GW. Most of it is combined heat and power, and a small part is sent to the natural gas pipeline network, generating 44.5 GWh of electricity and  $1.1 \times 10^5$  GJ of heat, respectively. By the end of 2013, there were about 8,000 biogas production plants in Germany, with an installed capacity of about 3.8 GW, 98% of which were used for power generation, and combined heat and power was implemented. That year, the electricity supply was  $2.7 \times 10^4$  GWh, and the heat supply was  $1.2 \times$

$10^4$  GW. It is estimated that by 2020, the total installed capacity of biogas power generation will reach 9,500 MW. Another 169 biogas plants transmit gas to the natural gas pipeline network, with a gas transmission volume of 900 million cubic meters.

## 2.2 Status quo of biomass energy distributed utilization in China

(1) Production and application of briquette fuel. In recent years, China has begun to attach importance to the development of the biomass briquette fuel industry. The National Development and Reform Commission proposed in the “Long-term Development Plan for Renewable Energy” that it strives to achieve the goal of 50 million tons of pellet fuel per year by 2020. At present, domestic biomass briquetting fuel is mainly used for industrial high temperature steam supply, including steel, textile, printing and dyeing, papermaking, food, chemical and other industries. Product standards, it is difficult to calculate the specific industrial scale, and it is estimated to be about 5 million tons per year. The National Energy Administration emphasized in the “Guiding Opinions on Energy Work in 2014” that the new biomass industrial and residential heating conversions during the year were 2 million tons and 800,000 tons (steam) respectively. According to the “Notice on Printing and Distributing the Work Plan for Strengthening the Prevention and Control of Air Pollution in the Energy Industry” by the National Development and Reform Commission, the National Energy Administration and the Ministry of Environmental Protection, we will strive to use more than 15 million tons of biomass briquette fuel in 2017.

(2) Biogas production and application. China is rich in biomass energy resources, and there are a wide variety of resources that can be used to produce biogas, including crop straw, livestock and poultry manure, and forestry waste. According to statistics, the total amount of resources that can be used to produce biogas in China is equivalent to about 700 million tons of standard coal (**Table 1**). If technical feasibility and market competitiveness are considered, the currently available resources are

about 250 million tons of standard coal, and the amount of biogas that can be produced is 199 billion cubic meters, which is equivalent to about

120 billion cubic meters of natural gas, which is equivalent to China's natural gas in 2014. 2/3 of the consumption of 180 billion cubic meters.

**Table 1.** Potential of biogas resources in China<sup>[2]</sup>

Resource type	Total resources		Amount of resources currently available	
	Physical quantity (100 million tons/year)	Biogas equivalent (100 million cubic meters)	Physical quantity (100 million tons/year)	Gas production (100 mil- lion cubic meters)
Livestock manure	25.0	1,500	12.5	750
Crop straw	6.0	2,900	1.2	580
Forestry waste	2.7	1,500	0.8	450
Agro-processing waste	2.0	60	1.0	30
Sewage sludge	0.1 (dry weight)	20	0.1	20
Urban and rural do- mestic waste	2.0	60	2.0	60
Organic sewage	20.0	100	20.0	100
Rural people's feces	—	80	—	—
Total	700 million tons of standard coal	6,220	250 million tons of standard coal	1,990

In recent years, China's biogas industry has made great progress. The output of biogas has reached 15 billion cubic meters per year, and the CO<sub>2</sub> emission reduction has reached 7.65 million tons. There are about 4,000 large and medium-sized biogas projects. However, in general, due to the relatively small scale of the biogas projects for processing agricultural organic wastes in China and far from cities and towns, only a small amount of biogas generated is used for power generation and centralized gas supply (the gas consumption for biogas power generation accounts for about 2.53% of the total gas production, and the centralized gas supply accounts for about 1% of the total gas production), and a large amount of biogas is used for the production and living fuel of the farm itself. The average pond capacity of agricultural biogas projects is only 283 cubic meters, and the large-scale biogas projects with a pond capacity of more than 1,000 cubic meters only account for about 9%. The development of biogas technology and industry is in urgent need of transformation and upgrading.

