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Development Status and the Biomass Energy Policies in China

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In the past decades, China has adopted a wide variety of policies to stimulate bioenergy development, playing a more significant role in China’s energy structure. However, bioenergy development in China is still at an early stage and lags far behind other foreign countries. This study is aimed to explore the reasons behind this sluggish development from a policy perspective. Bioenergy development potential and provincial geographic distribution were investigated in China, which shows that the total technical bioenergy potential was about 0.85 GtCE in China in 2015. After analyzing the calculated allocation flow of bioenergy, it can be drawn that biomass power generation accounts for the highest proportion of bioenergy applications. A three-dimensional policy analysis framework is put forward to analyze the selected representative 72 pieces of biomass policies. It is concluded that there are some unbalanced policy problems, such as lacking demand policies in the biomass power generation industry and few applications of voluntary policies.

1. Introduction

Energy is of vital importance for the sustainable development of the social economy (Hrayshat, 2007). According to the International Energy Agency (IEA), it is predicted that the global energy demand for economic growth will increase 70 % in 2050 in the 6 °C Scenario, accompanying global warming with a 60 % augment in greenhouse gas emissions against 2011 levels (IEA, 2014). In order to cope with these deteriorative climate changes, many countries around the world have continuously ratified the Paris Agreement to maintain the global temperature rise under 2 °C during the 21st century. Under such circumstances, bioenergy characterized by large quantity, non-pollution, and regeneration ability plays an irreplaceable role in promoting carbon dioxide mitigation. It will be more likely to become an optimal choice to ensure the world's sustainable development in the long run.

The renewable energy development, especially bioenergy, has to be prioritized to guarantee the harmonious coexistence of sustainable economic growth and environmental conservation in China (Elmore et al., 2008). The 13th Five-Year Plan (2016–2021) for Bioenergy Development in China (National Energy Administration, 2016) pointed out that regional development of bioenergy is constrained by some factors like difficulties in large scale collection of raw materials, low degree of nearby transformation, and insufficient utilization of distributed commercialization. However, apart from these causes mentioned above, imbalanced policy structure has also played an indispensable role in the sluggish development of bioenergy in China (Horst &Vermeylen, 2011).

Although a few studies have been conducted on the biomass policy in China (Zhao et al., 2012), they focus more on Chinese renewable energy policies rather than focusing specifically on biomass policy (Li et al., 2020). One of the disadvantages of previous studies is that they cannot well explore the existing problems of biomass policies to promote the biomass industry development in China. In order to have a more detailed study of the biomass industry in China, it is necessary to do a panoramic scan of the potential of Chinese biomass resources, which is the research basis of this paper. Further analysis revealed that the current primary use of biomass resources in China is power generation. On the basis of a more comprehensive collection of biomass policies in China, this work proposes a three-dimensional policy analysis framework, which can be applied to classify and analyze all selected biomass policies from three perspectives based on different policy impacts, main industrial activities, and different coercive degrees, to explore the problems of biomass policies and puts forward targeted suggestions. The novel contribution of this research attributes to the examined comprehensive picture of biomass resources and the clarified deficiencies of biomass policies in China.

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2. Technical bioenergy potential in China

In this work, biomass feedstock in China is divided into two main categories: biomass resources (including crop straw, forestry residues, agricultural production processing residues, livestock manure, municipal solid waste (MSW), waste cooking oils, and industrial wastewater & domestic sewage) and energy crops grown on different marginal lands (including shrubs land, sparse forest land, sparse grassland, river and canals, shoal land, bottomland, sand land, Gobi land, alkaline land, marshland, and bare land).

The calculation process of technical bioenergy potentials is described as the following. For the biomass resources, based on data in China Energy Statistical Yearbook and residues or wastes output ratios, the generation amount of agricultural and forestry biomass resources in seven categories have been calculated in this work. For the energy crops grown on marginal lands, based on Digital Elevation Model (DEM) and Net Primary Production (NPP) data, thresholds are set to screen the areas of various land resources suitable for energy crops. Given the screened marginal land types and areas, combined with the vegetation carbon ratio, root-shoot ratio, and conversion coefficient, etc., the work calculates the biomass amount of marginal lands. Finally, according to respective calorific values, all of the above biomass resources are converted into standard coal (Unit: tons of standard coal equivalent (tCE)) to represent technical bioenergy potentials, as illustrated in Table 1 & Figure 1 (the low calorific value of standard coal is 29.307 kJ/kg).

