Analysis on development path of distributed utilization of biomass energy in China

Shuguang Liu1,4, Yage Gao2, Bowen Xu1, Min Deng1 and Jia Jiang3

1 School of Mechanical and Electrical Eng., Huangshan University, China;
2 Department of Energy and Power Eng., Tsinghua University, China;
3 Research and Development Center, Anhui Dorje Electric Co., Ltd., China
4 Email: Liushuguang@hsu.edu.cn

Abstract. Biomass energy is an important renewable energy, which comes directly or indirectly from photosynthesis of plants and is generally derived from agricultural and forestry wastes. The main characteristics of biomass wastes in China are large amount, wide distribution, low utilization rate, great development potential and high urgency of environmental management. With the exhaustion of non-renewable energy and the increasingly serious environmental pollution, the utilization technology of biomass energy needs to be developed as soon as possible. In this paper, the significance of distributed utilization of biomass energy was discussed, and the technologies of distributed utilization of biomass energy were introduced, including direct combustion technology, biochemical conversion technology (fermentation and anaerobic digestion), thermochemical conversion technology (gasification and pyrolysis), liquefaction technology, dense moulding technology and supercritical fluid conversion technology. The application of biomass conversion technology, including biomass gasification for power generation, gasification for hydrogen production, pyrolysis for hydrogen production, fermentation for fuel ethanol, pyrolysis for bio-oil, solidification for solid fuel, composting for fertilizer production, anaerobic digestion for biogas production and catalytic pyrolysis for biofuel production, was discussed. Furthermore, the development path of biomass energy industry was discussed, and the future development of biomass energy distributed utilization technology was prospected.

1. Introduction

With the continuous development of the world economy, non-renewable energy dominated by traditional fossil energy is in shortage day by day, and the problem of environmental pollution is becoming more and more serious. In recent years, the price of oil continues to rise in the international market, and the energy competition is increasingly fierce. The energy problem has become one of the problems affecting the national strategy [1]. With the steady growth of China's economy and rapid industrial development, the demand for energy has increased greatly. Due to the attention paid to the depletion of traditional fossil energy resources and environmental problems, the 13th five-year plan of China has clearly indicated that it will further increase its support for clean energy to accelerate its replacement of fossil energy. The 13th five-year plan for the development of biomass energy released by the national energy administration clearly proposes that biomass energy will basically be commercialized and used on a large scale by 2020, the annual biomass energy consumption reaches 58 million tons of standard coal, the annual sales revenue is about RMB 120 billion, and the new industrial investment is about RMB 196 billion[2]. In addition, compared with coal, the content of
sulfur and nitrogen in biomass is lower, and combustion produces less nitrogen oxides and sulfur oxides, which can effectively alleviate air pollution [3].

In recent years, the technology of global biomass energy development and utilization has made rapid progress, and the application cost has dropped rapidly. The "biomass economy" supported by the biomass industry is regarded as the next economic form of the coming "baton" petrochemical-based "hydrocarbon economy" by the international academia. Therefore, systematically combing the development status and trends of biomass energy technology, clarifying the challenges faced by China's development of biomass energy and formulating future strategies are of great importance to promoting the construction of ecological civilization, energy revolution and low-carbon economic development, ensuring the construction of beautiful countryside, and tackling global climate change.

2. Overview of distributed utilization technology of biomass energy

Biomass, the biggest advantage is that it is the only renewable carbon resource that can be by thermo-chemical conversion, biochemical process and preparing liquid and gas fuels such as photochemical catalysis [3], involving pyrolysis, gasification, liquefaction, molding and direct combustion technology, can get easy in stocking transportation, convenient to use cleaner fuel.

