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System Analysis on the Organization and Management of the Industry of Biomass Solid Densified Fuel for Heating in China

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The problem of industrial organization and management is one of the main challenges for China to realize a rapid development of biomass solid densified fuel (BSDF) for heating following the targets of the 13th Five-Year-Plan. This manuscript developed a framework of system analysis, including the analysis on decision-making, execution, operation, market and information interactions, to identify key barriers existed in the organization and management of this industry and put forwards policy suggestions. The results present that China has already built an integrated organization and management system of this industry, and the key barriers include the contradiction between industry development and air pollution control, the weak economic competitiveness and the huge delay of information and feedback between the top decision-making and executive levels and the bottom engineering system level in the market. The main policy implications are that Chinese governments need to clearly define BSDF as a clean fuel or not, to enhance the financial support of BSDF for heating and to enhance market investigation by decision-making and executive levels.

1. Introduction

The utilized amount of bioenergy in 2015 in China only accounted for 7.6% of the total biomass resources that can be used for energy (NEA, 2016). The waste of large amount of agriculture and forest residues leads to on-site burning of crop straw and fire hazards (Jiang, 2015). Among various technologies of biomass use for energy, biomass solid densified fuel (BSDF), especially for heating, is a promising one to utilize biomass residues as energy in a large scale. However, the development of BSDF lagged behind the planned target in the 12th Five-Year (2011 - 2015). In the13th Five-Year-Plan (2016 - 2020) of Biomass Energy Development in China, the target is to increase BSDF from 4 Mtce/y in 2015 to 15 Mtce/y (NEA, 2016), with an annual growth rate of about 30 %. According to discussions of trade councils and the interview with government officials and entrepreneurs, the technology of BSDF for heating is just matured basically at present (Zhou et al., 2014). However, its economic efficiency is not as good as coal for heating (Ni et al., 2017). The rapid development of BSDF for heating still faces many challenges. One of the key issues is the unmatured organization and management mode of this industry, aiming at a rapid expansion of BSDF for heating industry in the business-oriented market. Considering BSDF for heating is not only a commercial product, but also a kind of public product of renewable energy, it is of importance to design a suitable organization and management mode, especially the organization and management by governments, to support the market development of BSDF for heating.

In previous studies, based on actual heat supply cases, this study (Michopoulos et al., 2014) analysed energy, environmental and economic performance of BSDF for heating by the method of life cycle analysis (LCA). Zhou et al. (2014) comprehensively researched the key problems of BSDF industry development in China. Wang et al. (2015) studied relevant issues of BSDF for heating industry development involving subsidy policy, carbon trading and business mode. Muhammad et al. (2016) evaluated the energy efficiencies, economic feasibility of the biomass gasification system for combined heat and power supply. In a summary, it still lacks research on BSDF for heating from the perspective of organization and management mode from top to bottom.

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To research the problem of organization and management mode of BSDF for heating, a framework of system analysis must first be established facing complexities of this problem. In previous studies, Ma et al. (2012) developed frameworks of system analysis method to analyse the development issue of oil and natural gas industry in China. These works provide good references for the method development of this study, but a new method must be established according to the characteristics of BSDF for heating industry and the system of organization and management.

According to the general system theory (Sun et al., 2015), this manuscript attempts to establish a framework of system analysis on the organization and management mode of BSDF for heating industry. Through the analysis of system elements and their relationships, the key barriers of the development of BSDF for heating industry are recognized, the effective policy mechanism to prompt a rapid development of BSDF for heating is analysed, and policy suggestions are proposed. Firstly, the system analysis framework is established and analytical procedures are introduced in Section 2. Section 3 analyses the sustainable development environment, system elements, information interaction among the elements, and identify barriers of the development of BSDF for heating industry. Section 4 gives main conclusions and policy implications.

2. Methodology

2.1 System analysis framework of BSDF for heating industry

A system (Sun et al., 2015) is a unit consisting of many elements with interrelation and interaction, having specific functions, and related to the environment. Based on the general system theory and the perspective of the organization and management of BSDF for heating industry, from top to bottom, BSDF for heating industry utilizes BSDF for heating as a special function with elements, boundary, and interrelation. Under the environment constraints of sustainable development, this industry organizes an open system. The system analysis framework of BSDF for heating industry is illustrated in Fig.1.