The total technical bioenergy potential of biomass resources and energy crops was about 0.85 GtCE in 2015, as shown in Table 1. Among them, biomass resources have a substantial technical potential of 0.52 GtCE, accounting for 60.86 % of the total technical bioenergy potential. Energy crops grown on 11 types of marginal land can generate 0.33 GtCE, accounting for 39.14 % of the total. To be specific, the technical bioenergy potential of crop straw, forestry residues, energy crops grown on shrubs land, and sparse forest land ranks in the top four places accounting for 25.02 %, 22.68 %, 16.8 %, and 12.57 %. It is reported that the total primary energy consumption in China is 4.98 GtCE in 2020. The current technical potential of bioenergy accounts for about 17 % of the total social energy consumption in China. Considering biomass resources, technology, market capacity, and other factors, bioenergy may account for about 10 % of the Chinese overall energy structure (Dudley, 2018). The biomass energy industry has great development potential in China.

Table 1: Technical bioenergy potential in China, 2015

Biomass resources	Annual available amount (10^8 t)	tCE (10^8 t)	tCE percentage (%)
(1) Crop straw	4.26	2.13	25.02
(2) Forestry residues	3.37	1.93	22.68
(3) Agricultural product processing residues	1.07	0.55	6.46
(4) Livestock manure	11.9	0.42	4.93
(5) Municipal solid waste (MSW)	1.29	0.06	0.71
(6) Waste cooking oils	0.05	0.05	0.59
(7) Industrial wastewater & domestic sewage	——	0.04	0.47
Subtotal	——	5.18	60.86
Energy crops grown on marginal lands	Area (10^4 hm^2)	tCE (10^8 t)	tCE percentage (%)
(1) Shrubs land	3665	1.43	16.8
(2) Sparse forest land	2970	1.07	12.57
(3) Sparse grassland	1995	0.3	3.53
(4) River and canals	1025	0.28	3.29
(5) Shoal land	571	0.06	0.71
(6) Bottom land	271	0.05	0.59
(7) Sand land	228	0.05	0.59
(8) Gobi land	294	0.04	0.47
(9) Alkaline land	360	0.03	0.35
(10) Marshland	76	0.01	0.12
(11) Bare land	48	0.01	0.12
Sub-total	11503	3.33	39.14
Total		8.51	100

3. Geographic distribution of bioenergy in China

Following the calculation of technical bioenergy potential in China in terms of different types of biomass resources, this section aims to discuss the geographic distribution of bioenergy. The technical bioenergy potential of biomass resources, including agricultural & forestry residues and organic wastes in critical provinces, has been illustrated in Figure 1(a). The total amount of top 17 provinces of technical bioenergy potential based on biomass resources accounts for 81 % of the national total. To be specific, the technical bioenergy potential of the top 17 provinces can be divided into three levels. At the highest level, the top four provinces containing the most considerable energy potential of biomass resources come to Heilongjiang, Inner Mongolia, Henan, and Sichuan, the amounts are 44.51 MtCE, 37.39 MtCE, 32.46 MtCE, and 32.3 MtCE, making up 28 % of the national total. In the second level, the technical bioenergy potential of Xinjiang, Jilin, Hebei, Shandong, Hunan, Guangxi, and Yunnan is between 20 MtCE and 30 MtCE, accounting for 33 % of the national total. Finally, in the third level, the technical bioenergy potential of Liaoning, Jiangsu, Anhui, Hubei, Jiangxi, and Guangdong is between 15 MtCE and 20 MtCE, accounting for 20 % of the national total.

Concerning the technical bioenergy potential of energy crops grown on marginal land, the top 13 provinces together account for 81 % of the national total. Specifically, the technical bioenergy potential of marginal land in Yunnan and Inner Mongolia has reached more than 40 MtCE, a total of 97 MtCE, accounting for 28.2 % of the national total. The technical bioenergy potential of Sichuan, Guizhou, and Guangxi is between 20 MtCE and 30 MtCE, accounting for 21 % of the national total. The technical bioenergy potential of Xinjiang, Heilongjiang, Gansu, Shanxi, Shaanxi, Hubei, Hunan, and Jiangxi is between 10 MtCE and 20 MtCE, accounting for 31.6 % of the national total, as illustrated in Figure 1(b). Heilongjiang, Inner Mongolia, Xinjiang, Sichuan, Yunnan, Guangxi, Hunan, and Hubei are the critical provinces for developing the biomass energy industry in China.

