China biomass-to-heat market evaluation and policy recommendations of development

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Abstract. This research focused on comparative analysis on the economic efficiency of biomass-to-heat with that of traditional modes of heat production by coal, oil and natural gas in a bid to determine the competitiveness, and potential for scaling up and commercialization. The research showed that BMF-to-heat is competitive and its cost is equivalent to coal in some regions in China, especially where with a higher demand for clean energy, BMF will become the best alternative. However, in regions where coal price is low, BMF is less competitive and supportive government policies are required to further promote its application. Biomass gasification and biomethane/biogas are slightly less competitive than coal, but slightly more than gas. They are relatively promising to commercialize. Based on the market evaluation research results, this paper proposes the policy recommendations for the large-scale and commercial development of biomass energy heating in China.

Keywords: BMF, Biomass-to-heat, Market evaluation.

1 Introduction

Biomass energy, a renewable and the fourth major energy after petroleum, coal and natural gas, holds a significant share in world energy consumption. There are proven technologies to develop and utilize biomass energy and its applications are diverse. It plays an important role in countering global climate changes, mitigating the imbalance between energy supply and demand, and protecting ecosystem. It will be an important contributor in energy transition on a global scale. Biomass energy is also the unique renewable energy that can be converted to several energy products, such as heat, electricity, fuel gas, liquid fuel, etc, among which biomass to heat accounts for large proportion, and is an important clean heating source that can be flexibly deployed and broadly applied.

China has abundant biomass resources. Thanks to favourable government policies since the Twelfth Five-year Plan, biomass-to-power and biogas among others have grown rapidly. Their commercialized development and utilization began to take shape, and associated technologies are basically sound and reliable. Since the 18th CPC National Congress, China government put ecosystem health and sustainability as one of their priorities. Environmental protection has been enhanced and air pollution prevention and control have

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been increasingly strengthened. In such a favourable circumstance, biomass moulding fuel (BMF) and biogas have been growing steadily and are ready for scaling up and industrialization. However, biomass-to-heat is still at its start-up stage. A complete industrial system hasn't been established yet, due to lack of specialization, under-commercialization, inadequate deployment experiences, as well as insufficient supportive government policies are still challenges faced the industry.

On December 21, 2016, China President Xi Jinping required to promote clean heating in winter in North China at the 14th Session of Leading Group for Financial and Economic Affairs (LGFEA). And in the report of the 19th CPC National Congress, this requirement is further stated as "to facilitate revolutionary energy production and consumption; build an energy system that is clean, low-carbon, safe and efficient; grow clean energy industry to promote green development and build a healthy and sustainable ecosystem". To move toward this vision, in December 2017, Guidance on Clean Heating in Winter in Northern China (2017-2021)and Guideline for Promoting the Development of Biomass-to-Heatwere promulgated by national ministries per requirement proposed at the 14th Session of LGFEA. These two policies provided strong support and great opportunities for biomass-to-heat to grow further[1-2].

To significantly promote the scaling up and commercialization of biomass-to-heat in China, to effectively solve air pollution problem due to heat supply during winter in North China, and to improve the government policies and mechanism that facilitate the commercialization of biomass-to-heat in China, CECEP initiated a project named "China Biomass-to-Heat Strategic Research" at the beginning of 2017, with support from National Energy Administration and Asian Development Bank andNational Key Research and Development Project. This research analysed the overall performance of biomass-to-heat market in China. It explored the business models for biomass-to-heat to be scaled up and commercialized in China, with reference to advanced biomass-to-heat technologies, government policies and best practices for commercialization from foreign countries. It also proposed recommendations on government policies. The achievements from this research will support the sound and sustainable development of biomass-to-heat industry in China.

2 National biomass-to-heat market competitiveness analysis

Currently, the modes of Biomass-to-Heat in China mainly include biomass CHP, BMF, biomass gasification and biogas/biomethane. Most of China's biomass-to-heat projects use BMF as heating materials. BMF has the characteristics of convenient transportation and storage, high fuel utilization[3-6].By the end of 2017, the annual utilization of BMF in China was about 13.2 million tons, and BMF was used in industrial, commercial facilities and residential heating. The amount of biomass-to-heat projects is about 1000, the heating area is about 80 million square meters, and the heat supply is about 2.3×10^8GJ. The main heating methods are hot water supply, steam supply, cogeneration, etc.