2.1. Biomass direct combustion technology

2.1.1. Layer combustion technology. Traditional layer combustion technology is spread on the grate cambium-like biomass fuels, blended with an air distribution, gradually to drying, pyrolysis, combustion and reduction process, combustible gas and secondary air distribution in the space of the above mix combustion. In Denmark, a special burning furnace has been developed for burning baled straw. A large bundle of straw is continuously transported to the water-cooled mobile furnace stack through the conveying channel by hydraulic piston. Because of straw ash melting point is lower, water-cooled furnace wall or flue gas circulation ways to control the temperature of the combustion chamber, make it less than 900°C. Denmark ELSAM company developed transform Benson type boiler heating by two stages, by four parallel feeder supply material, straw, wood chips can be fully burning in the grate, and also set in the furnace and the pipe with fibre-filter to reduce harmful substances in the smoke to the wear and corrosion of the equipment. The practical operation proves that the transformed biomass boiler operates stably and has achieved good social and economic benefits [4]. In China, many research units have developed various types of biomass layer burners according to the characteristics of the biomass fuel used, and the actual operation effect is good. Them based on the combustion characteristics of raw materials used, the structure of layer combustion furnace is to optimize the productive and furnace structure including double chamber structure [5], closed chamber of a stove or furnace structure [6, 7] and other structures, these are our layer biomass combustion furnace design provides a valuable experience.

2.1.2. Fluidized bed technology. Fluidized combustion has a series of advantages such as good heat and mass transfer performance, high combustion efficiency, low emission of harmful gases and large heat capacity, etc. It is very suitable for burning biomass fuel with large water content and low heat value. At present, the development and utilization of biomass energy by fluidized bed combustion technology in foreign countries has a considerable scale. Idaho energy products co., ltd. has developed and produced a fluidized bed boiler with biomass burning. The steam boiler's output is 4.5 ~ 50t/h, and the heating boiler's output is 36.67MW. The power output of the large circulating fluidized bed coal-fired power boiler developed by us CE company using Lurgi technology is 100t/h, and the steam pressure is 8.7mpa. The wood-burning fluidized bed boiler manufactured by B&W company of the United States was also put into operation in the late 1980s and early 1990s. In addition, Sweden USES forest waste such as branches and leaves as fuel for large fluidized bed boilers, which have a thermal efficiency of up to 80%. Denmark adopts high-efficiency circulating fluidized bed boiler, which sends hay and coal into the furnace for combustion at a ratio of 6:4. The boiler's output force is 100t/h and its
thermal power reaches 80MW[8]. In China, since the late 1980s, biomass fluidized bed combustion technology has also carried on the thorough research, domestic research units and boiler factory cooperation, joint development of various types of burning biomass fluidized bed boiler [9, 10], put into production after the running effect is good, and the promotion, there are many exported to foreign countries, the use of biomass energy in China played a great role in promoting. Such as Huazhong university of science and technology according to the physical and chemical properties and combustion characteristics of rice husk, designed with fluidized bed combustion mode is given priority to, supplemented by the combination of the suspension and the fixed bed combustion [11] combustion type fluidized bed boiler, the boiler has a fluidized coking performance good, stable combustion, not easily, etc.

2.1.3. Densification technology. The agriculture and forestry waste with a range of particle size of, such as sawdust, rice husk, twigs, straw, etc., after drying under certain pressure effect, can be squeezed into a bar, granular continuously, block and other solid fuel molding processing technology called biomass density molding technology [12]. Using lignin special glue adhesion, or add some additives or other adhesives to bond together become the molding fuel [13], biomass after extrusion effect, shrinkage, significantly larger density, moisture content, convenient storage and transportation [14]. This technology has been widely used in high efficiency combustion furnace, biomass gasifier and small boiler [15]. According to the difference of process characteristics, biomass densification process can be divided into three types: cold compression densification, hot compression densification and carbonization densification, each of which has its own characteristics and application scope.

2.2. Biochemical transformation technology
Biomass biochemical conversion generally has four types: landfill gas and compost technology; Parliamentary chamber biogas digester technology for small household; Largest and medium anaerobic digestion technology; The technology to make ethanol is superior. Among them, anaerobic digestion technology is divided into two types: anaerobic digestion technology of livestock excrement and anaerobic digestion technology of industrial organic wastewater. The technology of producing ethanol is to make ethanol or methanol liquid fuel by enzyme technology.

2.3. Physicochemical transformation technology
The physicochemical conversion of biomass energy generally consists of three aspects: first, dry distillation and liquefaction technology; Second, pyrolysis and vaporization technology; Third, the pyrolysis of biomass oil technology.