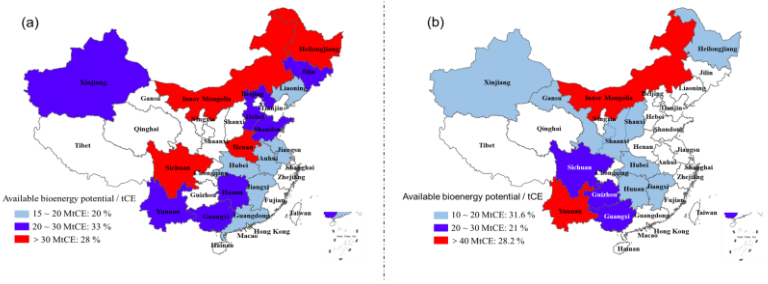

Figure 1: Spatial distribution of bioenergy in key provinces: (a) biomass resources including crop straw, forestry residues, agricultural production processing residues, livestock manure, MSW, waste cooking oils, and industrial wastewater & domestic sewage (b) marginal land including 11 types of land resources

4. Three-dimensional analysis on biomass policy in China

The actual utilization of biomass resources in China is relatively scarce, as illustrated in Figure 2, which is obtained based on this equation: $B_p = B_a \cdot \gamma \cdot (1 - \alpha - \beta - \mu)$. Here, B_p represents the potential biomass resources that can be converted into bioenergy; B_a represents the available biomass resources; γ represents different residues or wastes output ratios of the available biomass resources. α represents the ratio of biomass resources that should return to the soil. β represents the ratio of for other economic uses. μ represents the ratio of physical loss during utilization. The data of biomass feedstock supplies column is obtained by multiplying biomass resources B_a and residues or wastes output ratios γ. As for the final data of biomass uses column, it should multiply $(1 - \alpha - \beta - \mu)$ based on the former calculation.

Based on the above analysis and calculation, nearly 25.9 % of agricultural and forestry biomass resources are returned to the soil to maintain the carbon balance, about 43.73 % of the biomass resources are used for economic purposes such as papermaking and animal feed, as illustrated in Figure 2. Besides, during production and usage, the total loss amount of biomass reaches 202 MtCE, accounting for 24.34 % of the total. Only about 6 % of the total biomass resources, nearly about 50 MtCE, can be turned into real bioenergy. To be specific, during the application process of total bioenergy, the usage amount of heat and electricity, bioethanol, biodiesel, and biogas is 29 MtCE, 4 MtCE, 2 MtCE, and 15 MtCE, accounting for 3.49 %, 0.48 %, 0.24 %, and 1.81 %. It can be seen that biomass power generation and heating are the primary forms of biomass energy utilization in China, since biomass power generation technology is the most mature biomass utilization technology. Further, this section will analyze the biomass power generation policy from three perspectives, bringing some insights into the entire biomass energy industry.

4.1 Construction of biomass policy analysis framework

Previous research about the policies of biomass power generation in China focuses on the significance of subsidy policy with macroscopic qualitative methods rather than by micro quantitative means (Zhang et al., 2014). Besides, the design research on comprehensive theoretical frameworks based on different policies, which can coordinate various participants' interests, has not yet been formed. This section will put forward a three-dimensional policy analysis framework to explore the problems of biomass policy from a quantitative analytical perspective.

From the first analytical perspective, drawing on the most representative classification method proposed by Rothwell and Zegveld (1985), biomass policies are divided into supply type, demand-type, and environment type based on different policies' impact. Supply type mainly refers to the government's direct support aimed to expand the supply of biomass power generation industry, including scientific and technological information, infrastructure construction, fund investment, and public service. Demand type refers to the government's policies designed to expand the market demand by reducing market uncertainty or operational barriers and stimulating industry development, such as government procurement, outsourcing service, and trade control. The environment type acts on the overall environment to improve or optimize the policy background and the market environment, alleviating development risks and obstacles. It can be further divided into legal regulation, goal programming, taxes and subsidies, and financial support. From the second analytical perspective, according to the industrial activities of the life cycle and different participants, policies can be divided into five phases: research and development (R&D) phase, investment promotion phase, raw material resource phase, grid-connected production phase, and consumption phase. From the third analytical perspective, the classification method proposed by Howlett and Ramesh (2003) is based on different coercive degrees of policy tools, which is most widely used in the research field. According to different coercive degrees and government involvement in policy tools, it can be classified into three categories: compulsory instrument including government regulation, public enterprise, and direct provision, mixed instrument consisting of information & exhortation, subsidies, funding/special funds, property auctions, taxes & user charges, and voluntary instrument comprising of private markets, families and communities as well as volunteer organizations. According to the Chinalawinfo database, 72 pieces of biomass policies issued on the public portals of the central government and various ministries and commissions from Jan. 2000 to Jun. 2021 are selected based on the keywords “biomass”, “bioenergy”, “electric power”, and “energy conservation and emission reduction”. A total of 150 items of policy clauses related to biomass power generation are identified and classified into corresponding subclasses.