(3) Biomass gasification power generation and gas application. Biomass gasification for power generation and gas application is a distributed utili-

zation method of biomass energy with Chinese characteristics. Based on biomass pyrolysis gasification technology, China has developed a biomass pyrolysis gasification centralized gas supply system to meet the needs of rural residents for cooking and heating, and related technologies have been preliminarily applied. Among them, the use of biomass pyrolysis and carbonization technology to build a multi-generation system of biomass charcoal, gas and oil to provide living gas for rural residents, while producing biomass charcoal and biological tar, has achieved good economic and social benefits. Anhui and Henan have been initially promoted and have good development prospects<sup>[3]</sup>. In terms of biomass gasification power generation, a variety of fixed-bed and fluidized-bed gasifiers have been developed that use biomass such as wood chips, rice husks, and straw as raw materials. Gasification power generation devices are exported to Thailand, Myanmar, Laos and Taiwan region of China. It is one of the countries with the most applications of small and medium biomass gasification power generation in the world.

### 3. Main technologies for distributed utilization of biomass energy

At present, there are a variety of biomass energy distributed utilization technologies that

are basically mature<sup>[4]</sup> and most likely to be marketed, including biogas, biomass molding, biomass gasification, biomass heating and utilization, etc. The development status of relevant core technologies is shown in the **Figure 2**.

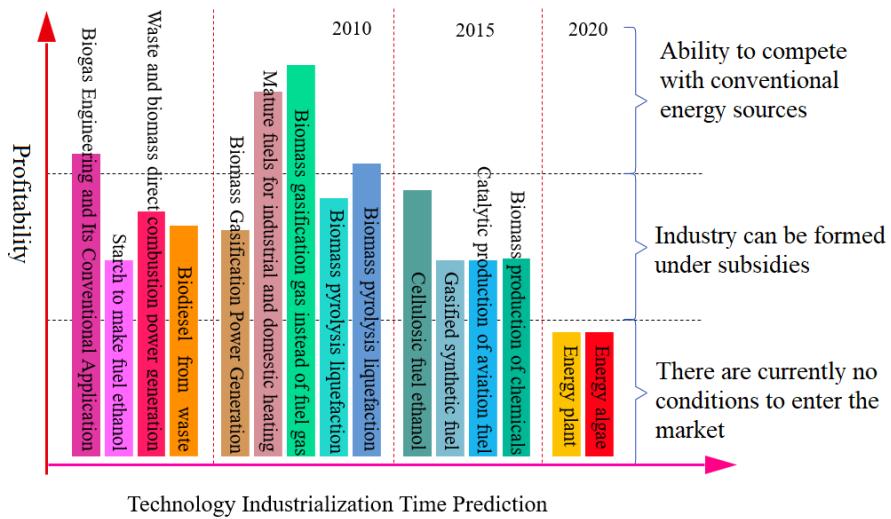


Figure 2. Status quo of distributed biomass energy technology.

#### 3.1 Large and medium-sized biogas technology

Biogas projects deal with a wide range of organic wastes, such as livestock and poultry manure, silage, expired grains, kitchen residues, domestic organic wastes, animal slaughtering wastes, agricultural and sideline product processing wastes, etc. A mixture of several organic wastes. Due to the rapid development of livestock breeding in China in the past 10 years, the total discharge of livestock and poultry manure far exceeds the environmental carrying capacity<sup>[5]</sup>. Therefore, biogas engineering will play a multi-functional role (energy production, comprehensive utilization and environmental protection, etc.), and has broad application prospects.

Large and medium-sized biogas projects are very mature and they are the main method for distributed utilization of biomass energy. However, the traditional biogas utilization methods in China are mainly household biogas digesters, which are small in scale and low in efficiency; however, there is still a big gap between large and medium-sized biogas projects compared with foreign technologies, and the level of equipment technology and manufacturing technology is not high. For example, the inter-

national CSTR gas production rate of the process can reach  $15 \text{ m}^3 \cdot \text{m}^{-3} \cdot \text{d}^{-1}$ , and the thermal power system rate can reach 90%, while the gas production rate in China is only  $0.8\text{--}5.0 \text{ m}^3 \cdot \text{m}^{-3} \cdot \text{d}^{-1}$ , and the power generation efficiency is only 35%. At present, the large and medium-sized livestock and poultry manure biogas projects that have been built in China have not considered full utilization of resources in the process design stage, and most of them do not use combined heat and power. The output rate is very low.

#### 3.2 Biomass molding technology

There are two main types of molding technologies: one is pellet fuel molding machine, and ring die machines of different specifications are the mainstream models of pellet fuel molding machine; the other is rod or block molding machine. For farm applications, the raw material is crop straw, most of which are large-pitch, large-diameter extruders, and there are also hydraulically driven piston stamping machines. At present, biomass briquette fuel has been produced on a production line from raw material collection, drying, pulverization, packaging, and sales, with a high degree of automation, scale and commercialization.