The main purpose of biomass dry distillation technology is to produce biomass carbon and gas at the same time. It is to convert small substances with low energy density into fixed carbon or gas with high heat value, which can be used for different purposes. Biomass liquefaction technology, type the biomass raw materials through the use of chemically converted into liquid fuel technology, its essence is to solid organic macromolecule polymer into liquid of small molecule organic material, general process is as follows: decomposition of biomass materials for macromolecular compounds; Parliamentary resolves large molecular chain organic matter until it can be dissolved by reaction media. Residues is hydrolyzed or dissolved in solvents under high temperature and pressure to obtain small liquid organic molecules.

Biomass pyrolysis is to convert biomass into fuel vaporization technology, namely by biomass raw materials in the macromolecular structure under high temperature decomposition, fracture or reforming produce light combustible gas fuel, such as CO, H₂, CH₄ and so on.

Biomass pyrolysis system oil by thermal chemical methods to convert biomass into liquid fuel technology, and liquefaction technology, liquid fuel produced by pyrolysis oil technology generally consists of bio-oil, non condensable gas and coal, such as ether, ester, ketone, phenol, alcohol, organic acids, etc.
2.4. Solid waste treatment technology
For the treatment of solid waste, there are three traditional methods: landfill, incineration and biochemical treatment. Landfill and incineration waste resources and energy. At present, the recycling of waste biomass energy at home and abroad made a more in-depth research, mainly adopts way feed, fertilizer, gas, fuel and other raw material for the use of scientific and effective. If it is processed into feed, make full use of its nutrients; Composting technology was used to treat courtyard waste, organic biological waste, organic residual sludge and agricultural waste. Biogas technology is used to treat all kinds of organic waste in agriculture, industry and human life. In order to avoid secondary pollution, biogas slags and biogas slurry should be reused. Biogas slags and biogas slurry can be directly used as fertilizers or separated into commercial fertilizers by solid solution. The former loose, fine and amorphous biomass raw materials can be compressed into rod, granule, block and other forming fuels under certain conditions by using the compression and molding technology of biomass [16].

2.5. Supercritical transformation technology of biomass
Supercritical fluid (SCF) is a kind of above at the critical temperature and critical pressure, physical property between gas and liquid have good liquidity, transitivity, diffusivity and solubility of the fluid. It doubles as a dual nature and the advantages of the gas and liquid, near the critical point, small changes in the pressure and temperature, can cause fluid density, solubility and dielectric constant of the larger changes in the physical. Supercritical water can dissolve most organic compounds and gas, high density, low viscosity characteristics of biomass in supercritical water gasification and pyrolysis heat utilization efficiency is higher than normal, the biomass of supercritical water gasification technology has been widely attention, has great development potential [17]. As required for supercritical water gasification reaction temperature and reaction pressure is higher, to the requirement of equipment and material for biomass in supercritical water gasification in the related research has been curbed, research on this aspect in China starts late [18]. Along with the people of the unique physical and chemical properties of supercritical water constantly to understand and study, found in biomass pretreatment, pyrolysis, liquefaction, and the preparation of biodiesel can be the application of supercritical fluid technology for biomass resources and efficient use of [19]. Such as biomass supercritical pyrolysis hydrogen production, biodiesel supercritical preparation, biomass supercritical liquefaction and biomass supercritical pretreatment. The technology of supercritical conversion of biomass has great application potential, especially in the field of supercritical water gasification hydrogen production and supercritical methanol esterification biodiesel production. But due to the reaction conditions of supercritical fluid are demanding, on energy consumption and equipment requirement is high, the loss is big, causes the production cost is higher, at present about supercritical fluid in biomass energy conversion applications mostly in research stage, technology and system research to improve [20] there are huge development space.