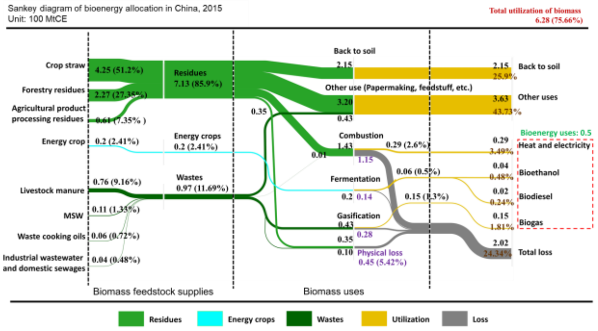

Figure 2: Energy allocation Sankey diagram of biomass and bioenergy in China, 2015

4.2 Results and discussion

After collecting and analyzing biomass power generation policies, analysis results can be obtained based on a three-dimensional policy analysis framework. From the first analytical perspective, as illustrated in Figure 3, Chinese biomass power generation policies are dominated by environment type (63.64 %) and supply type (36.36 %). It is clear that in order to achieve healthy and sustainable development of biomass power generation industry, the Chinese government applied enormous environmental policies mainly consisting of legal regulation (26.73 %) and goal programming (25.17 %) to optimize the market environment and reduce development obstacles. However, considering the effectiveness of those policies, too high a percentage of legal regulation and goal programming is overwhelmed for the whole industry, which needs to be simplified to enhance policy effectiveness. Furthermore, the Chinese government also adopted supply-oriented policies comprising scientific and technological information (16.13 %) and infrastructure construction (14.23 %) to expand the biomass power generation industry's supply directly. Given that the biomass power generation industry is still booming, it is sensible for the government to attach vital importance to these policies. However, when it comes to the government's preferential fund policies like taxes & subsidies (7.9 %) and financial support (4.2 %) of environmental policies or the fund investment (3.2 %) of supply-oriented policies, respective policy proportions are pretty small, which is deadly detrimental for the development of biomass power generation industry. Since at the early stage of development, the whole industry will need capital support for infrastructure construction and the introduction of advanced technologies. Even worse, the absence of demand-type policies leads to extremely insufficient demand for the biomass power generation industry, resulting in sluggish market development. Based on the above analysis, when relevant policies will be formulated and carried out in the future, the government should prioritize preferential fund policies and demand-oriented policies to stimulate market demands. Then further development and expansion of the biomass power generation industry will be realized, evoking relevant enterprises and other institutions' enthusiasm for market participation.

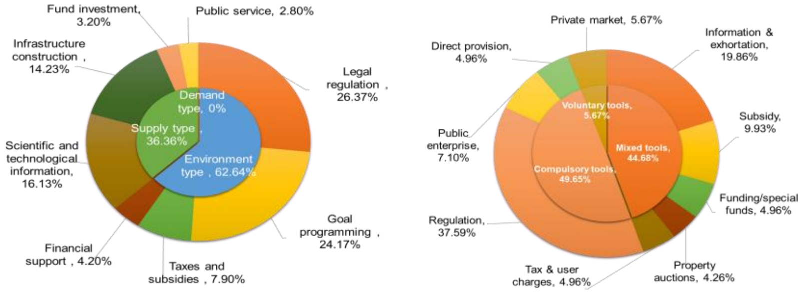

Figure 3: On the left-hand side, percentage diagram of different types of policies, On the right-hand side, policy percentage diagram of different compulsory levels

From the second analytical perspective, as illustrated in Figure 4, biomass power generation policies of both environment type and supply type can be further divided into the following five sub-types according to different phases of the industrial activities. The distribution of environment type policies related to different industrial activities is quite uneven. Specifically, the policy percentages of the R&D and consumption phases are 3.97 % and 1.52 %, accounting for only a tiny fraction of environment-type policies. However, the policy percentages of middle phases like the investment promotion phase (15.15 %), raw material resources phase (17.42 %), and grid-connected production phase (25.76 %) are comparatively high. It is the same case for supply-type policies, except for the policy percentage of the R&D phase (10.61 %), which is relatively higher than that of environment-type policies. The whole industrial activities containing environment type and supply type policies, policy percentages of R&D phase, investment promotion phase, raw material resources phase, grid-connected production phase, and consumption phase are 14.4 %, 21.95 %, 27.27 %, 33.34 %, and 3.04 %. Policy support for the R&D and consumption phases is relatively scarce, indicating that the industry's development impetus from R&D and consumption is limited.