The production of briquette fuel in China takes crop straw as the main raw material, and the forming characteristics and combustion characteristics of straw are very different from forest residues, so foreign technology and equipment cannot be copied. At present, significant progress has been made in biomass punching briquetting technology and device, extrusion briquetting technology and device, baking carbon technology and device, etc., However, there are still problems such as high energy consumption, serious wear and short service life of biomass molding machines in China. It is necessary to further strengthen technological research and development and improve energy utilization efficiency. In addition, the combustion application technology of straw-fueled boilers is still immature, and core technologies and equipment are still lacking. There is no mature boiler product manufacturer. Problems such as slagging, coking, corrosion and serious fly ash are prone to occur in boiler combustion, and operation and maintenance are not easy. Therefore, improving the adaptability of boilers to straw briquette fuel is one of the key technologies for large-scale promotion of biomass briquette fuel.

### 3.3 Biomass gasification technology

The main advantage of biomass gasification is to convert the low-grade biomass fuel that is difficult to burn into gas to achieve clean and efficient combustion, which is an effective way for the distributed utilization of biomass<sup>[6]</sup>. China's small-scale biomass gasification and utilization technology has reached the international advanced level, especially in gasification power generation and biogas replacement of industrial fuels. However, in general, the current gasification equipment has poor adaptability to fuel and is sensitive to changes in raw material moisture, ash or calorific value; gasification power generation still has low efficiency, poor stability and too complicated gas purification system. It is necessary to improve the efficiency of biomass gasification and its automatic control level; biomass gas combustion has problems, such as immature matching technology between gas and conventional combustion equipment (such as boil-

ers, kilns, etc.), and it is urgent to solve key technologies such as efficient combustion of biomass gas, coupling control of gasification system and industrial boiler/kiln. Therefore, developing new biomass gasification technologies and equipment, improving and improving gas utilization efficiency, building demonstration projects, and forming commercial solutions for distributed biomass gasification utilization are the main directions of biomass gasification technology development.

### 3.4 Biomass pyrolysis technology

Biomass pyrolysis technology can convert low-grade biomass into high-grade charcoal, fuel oil, etc., and is one of the main ways to utilize biomass at high value. The research on biomass pyrolysis technology in China is relatively early, but the progress of industrialization is slow, mainly because the research is mainly based on a single technology and lacks systematicness, and there is still a big gap compared with countries such as Europe and the United States. In particular, there are obvious gaps in the development of high-efficiency reactors, optimization of process parameters, refining of liquefied products, and the impact of biofuels on engine performance. At the same time, the pyrolysis technology still has the following problems: the cost of bio-oil is usually higher than that of mineral oil, the bio-oil is incompatible with traditional liquid fuels, and special fuel processing equipment is required; the chemical properties are unstable, phase separation, precipitation and other phenomena will occur in long-term storage, and it is corrosive; due to the instability of physical and chemical properties, bio-oil cannot be directly used in existing power equipment at present, and must be modified and refined. These are the bottlenecks that hinder the large-scale utilization of biomass pyrolysis. In view of the above gaps and problems, future research focuses on how to improve the yield of liquefied products, seek high-efficiency refining technologies, improve the quality of bio-oil, reduce operating costs, and realize comprehensive utilization and industrial production of products<sup>[7]</sup>.

## 4. Development prospect analysis of distributed utilization of biomass energy

### 4.1 Development potential analysis of distributed utilization of biomass energy

The key to the development of distributed biomass energy is to adapt to local conditions, and cannot be separated from local social and economic development conditions and pursue unrealistic development goals. At present, the main functions of biomass energy development and utilization in China are environmental protection and energy saving. The purpose is to reduce pollution, provide economical and feasible clean alternative energy,

and reduce the pressure of fossil energy. In terms of positioning, in the near future, we should focus on the strategic needs of energy conservation and emission reduction to realize partial replacement of industrial fuels, reduce the consumption of coal/fuel/gas, and reduce the cost of emission reduction of enterprises; in the long run, liquid fuel substitution should be developed to realize the large-scale production of biomass liquid fuels, large-scale cultivation of energy crops and commercial utilization of energy algae<sup>[8]</sup>. According to industry development analysis and forecast, the development of China's distributed biomass energy technology industry can be roughly divided into two stages (Figure 3).