3. Industrial development path
3.1. Building distributed energy system
In China, biomass energy raw materials are distributed in vast agricultural land and forest land, but biomass energy density is small and the volume of raw materials is large. Due to the limitation of transportation, it is more appropriate to control the optimum radius of raw materials transportation in biomass energy production plants at 100 km, which determines that biomass energy is a typical distributed energy. In order to build a distributed energy system, the scale of biomass energy production enterprises should not be too large, and the scale of production plants should be set up according to the amount of raw materials. The scale of biological power plants is generally 30 mw, and 100,000 tons of biomass fuel processing plants are suitable, so the production plants should be well constructed. According to the scientific planning of resources, it is very important to prevent blind construction leading to inadequate raw materials leading to vicious competition in the market, resulting in loss of investment, frustration of enterprises and waste of social resources. As long as the
experience and lessons of the development of China's biomass energy industry in recent years are carefully summarized and analyzed, China's biomass energy industry will surely be in the future. Achieving sustainable development under the concept of scientific development and innovative development [21].

3.2. Promoting the reform of institutional mechanisms

The current energy market in China mainly relies on the absolute monopoly operation of the central enterprises, which will inevitably lead to inefficiency, reduced efficiency and higher cost of social payment monopoly. Under such a monopoly system, innovation risks are great, and monopoly enterprises lack innovation power. Private enterprises have inherent innovative elements, but in the face of monopoly market, the innovation of private enterprises can not get fair and fair treatment of the market, it is difficult to adhere to innovation, and can not form a social environment to encourage innovation at all. Reform has become the consensus of the whole society. The new leaders of the Party and the state have indicated that they should strengthen the reform of monopoly industries, break monopoly and encourage competition have become the inevitable trend of the reform of energy system and mechanism in China. Now we choose to reform the system and mechanism from the rural energy market. The conditions and time are the most mature. First, the rural energy market accounts for a small proportion of China's energy consumption market, with electricity accounting for 20% of the country's electricity consumption (excluding county-level industrial parks); petroleum diesel products accounting for about 30% of the country's consumption; and coal consumption is about 550 million tons per year. Rural areas are vast and sparsely populated, and the concentration of energy commodity supply is far lower than that of urban areas. This shows that the operational assets invested by the central enterprises of monopoly industries in rural areas are not the assets with strong profitability, even the assets with the worst profitability of the central enterprises of energy. Taking the rural energy market as a breakthrough point to carry out the reform will not harm the core interests of monopolizing the central enterprises. The pilot reform of the rural energy market can realize the dividend of reform put forward by Premier Li Keqiang, which is worth a try [22]. It is of realistic and long-term significance to carry out reforms in areas where the current market volume is limited, the interests are meagre and the future is bullish. It is very operable to introduce innovation and competition mechanism to the vast rural energy market in China.

3.3. Improving the construction of rural energy market

(1) Establishing the production, supply and marketing system of rural biomass diesel market. In the process of building rural energy market in China, priority must be given to the most urgent and shortage of diesel oil in rural energy market and the whole industrial chain system of its production and circulation. The energy commodities used by agricultural, fishery and forestry machinery and agricultural logistics transportation tools in China are all diesel products. Once the oil safety problems occur, it will directly affect agricultural production. In recent years, there are often situations of diesel oil shortage, limited diesel oil and even queues of several kilometers long without diesel oil. At present, China's annual consumption of fossil diesel oil is about 160 million tons, and about 50 million tons in the rural market. China can fully support the industrialization of non-grain bio-fuel technology, build the production, supply and marketing system of rural bio-diesel market, and contribute to the construction of an independent, safe and stable rural energy system. Now it can be produced with biomass raw materials equivalent to about 100 million tons of standard coal. Fifty million tons of non-grain biomass diesel oil have completely replaced rural diesel products. If the remaining raw materials are used to produce biogas products, it will be possible for farmers to use clean gas as living energy, and then use the remaining raw materials for power generation to meet rural power demand [23]. Now, power generation projects should be considered at last, because the counties of rural power supply projects in China have built a sound security system, many sources of electricity are relatively easy to supply, and China's oil and natural gas resources are scarce, market demand is very large, fuel and gas products are energy commodities in short supply, which are greatly affected by the International
market. Therefore, we should seize the opportunity to develop China's rural non-grain biomass fuel industry, which involves the national energy security strategy, but also the sustainable development of China's economy, ecology and society.