Moreover, many policies focus on the middle phases and neglect both ends. A balanced and overall policy support system involving whole industrial process activities is urgent to form. Besides, the government should invest more capital in establishing biomass technology research institutes, the formulation of industry standards, and the progress of related technology R&D areas. In the consumption stage, the government is supposed to strengthen the publicity and education of biomass power generation and increase subsidy policies for consumers to purchase biomass power.

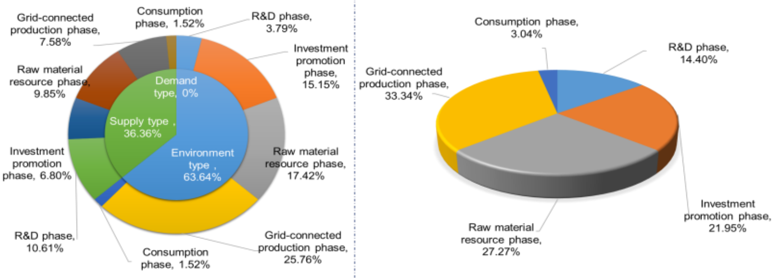

Figure 4: Policy percentage diagram of industrial activities

From the third analytical perspective, biomass power generation policies of different compulsory degrees are analyzed, as illustrated in Figure 5. It can be seen that compared with voluntary tools accounting for a relatively small proportion of 5.67 %, compulsory tools and mixed tools respectively make up high proportions of 49.65 % and 44.68 %. Specifically, among compulsory tools, the regulatory tools account for the most, about 37.59 %, followed by public enterprise 7.10 %, direct provision 4.96 %. Too many regulatory tools will hurt the development of the biomass power generation industry since those policies prohibit the innovation and initiative of participants. Among the mixed tools, information & exhortation account for a relatively high 19.86 %, followed by subsidy 9.93 %, funding/special funds 4.96 %, taxes and user charges 4.96 %, and property auctions 4.26 %. Various preferential fund policies accounting for nearly 20 % of mixed tools have been implemented in the biomass power generation industry, which is conducive to dramatically stimulating the development momentum.

However, the absence of voluntary policy tools will inhibit the formation of competitive mechanisms in the biomass power industry, resulting in no innovation driving force for enterprises. Hence, more voluntary policies and simplified regulatory policies are supposed to be carried out to promote the successful development of the biomass power generation industry. The proportion of regulatory tools is supposed to be reduced to make decision-making more scientific and democratic. Besides, more operational policy content should be added to encourage supportive participants as well as their positive behaviors in the industry. These three aspects of policy tools are interconnected and overlapped with each other to influence the biomass power generation industry together. Specifically, the biomass power generation policy involves all policies of supply type and environment type, which have achieved policy intervention into each activity phase of the whole industry. While different coercive policies also have been comprehensively applied to promote faster industrialization.

5. Conclusion

This work introduces the technical bioenergy potential, geographic distribution, and biomass & bioenergy flow analysis in China. On this basis, it focuses on the current more mature biomass power generation-related policy issues, and the conclusions are as follows:

First, current biomass resources in China are mainly agricultural, forestry residues, and organic wastes, the use of marginal land to grow energy crops has not yet to be vigorously developed. The former's technical bioenergy potential is 518 MtCE, while the latter's potential is 333 MtCE. Second, the current biomass policy tools of environment and supply type are redundant, and demand-based policy tools are lacking. Third, as far as the entire biomass power generation industrial chains are concerned, a complete policy support system has not yet been formed. The industry has limited impetus from both ends of industrial chains. Finally, it is recommended to promote the development of the entire biomass industry by strengthening macro-control, creating a good market environment, expanding investment and financing channels, and building a complete biomass energy service system. This work can provide enlightenment for the healthy and sustainable development of the entire biomass energy industry.

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