Figure 3. Development priorities and potential prediction of my country's biomass energy distributed utilization industry.

(1) Recent (2015–2020). Biomass decentralized heating and natural gas replacement technologies are basically mature, and the industrialized business model is basically established. The industrialized technologies and products are mainly based on biomass decentralized heating and biomass replacement of natural gas. Application demonstration stage. The key industries developed at this stage include: biogas engineering and its combined heat and power system, biogas preparation vehicle gas system, biomass gasification gas kiln combustion system, biomass gas boiler combustion system, biomass combined heat and power system, high efficiency biomass heating boilers, straw briquette fuel combustion boilers, briquette

fuel household heating equipment, briquette fuel household stove equipment, aquaculture and other large-scale sewage biogas projects, etc.<sup>[9]</sup>

(2) Medium term (2020–2030). Biomass decentralized heating and natural gas replacement technologies and products are in a stage of rapid development, with increasingly significant industrial scale, economic benefits, and emission reduction benefits; technologies and products for decentralized utilization of biomass energy as living energy in urban and rural areas are becoming more and more mature, and national/local governments are increasingly mature. The policy measures for the use of biomass energy in new urbanization will be further strengthened, and the status of dis-

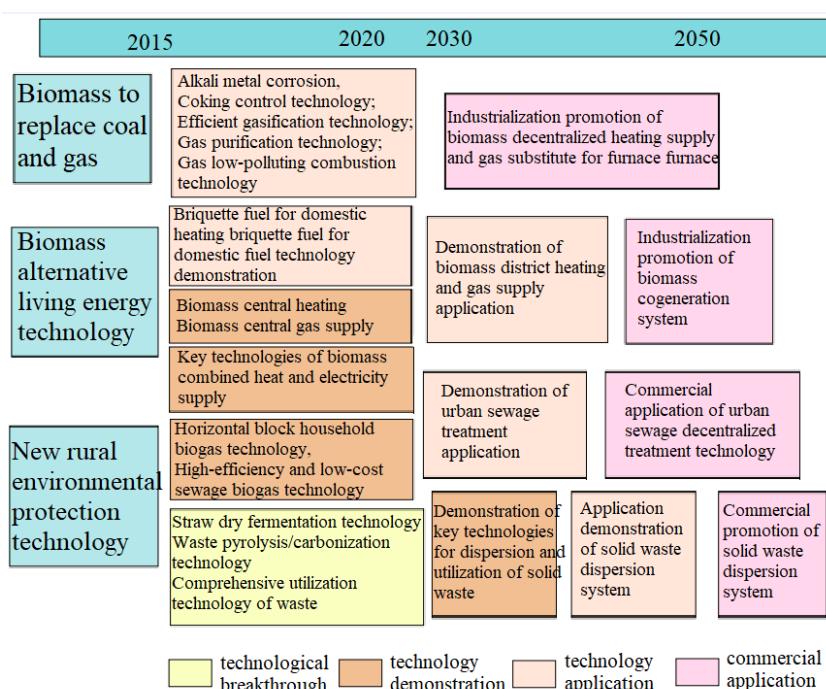
tributed biomass energy technology to provide energy supply and environmental protection solutions for new urbanization have been preliminarily established. The key industries developed at this stage include: biomass gasification central gas supply system, biomass central heating system, biomass cogeneration system, biomass replacement LPG fuel integrated system, waste pyrolysis incineration equipment, waste/biomass mixed carbonization/gasification system, waste grading and comprehensive utilization, straw/manure mixed fermentation equipment systems, household biogas modular system, etc.

## 4.2 Development map of biomass energy distributed utilization

Traditional coal-fired gas replacement, urban/rural clean energy supply and rural ecological environment protection are the three major development directions of distributed utilization of biomass energy. The relevant core technologies include alkali metal corrosion and coking control technology, high-efficiency biomass gasification technology, biomass pyrolysis/carbonization technology, straw dry fermentation technology, biomass gasification gas purification technology, biogas purification technology, biogas low-polluting combustion

and power generation technology, etc. Among them, in terms of biomass energy coal-fired gas substitution, the key technologies have basically matured, and most systems have completed application demonstrations. If conditions are met in terms of policy and economy, it is expected that industrialization and large-scale promotion and application can be realized within 5–10 years. In the aspect of rural ecological environment protection, the utilization technology of straw and other solid wastes has the conditions for industrialization; the key technologies such as scattered-scale garbage/sewage treatment system, household biogas upgrading, and straw biogas preparation are in the research and development stage; in terms of urban/rural clean energy supply, biomass clean utilization technology is in the project demonstration stage, and the core technical issues include biomass briquette fuel household heating modular technology, biomass household gas modular technology, etc.