(2) Building green energy demonstration counties. During the Twelfth Five-Year Plan period, the State plans to build 200 green energy demonstration counties throughout the country. The second batch of 100 green energy demonstration counties should be re-planned based on the experience and lessons of 100 demonstration counties before summing up. For the second batch of 100 green energy demonstration counties, the state should formulate higher construction standards and raise the technical and commercial threshold. In order to make breakthroughs in solving the shortage of energy commodities and related institutional mechanisms in the demonstration counties supported by national planning, we should build a new rural energy system based on the world's most advanced technological level and standards, combined with institutional mechanism breakthroughs. We should support the use of agricultural and forestry wastes to produce rural energy-deficient commodities such as biodiesel and methane gas, give priority to the production of biofuel and gas from agricultural and forestry wastes, and promote the market-oriented reform of rural fuel and gas in China. In particular, we should accelerate the construction of a fair and fair market operation mechanism from the institutional mechanism. Therefore, the second batch of 100 green energy demonstration counties should improve their standards on the basis of new technologies and truly promote the construction of rural distributed energy model in China. If the construction of 100 green energy demonstration counties is successful, it is possible to carry out a thousand counties project in the 13th Five-Year Plan, comprehensively promote the formation of the basic pattern of rural energy market with biomass energy as the main body, realize that rural energy mainly comes from various energy commodities produced and processed by agricultural and forestry wastes, and build an independent, safe and stable rural energy system [24].

(3) Improving relevant industrial policies and renewable new energy sources. The state must support and support relevant industrial policies. Through the formulation of policies and regulations, it is strictly prohibited to incinerate agricultural and forestry wastes at will, grant non-grain biomass fuel and gas enterprises the franchise to collect agricultural and forestry wastes, and conduct franchise management like the state's oil, natural gas and coal resources, prevent the chaos of the purchase market of agricultural and forestry wastes raw materials, and ensure the stable supply of raw materials for enterprises producing non-grain fuel and gas. A large part of the cost of raw materials in the production and operation of non-grain biomass fuel and gas production enterprises is the cost of raw materials. This part of the cost transfers benefits to farmers. It not only solves the environmental pollution and ecological damage caused by farmers' incineration of agricultural and forestry wastes at will, but also promotes the employment of surplus rural labor force and helps farmers to become rich. These two contributions are impossible for fossil oil enterprises to do [25]. To formulate fair industrial policies to support the development of biomass fuel and gas enterprises is the prerequisite for speeding up the development of China's biomass energy industry. The existing subsidy policies for moulding raw materials and energy-saving subsidy policies for agricultural and forestry wastes to replace coal combustion are difficult to grasp in the actual operation process, easy to drill holes, and easy to cause corruption. Therefore, for the production and circulation of non-grain biomass fuel oil and gas, financial funds should be directly subsidized to terminal commodities. This can eliminate corruption, and the standards are easy to master and operate.

4. Conclusions
As the core of renewable energy, the development and utilization of biomass energy can not only improve the ecological environment, strongly support the construction of beautiful and livable villages, but also solve the energy shortage in rural areas, promote the rural energy revolution, promote the development of green agriculture and create new economic growth points, which is an important way to achieve the sustainable development of energy, environment and economy. In the new era, the utilization of biomass resources should take a comprehensive and high-value path. Closely around the
major needs of urban-rural integration development, Rural Revitalization and environmental pollution control, through scientific and technological breakthroughs, especially basic scientific discoveries, we can find a new path for the high-value use of biomass and find a new plan for the development of biomass industry. Focus on high-value transformation approaches such as bio based materials, chemicals and high-quality fuels, increase industrial added value by relying on scientific and technological innovation, and realize the transformation and upgrading of biomass industry. At present, biomass energy industry is in the key stage of technological breakthrough and commercial application development. The development of biomass energy needs to be combined with the actual situation of our country, face various challenges, do a good job in top-level design, grasp the basic and forward-looking technology development direction, innovate the development mode, and provide scientific and technological support for the rapid development of China's biomass energy industry.