2.1 Comparative analysis on the economy of BMF for heat production

Biomass boilers are mature in technology, equivalent to coal-fired boilers in efficiency index but obviously better than coal-fired boilers in flue gas emission index, so biomass boilers have good environmental performance. In regions with higher regulatory requirements on environment, coal has already been prohibited or restricted for use and BMF is expected to become an ideal alternative fuel. Table 1 is the comparative analysis on the economy of BMF-fired boilers and coal-fired, gas-fired, oil-fired and electric boilers based on the prices of each type. BMF has different prices in different areas. Currently, southern areas typically use biomass pellet fuels that are mainly processed by forestry

residuals, and the price is about 1,000 Yuan per ton; In Northern areas, BMF made from straws are generally used, and the price is 550-850 Yuan per ton. Therefore, if the calculation is based on 900 Yuan/ton for biomass pellets and 600 Yuan/ton for biomass briquettes, then the unit heating cost would be about 66.4 Yuan/GJ and 56.7 Yuan/GJ respectively, meaning heating cost is much lower as compared with the price for heat produced by natural gas, fuel oil and electricity for commercial use. However, under the current situation of lower coal price, the heating cost of coal-fired boilers is even lower at about 51 Yuan/GJ. Yet, with the increasing demand for clean heating, coal-fired boilers have been restricted and BMF-fired heating is becoming a beneficial supplement to coal-fired heating.

Table 1. Economic comparison between BMF and other sources for heat production.

Fuel Type	Lower Heating Value	Fuel Price (RMB,yuan)	Boiler Efficiency	Unit Heating Price (RMB,yuan)
Natural gas	36,000 kJ/m^3	3.5 Yuan/m^3	92%	148 (Yuan/GJ)
Fuel oil	41,868 kJ/kg	4,600 Yuan/ton	88%	175 (Yuan/GJ)
Coal	20,900 kJ/kg	500 Yuan/ton	65%	51 (Yuan/GJ)
Electricity for commercial use	3,600 kJ/kWh	0.7 Yuan/kWh	97%	281 (Yuan/GJ)
BMF	16,000-19,000 kJ/kg	900/600Yuan/ton	85%	66.4/56.7 (Yuan/GJ)

To sum up, BMF technologies are mature, so it might become the best alternative and rather economical due to the restriction of use of coal in areas with a higher demand for clean energy. However, in regions where coal price is relatively lower, BMF is less competitive and thus difficult for popularization and continue to require for government policy support.

2.2 Comparative analysis of the economy of biomass gasification for heat production

For biomass gasification for heating, the technical threshold is lower and the energy conversion process is less harmful to the environment. In addition, the sulphur content (＜0.3%) and ash content (＜10%) are much less than that of coal resources [7-8]. Therefore, biomass gasification is a relatively clean fuel. Without desulfurization, biomass gasification can meet the emission standards by adopting only simple and low-cost ash treatment equipment. Under the existing market environment, biomass fuels have reached the level of competing with traditional fossil energies in heat production. Table 2 shows the comparison between biomass gasification and other traditional fuels including natural gas, diesel and coal in steam production. It indicates that biomass gasification is more economical compared with petroleum and natural gas but a bit less economical than coal for heat production.

Table 2. Economical comparison between biomass gasification and fossil fuel for heat production.

Item	Biomass Gasification	Natural Gas	Diesel	Coal
Heating value	1,200 (Kcal/m^3)	8,500 (Kcal/m^3)	10,200 (Kcal/kg)	4,200 (Kcal/kg)
Unit price	0.5 Yuan/m^3	3.5 Yuan/m^3	6.0 Yuan/kg	0.8 Yuan/kg

(RMB, yuan)				
Heat conversion efficiency (%)	85	90	90	70
Burning consumption per ton of steam	555.6 (m^3)	80.7 (m^3)	67 (kg)	163 (kg)
Fuel cost per ton of steam (RMB, yuan)	277.8 Yuan	313.8 Yuan	446 Yuan	186 Yuan

2.3 Comparative analysis of the economy of biogas/biomethane for heat production

With the improvement of the biomass feedstock collection system, the feedstock supply service standards and system have been further improved. So, the feedstock collection will become more efficient and the collection costs will be effectively controlled. The cost of biomethane is usually calculated on the basis of the cost of biogas, which is the addition of 0.3-0.5 Yuan for per cubic meter adding the biogas purification cost. Table 3 shows that the production cost of biomass fuels will be lower than that of natural gas. In this case, natural gas will be gradually replaced for heat production with the decreasing costs of biomethane. It is estimated that biomethane will be obviously more economical after 2030 and will become a key drive in gas heating in the future.

Table 3. Biomass Gas Cost Analysis (Unit: Yuan/m^3).