Based on the current research and development of relevant core technologies and their application status, China's distributed biomass energy technology is mainly in the stage of technological improvement and application demonstration in the near (**Figure 4**).



**Figure 4.** Development roadmap of distributed biomass energy technology in China.

## **5. Analysis of development conditions for distributed utilization of biomass energy**

Biomass raw materials are dispersed and the types are complex. In essence, biomass energy is more suitable for decentralized utilization<sup>[10]</sup>. Therefore, the development of distributed utilization modes such as biomass heating, gas supply and heat/electricity/gas co-production is the most suitable for biomass energy in China. The main direction of development, but from the current situation of industrial development, the main bottleneck restricting the development of distributed biomass energy industry is economy and reliability. In order to realize the development goals and potentials of the above-mentioned distributed biomass energy industry, we must focus on solving these two problems in order to create favorable conditions for the development of the industry.

### **5.1 Technological innovation and application demonstration**

Technological innovation is the basis for improving the economics and reliability of the distributed biomass energy industry<sup>[11]</sup>. The government should increase investment in scientific research, enhance technology R&D and technology transfer capabilities, conduct key technology research and innovation, system integration and engineering demonstrations, and promote the development of distributed biomass energy technology industrialization.

(1) Develop key technologies for replacing industrial fuels with biomass to ensure that biomass can be used stably in industrial equipment such as boilers and kilns. Including: researching high-efficiency biomass combustion technology with strong fuel adaptability, preventing the influence of unqualified fuels, and realizing controllable combustion temperature in the furnace; researching and solving problems such as coking in the furnace and corrosion of heat exchange equipment in the process of biomass utilization<sup>[12]</sup>; developing adaptation biomass gasification technology for various raw materials, focusing on solving technical prob-

lems such as low tar, large load, and high stability.

(2) Develop common technologies related to rural environmental protection and rural living energy supply, so that distributed biomass energy can become an effective way to ensure new urbanization energy and rural environmental protection. In order to achieve low cost and improve reliability, it is necessary to combine biomass energy utilization technology with China's rural development needs, carry out engineering demonstration and long-term commercial application, and effectively improve the reliability and practicability of the technology. The leading role of the industry, guiding and promoting the development of related industries.

#### **5.1 Business model and policy support**

China's distributed biomass energy industry is still in its infancy, with low user recognition and an immature business model. At the same time, compared with traditional energy, the distributed biomass energy industry has the disadvantages of large unit investment and high operation and maintenance costs. The government should strengthen policy support and guidance, encourage commercialization demonstration, business model innovation, and improve its market competitiveness.

(1) Continuously innovate and improve the business model of the distributed biomass energy industry. First, improve the system integration capabilities of bioenergy equipment, organically combine equipment manufacturing, processing and sales of core equipment, core technology research and development in complete equipment development, technical services and engineering installation and commissioning; secondly, build a market network of bioenergy fuel production and suppliers, and provide users with solutions to ensure fuel supply while focusing on biofuel collection, processing and production; after that, establish a business model that reduces users' worries, utilize core technologies and low-cost equipment, and provide customers with comprehensive solutions for decentralized utilization of biomass energy through professional fuel supply and project operation management, forming a market-valued business model. Market competitiveness of biomass energy.

(2) Formulate economic incentive policies to convert the environmental advantages of biomass energy into cost advantages. The unit heat cost of biomass fuel is much higher than that of fossil energy. It is not economical to simply use biomass energy to replace coal and natural gas. However, biomass is a renewable clean energy with significant emission reduction advantages and environmental benefits. The government should formulate corresponding incentive policies and establish an incentive mechanism for industrial development, including incentives for project establishment, tax and environmental protection load reduction, thermal power price subsidies, CO<sub>2</sub> emission reduction subsidies, urbanization construction subsidies and other policies to improve its economy and mobilize the distribution of social development. enthusiasm for biomass energy<sup>[13]</sup>.

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## Conflict of interest

The authors declared no conflicts of interest.

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