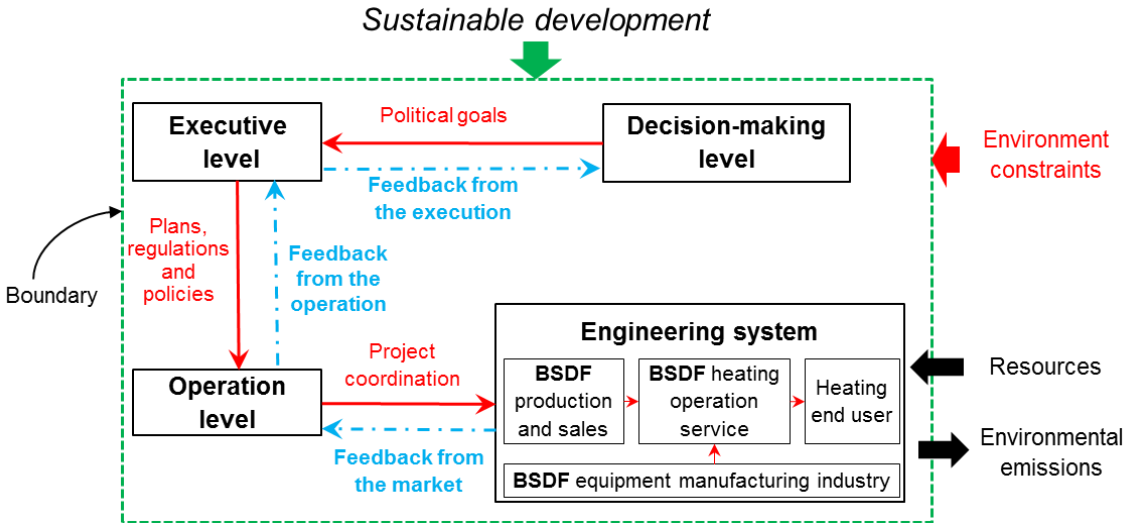

Figure1: System analysis framework of the organization and management mode of BSDF for heating industry

According to Figure1, referring to the characteristics of China's governmental administration, the basic elements of the framework includes decision-making level, executive level, operation level and engineering system level, and these elements interact by information flows and feedbacks. The connotations of these elements are as follows: a) Decision-making level: The top decision-makers in the national government to decide political goals for the sustainable development, such as the National People's Congress and the President. b) Executive level: the governmental departments of national, provincial and municipal level, who make plans, regulations and policies to realize political goals and decide the targets of industry development, such as the State Council, National Energy Administration, Ministry of Environmental Protection and corresponding departments in provincial and municipal governments. c) Operation level: local governments who implement the plans, regulations and policies, such as county-level governments with sound functions. It connects the level of executive and engineering system of BSDF for heating industry, and it is essential for final implementation of the industry development. d) Engineering system: The production and sales of BSDF, operation service of BSDF, heating end user and BSDF equipment manufacturing industry, which together realize the transformation of energy, funding and other resources into final heating service to end users based on the market mechanism.

2.2 System analysis procedures

According to the framework in Fig.1, the system analysis procedures are as follows: 1) Analysis of the four elements in the system, including decision-making level, executive level, operation level and engineering system, 2) Analysis of information interactionsamongthoseelements,3) Analysis of barriers and way-out for the promotion of BSDF for heating industry. The data and information are mainly from discussions of trade councils, literature review and field survey.

3. Results and discussion

3.1 Four elements in the system

3.1.1 Decision-making level

The overall plan of socialism construction with Chinese characteristics decides the top prioritized goal is still economic growth. However, the construction of ecological civilization has also become an essential goal in recent years. For example, in 2016, China signed the Paris Agreement on Climate Change, specifically conformed the target that the non-fossil energy in primary energy consumption will be reduced by 15 % and 20 % by the 2020 and 2030. Besides, the 18th National Congress of the Communist Party of China and the Third Plenary Session of the Eighteenth Central Committee decided the overall layout of ecological civilization construction.

At present, the air pollution, especially the fine particulate matter issue, is an essential challenge for China to achieve sustainable development (CSC, 2013), besides the challenge of global climate change (Xi, 2015). In a summary, the political goals of China decide that the development of BSDF for heating industry must realize simultaneously the supporting to economic growth, the reduction of emissions of air pollutants and GHG emissions.

3.1.2 Executive level

Under the guidance of the political goals from decision-making level, executive level makes related plans, regulations and policies to promote and manage the development of BSDF for heating industry. Some of the related national plans, regulations and policies are listed in Table 1. They cover not only the promotion of BSDF industry, but also to enhance the air pollution control and GHG emission reduction.