Type of gas/development stage	2020	2030	2040	2050
Natural gas	2.71	3.6	4.27	4.52
Biomass pyrolysis gas	2.13	2.47	2.85	2.85
Livestock and poultry methane	2.76	3.1	3.45	3.45
Industrial biogas	1.72	2.07	2.41	2.59
Biomethane	2.54	2.89	3.23	3.32

3 Analysis on the development potential for commercial-scale biomass-to-beat in China

3.1 Large-scale and commercialized development potential for BMF

As mentioned in the Medium and Long-term Development Plan for Renewable Energy in China, by 2020, the utilization of bioenergy will be basically commercialized and in scale, and the annual utilization amount is expected to reach 50 million tons. Under the support of environmental protection policies and the condition of a fair market, the utilization amount of bioenergy may surpass 100 million tons by 2030, which may replace 80 million tons of coals for heating, reduce more than 100 million tons of straw burning in the open air and decrease 40 billion cubic meters of natural gas import. Among the 100 million tons of BMF, 70 million tons are for industrial use, which can provide 350 million tons of clean steam each year, replace 50% of the coal consumption by coal-fired industrial boilers with a production capacity of less than 10 tons; the rest 30 million tons are used for heat production, which can provide clean heating for 1 billion square meters of civilian and commercial buildings. Every additional private investment of 10 billion Yuan each year would create one million jobs and increase 10 billion Yuan rural income, which could form

a new strategic emerging industry with an annual output value of 200 billion Yuan. An annual increase of 15 million tons in the BMF industry would mean 150 million tons of CO2 emission reduction by 2030.

In around 2005, China started to develop the BMF industry. After going through the initial exploratory stage and the primary transition stage, BMF produced in 2010 was only around 500,000 tons due to insufficient demand for end-users' market as well as immature processing and combustion technologies. Starting from 2013, with promulgation of strict domestic environmental protection policies, the trend for replacing coals became obvious. At the same time, the briquette processing technologies and equipment have become basically mature and there have somewhat breakthroughs in the market space. According to statistics of the NEA, the production capacity of BMF reached 8 million tons and the estimated market size was 8 billion Yuan in 2015. On the other hand, biomass only accounted for 1%-2% of the heating industry at present. Driven by policies for coal replacement, the proportion of Biomass-to-Heat is expected to increase. Comparing with Sweden where bioenergy industry is mature, the proportion of bioenergy in the energy utilization structure in 2015 exceeded 34%, and 60% of the bioenergy were used for heat production. During the same year, China's annual utilization of bioenergy was equivalent to 35.4 million tons of standard coals, but BMF produced was only 4 million tons, representing less than 0.1% of the total energy consumption, and thus there is an enormous potential for BMF development.

3.2 Potential for large-scale and commercialized development of biomass gasification

Opportunities and challenges co-exist in China's energy utilization that is shifting from the existing traditional mode based on fossil energy to the development of new energy. Presenting one type of new energy for energy industry development directions, biomass gasification has a huge market potential in heating. After more than a decade of healthy development, the Biomass-to-Heat industry is ushering a new era due to the flexibility of raw materials and the carbon neutrality and sustainability of the products.

At present, the treatment of forestry residuals has become a strict demand for environmental protection, and industrial solid wastes treatment has become an indicator for enterprise operation assessment. As the use of coal has caused an increasing pressure on environment protection, biomass gasification is well positioned to offer an effective solution for heat production, which becomes a key development direction for the substitution of coal for urban heating, central heating and heating supply for industrial parks, and provides clean energy for new cities, towns and villages.

With the gradual establishment of the market order of biomass resources, regional centralized collection and storage system and the price system have been improved a lot. In the meantime, as advanced research on biomass gasification technologies continues, biomass gasification efficiency will be substantially improved, thereafter issues related to environmental protection and energy conservation will be properly resolved. Driven by multiple favourable factors, such as the formation of the market mechanism, industrial and technological innovation, and the gradually clear direction of domestic policies, there should be a speeding substitution of coal-fired and oil-fired heat production by the Biomass-to-Heat system driven by biomass gasification technologies. Therefore, it is possible to see a large-scale and commercialized application of biomass gasification for heat production. It is anticipated that, between 2020 and 2050, the projects for biomass gasification heat supply will be all-round promoted for commercialization driven by maturity of biomass technologies and improved bioenergy system.