Acknowledgment
This work is supported by the emergent engineering research and practice project in Anhui (2017xgkxm47), the major project of teaching and research in Anhui (2017jyxm0454), the project of practical education base of school-enterprise cooperation in Anhui (2018sjjd079) and Huangshan university talents start-up project (2019xkjq008).

References
[1] Mohr S H, Wang J, Ellem G, et al. 2015 Projection of world fossil fuels by country Fuel 141 120-135.
[2] The national energy administration. The 13th five-year plan for biomass energy development. http://zfzxgk.nea.gov.cn/uto87/201612/t20161205_2328.htm?keywords=2017-2-27.
[3] Dumitrache A, Akinosho H, Jr R M, et al. 2016 Consolidated bioprocessing of Populus using Clostridium (Ruminiclostridium) thermocellum: a case study on the impact of lignin composition and structure Biotechnology for Biofuels 9(1)
[4] LU Li 2015 Study on comprehensive evaluation of biomass pyrolysis and refined liquid fuel. Zhejiang university
[5] HE Hongyu, MA Xiaoqin, CHEN Xuejun 2001 Installation and use of biomass boilers in thermal power plants Rural energy 1 21-22
[6] TIAN Yishui, ZHANG Jianming, CHEN Xiaofu 2002 Research and design of straw direct-fired hot water boiler heating system Journal of agricultural engineering college 18(2) 87-90
[7] ZHAI Xuemin 2000 A new design concept of bagasse boiler Industrial boiler 2 9-12
[8] HE Yuheng 2001 Development and design of burning oil, wood chips, wood powder green star boiler Industrial boiler 3 21-23
[9] LI Bingxi, LU Huilin 2000 Combustion of bio-fertilizer fluidized bed boiler Thermal power engineering 5(8) 344-348
[10] CHEN Guanyi, FANG Mengxiang, LUO Zhongyang 1999 Experimental research and design of biomass fluidized bed Thermal power generation 5 19-23
[11] LIU Hao, HUANG Lin, LIN Zhijie 1996 Design and operation of rice hull fluidized bed boiler Industrial boiler 1 5-6
[12] ZHAO Tinglin, SHU Wei, DA Jun 2007 Research status and development of biomass dense forming technology New energy industry 4 29-33
[13] CHEN Jun, TAO Zhanliang 2004 Energy chemistry Chemical industry press, Beijing
[14] ZHANG Bailiang 1999 Rural energy engineering China agricultural press, Beijing,
[15] Jiang jianchun 1987 Foreign wood compression molding fuel. Forest chemistry and industry 6 35-36
[16] HAO Xiaohong, GUO Lijin 2002 Research review on hydrogen production by catalytic gasification of hygroscopic materials in supercritical water Journal of chemical industry 53(3) 221-228
[17] ZHU Daofei 2008 Experimental study on the liquefaction and transformation of biomass in supercritical water. Kunming university of technology
[18] HUANG H J, YUAN X Z. 2015 Recent progress in the direct liquefaction of typical biomass. Progress in Energy and Combustion Science 49 59-80

[19] XIANG Yangyang, ZHUO Jinsong, WU Helai 2012 Application of supercritical fluid in biomass conversion technology. Chemical progress 3(s1) 30-35

[20] DAS O, SARMAH A K. 2015 Mechanism of waste biomass pyrolysis: effect of physical pretreatments. Science of the Total Environment 537 323-334

[21] F Chen Juan, Wang Yapeng 2013 Analysis of Distribution and Scale Control of Biomass Energy Industry in Hubei Province Agricultural Technology Economy 8 47-51

[22] Qi Tian and Shao Penglu 2013-01-12 To solve rural poverty, priority should be given to promoting biomass energy China Economic Report

[23] Wu Haitao, Zhou Jing, Chen Yuping 2013 Sustainability analysis of resource utilization in straw energy utilization. China's Population, Resources and Environment 2

[24] He Renfei 2013 Regional Distribution, Development and Utilization Evaluation of Biomass Energy in China. Lanzhou University

[25] Tao Yuan 2013-08-01 The future of biomass solid fuel is promising China Electric Power Daily