With the huge disparity of resources and environmental conditions in China's various regions, the provincial and municipal governments are essential to execute national plans, regulations, and policies based on regional situation, and make specific programs and measures to implement them. For example, Changchun City in Jilin Province, which is rich in agricultural straw resources, has a great potential of the development of BSDF for heating industry. Changchun City is located in cold areas, so there is a great need of heating in winter. Corn Straw Densified Fuel (CSDF) is a form of BSDF for heating. Table 2 summarizes policies and measures that Changchun take to promote CSDF for heating. Changchun City launched a program named as *"low-carbon energy demonstration township and demonstration counties"* to promote the development of bioenergy and agricultural straw resources utilization, which include the development of CSDF for heating.

It seems both national and local governments had developed comprehensive policies and measures to promote the development of BSDF for heating, and formed a good basis of the development of this industry. However, there are still some issues like the lack of adequate financial support, the contradictions between BSDF development planning and air pollution regulations, and the lack of specific action plans and so on (Song, 2017).

3.1.3 Operation level

The operation level is generally the county-level governments with sound functions, which is the grass-roots level for the implementation of the development of BSDF for heating industry. For example, this level takes orders from executive level, and then organizes and manages the project development of BSDF for heating industry referring to all the plans, regulations and polices.

We can take Jingyue County in Changchun City as a case to further explain the activities of this level. Some part of the County is constructed as high-polluting fuels restricted zone by Changchun city, and the other is permitted area. Jingyue County implements relevant policies and measures to simultaneously promote the development of clean energy, clean air and agricultural straw comprehensive utilization. Currently, the main measure taken by this County are to shut down the boilers smaller than 10 t vapor/h, to develop the bioenergy and other clean energy for heating, to promote the use of agricultural straw energy and so on. In 2016, the Jingyue County government raised about 0.73 MUSD to buy 30 BSDF special boilers and 9 electric boilers to replace the coal-fired boilers in schools, hospital and other public service organization, and providing financial subsidies for those using special BSDF boilers to replace coal-fired boilers for heating. At the same time, the local Environmental Protection Agency (EPA) strengthened the supervision and management of heating equipment. Though those measures promoted the development of BSDF for heating industry in Jingyue County, it also encountered some problems in the high-polluting fuels restricted zone because of the contradiction

among the utilization of BSDF, air pollution control and economic benefits. The reason is that: 1) according to the air pollution regulations, the County must use natural gas, electricity and other clean energy to replace the coal-fired boiler smaller that than 10t vapor/h in the high-polluting fuels restricted zone, but there is no policy defining BSDF for heating as a clean energy; 2) the high-polluting fuels regulations point out that direct burning of biomass fuels belongs to high-polluting fuels, but the regulation does not show whether BSDF is clean energy or not; 3) the air pollutants emission standard of BSDF boilers still uses the standard of coal-fired boiler; 4) the economic benefits of BSDF for heating is better than the use of natural gas and electricity, but worse than the use of coal.

This case illustrate that the practices of operation level reveal the problem of the lack of coordination among various regulations and policies, and it leaves to operation level to solve the contradictions without clear guidance from the executive level.

Table 1: National laws and policies on BSDF for heating

Category	Laws and policies	Years
BSDF for heating Development planning	Renewable Energy Law	2009
	Medium and long term development plan for renewable energy	2007
	The 13th Five-year-Plan for renewable energy development	2016
	The 13th Five-year-Plan for biomass energy development	2016
	The 13th Five-year-Plan for energy technology innovation	2017
Environmental protection	Integrated Reform Plan for Promoting Ecological Progress	2015
	Environmental protection Law	2014
	Air Pollutants Control Law	2015
	The 13th Five-Year-Plan for Ecological Environment Protection	2016
	The 13th Five-Year-Plan for Control Greenhouse Gas Emission	2016
	Air pollutants emissions standard of boiler	2014
Special action plan	Air Pollution Control Action Plan	2013
	Energy sector to strengthen air pollution prevention and control work program	2014
	Notice on the construction of BSDF boiler heating demonstration project	2014
	Interim measures for alternative management of coal consumption reduction in key areas	2014
Agriculture and forest residues utilization	Opinions on accelerating the comprehensive utilization of crop straw	2008
	National forestry biomass energy development plan (2011-2020)	2013
Finance and tax	Interim Measures for the administration of special Funds for renewable energy development	2015
	Interim measures for the administration of funds for energy conservation and emission reduction	2015
	Notice on adjusting and perfecting the policy of comprehensive utilization of resources and value - added tax	2011
	Notice on the scope of initial processing of agricultural products for the release of preferential policies for enterprise income tax	2008

3.1.4 Engineering system level

The basis of this level's analysis is the management mechanism of the supply and demand, and the discussions on that is as follows. 1) in the stage of BSDF production and sales, it is required a stable supply of biomass materials with a reasonable price to control the production cost, and also a stable market of BSDF with a reasonable price to ensure the profit; 2) in the stage of BSDF heating operation service, it is required a reasonable price of BSDF to ensure the profit in the existing heating market with already built price of heating service and heating network. Meanwhile, the BSDF boilers must meet the environmental standards; 3) in the stage of heating end-user, it is mainly the requirements from enterprises and organization using BSDF for heating by themselves and residents directly using BSDF for heating in their houses. They both require the clean and cheap fuel, similar as the enterprises of heating operation service of BSDF.