3.3 Potential for commercial-scale development of biogas/biomethane

According to its production characteristics, the biomethane will be primarily used as domestic fuel and vehicle fuel as well as for power generation. In addition, biomethane may also be used as fuel for heating. Therefore, the use of biomethane as urban natural gas, power generation, industrial, and transportation fuels is similar to the use of natural gas in the same market. Considering natural gas is widely used in these areas, the development of future market for biomethane should focus more on the new demand of the natural gas market. The estimate of the above types of new market demand indicates that the future market demand for biomethane use will be about 98 billion cubic meters, mainly including:

Urban gas: demand for additional 17.1 billion cubic meters is expected. This mainly contributes to the construction of "new-type urbanization". Due to its production characteristics that fit for urban gas, this will become the key area for biomethane development.

Natural gas for power generation: in such markets, biomethane can be primarily used as CHP or distributed energy, and the new demand of these two types of market is 35.5 billion cubic meters. For large-scale natural gas fuelled power generation, it is difficult for a complete replacement by biomethane due to limited production scale of biomethane. Therefore, although the demand of such markets is huge, there are some difficulties technically to meet the demand.

Industrial fuel: fuel for replacement of coal-fired boilers and heating boilers is the main feature in such a market, and the new demand for such fuel is 29.4 billion cubic meters. Driven by the implementation of the Action Plan for Air Pollution Prevention and Control and the clean heating policies in Northern areas, the substitution of biomethane in such market will be more important, but the energy used for industries and residential heating requires a secure and stable supply. The use of biomethane in this area still needs the combination with traditional fossil energies and the full integration with local energy supply system for the realization of secure and stable supply.

4 Conclusions and policy recommendations

4.1 Heat production by BMF

First, BMF should be included in the national environmental protection strategy. It is necessary to classify biomass moulding fuel as a clean energy and clearly promote "Biomass Replacing Coal" projects. It is necessary to strengthen the coordination between environmental protection and energy departments, abandon the traditional perception on BMF, and clearly define it as a clean and renewable energy resource for BMF boiler heating. It is also an important solution to prevent air pollution and control the open burning of straws.

Second, establish emission standards reflecting BMF's clean and renewable feature. BMF boiler, equipped with combustion technology and air distribution adjustment, could meet the natural gas emission standards. Therefore, it is necessary for government to develop emission standards for BMF boiler, reflecting BMF's clean and renewable feature, to ensure the healthy development of the BMF industry.

Third, develop BMF industry standards. Industry standards include collection, storage, transport and other mechanical equipment standards, production and processing technology standards, BMF product standards, BMF boiler design, manufacturing and installation standards, biomass boiler heating operation and management quality system certification standards, biomass boiler heating emission standards, etc.

Fourth, policies to promote fair competition between BMF and natural gas shall be provided. Looking to introduced policies for replacing and transforming coal-fired boilers, we have given plenty to coal-to-gas projects while rendering little in heat production by BMF, making the latter unable to enjoy equal market access and policies compared with natural gas heating. It is recommended therefore that laws and regulations be improved to offer policies suitable for heat production by BMF.

4.2 Biomass gasification-to-heat

First, strengthening supportive policies, preparing development plans of biomass gasification-to-heat industry to serve as guidance for project approval, construction, and supervision. Relevant sectors under the guidance of and through coordination among government departments shall develop a guiding plan for biomass gasification heat production industry with rigid requirements to ensure a sound and well-regulated industry.

Second, standards and norms of biomass gasification-to-heat shall be developed. The industry, lacking well-established standardized systems, is hard to monitor and regulate and thus in need of improved standards and norms to facilitate supervision in this field. We shall develop pollutant discharge standards for the biomass gasification industry setting emission limits and making emission density and total amount under control.

Third, building a preferential utilization mechanism for biomass gasification-to-heat and widen subsidy range of biomass utilization. We shall make policies to support preferential utilization for biomass gasification-to-heat and subsidies for producers, the industry can obtain the benefits other distributed energy sectors have been enjoying for a long time. We shall also expand the coverage of fiscal and taxation favourable policies such as income tax relief and VAT immediate levy and refund, to include gasification heat production projects with agricultural waste and leftover, remaining water, and residual slag as the raw materials.

Fourth, establishing a government-led, multi-input commercialized development mechanism. That means to create a multi-input financing mechanism that enterprises driving, social participating, attracting private investment under guidance of central government, providing wider access to financing for the whole industry and promoting the commercialization development of biomass gasification-to-heat.

4.3 Heat production by Biogas/Biomethane

First, establish a Multi-sectorial collaborative leadship system to jointly promote industrial development. A collaborative management system for biogas industry needs to be established. With participation of multiple sectors including departments of finance, reform and development, agriculture, environment protection, energy, housing and urban-rural development, tax, and quality control, the objectives, plans, policies and standards for the development of the industry should be jointly defined and developed, so that policies formed with joint efforts help promote the development of the industry.

Second, construction and planning of biomass energy development and utilization projects shall be strictly controlled by local governments to avoid vicious competition of biomass resources. An investigation of agricultural, industrial, and municipal organic waste resources shall be carried out before planning for comprehensive use of biomass energy on national and provincial level according to the status quo of biomass utilization and projects implementation. Biomethane projects in the plan shall be properly arranged and those beyond must not be permitted to prevent unhealthy competition for biomass resources.

Third, introduce social capital to the collection, storage and transportation of agricultural organic wastes, establishing a new business model. With regard to government's innovative investment mode, it is proposed that, on the one hand, the government is to use

multiple modalities integrated with such funds as straw burning prohibition funds and animal farm wastes discharge fees/environment tax as well as investment subsidy, equity investment, purchasing service and PPP to introduce social capital for the collection, storage and transportation of agricultural organic wastes. On the other hand, the government should improve preferential tax policyand list the collection and treatment services of agricultural organic wastes within the refund of value-added tax and tax relief of the income tax as soon as possible. China should also actively support biogas enterprises featuring high technical level, strong capital strength, honesty and integrity to be involved in the treatment of crop straws and animal wastes, and provide them with preferential value-added tax and income tax.

Fourth, implement the policy of blanket guarantee for purchasing biomethane products. China needs to develop the policy of blanket guarantee to purchase biomethane products according to relevant regulations of "Renewable Energy Law". China should include biomethane development in the national energy and ecological strategies, break down industrial barriers and discrimination, promote the integration of biomethane and biogas power generation into gas pipe and grid, and provide access to relevant national subsidies. China needs to promote the full purchase or guaranteed purchase of biomethane by pipe network enterprises, improve the supporting policies for central gas supply pipe network construction, and guarantee a fair market treatment for biomethane and biogas power generation and centralized heating supply. China needs to clearly require that enterprises engaged in gas grid operation and sales must purchase full local biogas products at reasonable price.

Fifth, establishing statistical, monitoring and evaluating system of biomass industry, strengthening the industry management. Establishing biomethane information platform to track progress of planned projects. Providing theoretical basis for industrial development according to advantages of big data technology in scientific site selection and risk prediction. Striving to change the current situation of "taking construction as more important than operation", establishing a post-evaluation system, and statistics, monitoring, evaluation system for the biomethane industry; setting up a project rating evaluation mechanism, to rate completed projects by environmental impacts, technological advancement, and sustainable operation & innovation capability. The ratings will affect subsidies and tax incentives rendered to projects as a way to ensure the project quality and performance up to the standards after their completion. The blacklist or credit system is adopted to circulate a notice of criticism against and punish companies that have been repeatedly given bad records.

Sixth, strengthening the system of performance evaluation and assessment. China needs to take the utilization of agricultural organic wastes and development of biomethane as key indicators and include them in local government's performance evaluation system. Moreover, all relevant management departments need to jointly carry out regular performance evaluation on biogas supporting policies released and implemented, and timely adjusts areas of support and priorities in the policies according to the implementation effect of these policies.

References

1. Guidance on Clean Heating in Winter in Northern China (2017-2021), National Energy Administration, 2017, http://www.nea.gov.cn/2017-12/27/c_136854721.htm
2. Guideline for Promoting the Development of Biomass-to-Heat, National Energy Administration, 2017,http://zfxxgk.nea.gov.cn/auto87/201712/t20171228_3085.htm

3. Xiaohong Chen, Zhiyong Wang, Tianyu Mao, Present Situation and Development Prospect of Biomass Briquetting Fuel Industry, *China Resource Comprehensive Utilization*, 2018, 36(6): 83-85
4. Lei Wu, Research on appliance of biomass-to-heat, *Construction and Budget*, 2016, 3: 45-47
5. Jianchun Jiang, Prospect on research and development of biomass energy utilization, *Chemistry and Industry of Forest Products*, 2002, 22(2): 75-80
6. HainingNie, Xiaolin Huang, Zhiyong Zeng, Present Situation and Development Prospect of Clean Energy Heating in China, *Energy and Energy Conservation*, 2018, 12: 87-89
7. Yanyang Liu, Research on biomass Pyrolysis for producing bio-oil, *Jilin Agricultural University*, 2005
8. Chao Wang, Guanyi Chen, Process Simulation on Fluidized Bed Pyrolysis of Biomass, Advanced Materials Research, 2012, 356-360: 2265-2269