Currently, the main contradictions in the market is the unstable supply and fluctuating price of biomass materials, the comparatively high cost and price of BSDF and the doubt about the emission performance of air pollutants of BSDF boilers (Ni et al., 2017). Therefore, it raises the requirements to operation level to coordinate these issues in the organization and management of BSDF for heating projects in county-level, and also to executive

level to improve plans, regulations and policies to give a clearer guidance of the development of BSDF for heating industry for the operation level.

Table 2: Changchun City agricultural straw energy utilization policies

Category	Policies	Years
Promoting straw energy utilization	Suggestions on promoting the comprehensive utilization of crop straw	2016
	Implementation plan of straw energy utilization in Jilin Province	2016
	Jilin Province "low carbon energy demonstration township" and "low carbon energy demonstration county construction" guide	2016
Air pollution governance	Notice of Changchun government on delineating high-polluting fuels restricted zone	2014
	Changchun City air pollution control action plan to implement the program in 2015	2015
	Changchun City Clean Air Action Plan (2016-2020)	2016

3.2 Information interactions among system elements

The above system elements are all connected by information flows and feedback flows, as illustrated by the solid and dashed lines in Fig.1. The information flows follow a top-down sequence. The level of decision-making inputs information of political goals to executive level, and executive level gives information to operation level by plans, regulations and policies in national, provincial and municipal level. The operation level shares information of project coordination to various stages of engineering system in the market and quickly gets feedback flow from the market. Then, the feedback flows follow a bottom-up sequence by first from market to operation level, then from operation level to executive level and finally from executive level to decision-making level. The top-down of information through several levels one by one and the bottom-up of feedback through those levels one by one results a huge delay of information from decision-making to the market and also feedback from the market to decision-making. It is an important reason bringing the lag behind development of BSDF for heating industry and many contradictions between the market and the policies.

3.3 Barriers and way-out to promote the development of BSDF for heating industry

Referring to the above analysis, the barriers and way-out to promote the development of BSDF for heating industry can be summarized as follows: 1) the first barrier is that it is not clear whether or not BSDF can be used in the high-polluting fuels restricted zone referring to existed policies, and the way-out is to clear define BSDF as a clean fuel or not in environmental policies and standards; 2) the second is that BSDF for heating now is not so economic compared with coal for heating, and the way-out is to improve policies to enhance the financial support for the biomass collecting, BSDF production, BSDF sales and heating operation; 3) the third barrier, also the radical one, is the huge delay of information and feedback between the top decision-making and executive level and the bottom engineering system level, and the way-out is to enhance market investigation in decision-making and executive level and to enhance the participation of people from engineering system in the discussion of decision-making and executive level.

4. Policy implications

The policy implications of this study is that proper actions must be put forward to overcome the three barriers to realize a rapid development of BSDF for heating industry in China, including: 1) it must be clearly defined whether or not BSDF is a clean fuel, especially in the high-polluting fuels restricted zones; 2) the economic competitiveness of BSDF for heating must be improved by more policy support; 3) the market investigation by decision-making and executive levels as well as the participation of people from operation level and engineering system in the discussion of decision-making and policy execution must be both enhanced.

5. Conclusions

This study developed a framework of system analysis to research the problems of the organization and management system of the development of BSDF for heating industry. This paper analysed the four elements of the organization and management system, including decision-making level, executive level, operation level and engineering system level, discussed the information and feedback interactions among the four elements, and identify the barriers and way-out to promote the development of BSDF for heating industry. The main conclusions are as follows.

1) China has already built an integrated organization and management system of the development of BSDF for heating industry. The development of this industry now is encouraged by political goals, promoted by national, provincial and municipal plans, regulations and policies, and also coordinated by county-level governments.
2) The key barriers of the organization and management of the development of this industry are firstly the contradiction between industry development and air pollution control, secondly the weak economic competitiveness compared with coal for heating and thirdly the huge delay of information and feedback between the top decision-making and executive levels and the bottom engineering system level in the market.

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