Energies **2015**, *8*, 7122-7139; doi:10.3390/en8077122

OPEN ACCESS

energies

ISSN 1996-1073

www.mdpi.com/journal/energies

Review

A Supply-Chain Analysis Framework for Assessing Densified Biomass Solid Fuel Utilization Policies in China

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Academic Editor: Vincenzo Dovì

Received: 6 January 2015 / Accepted: 24 June 2015 / Published: 14 July 2015

Abstract: Densified Biomass Solid Fuel (DBSF) is a typical solid form of biomass, using agricultural and forestry residues as raw materials. DBSF utilization is considered to be an alternative to fossil energy, like coal in China, associated with a reduction of environmental pollution. China has abundant biomass resources and is suitable to develop DBSF. Until now, a number of policies aimed at fostering DBSF industry have been proliferated by policy makers in China. However, considering the seasonality and instability of biomass resources, these inefficiencies could trigger future scarcities of biomass feedstocks, baffling the resilience of biomass supply chains. Therefore, this review paper focuses on DBSF policies and strategies in China, based on the supply chain framework. We analyzed the current developing situation of DBSF industry in China and developed a framework for policy instruments based on the supply chain steps, which can be used to identify and assess the deficiencies of current DBSF industry policies, and we proposed some suggestions. These findings may inform policy development and identify synergies at different steps in the supply chain to enhance the development of DBSF industry.

Keywords: Densified Biomass Solid Fuel (DBSF); biomass; DBSF industry; policy analysis; China

1. Introduction

Due to the rapid development of economies and society in recent years, the demand for energy increases significantly in the global world, while the limited fossil energy and high emission of pollutants makes government begin to emphasize and encourage the use of biomass energy [1]. The World Energy Council (WEC) predicted that the proportion of biomass in the total global renewable energy will be increased to 60% by 2020 [1,2].

Generally speaking, the final products of biomass include three forms, *i.e.*, gaseous, liquid and solid ones [2], among which Densified Biomass Solid Fuel (DBSF) is a typical representative of the solid form of biomass. After being processed and treated under a certain temperature and pressure, many loose raw materials such as straw, twigs, sawdust, *etc.* can be squeezed into special shapes and changed into DBSF with high density and low ash contents, which makes it convenient for transportation and combustion, and cost-effective to be utilized [3]. DBSF can be widely used for steam, in hot water boilers as fuel, and for power generation by direct combustion or CHP (combined heat and power). Table 1 shows the main differences between DBSF and traditional fossil fuels. Among them, Datong Coal as one kind of high quality coal in China, was selected as a typical fossil fuel representative with low ash content.

Table 1. The property difference between the Densified Biomass Solid Fuel (DBSF) and Datong Coal.

Fuel Type	ρ (g/cm^3)	S_{ad} (%)	A_{ad} (%)	FC_{ad} (%)	FT (°C)
DBSF	1.0–1.4	0.05–0.2	1.0–13	13–20	1000–1200
Coal (Datong)	1.25–1.5	1.78	12.04	47.82	1500

ρ means density, and DBSF's density has less difference with that of coal. S_{ad} is Sulphur content (Air dried basis). S_{ad} in per unit of DBSF is much less than that of Datong Coal. Generally, S_{ad} in DBSF from straw is not more than 0.2%, and that from woody material is only about 0.05%. A_{ad} refers to ash content (Air dried basis). The ash content of corn straw DBSF accounts for about 8%, and that of woody DBSF is roughly 5%. Only the ash content of DBSF made from Rice straw and rice husk reach 13%. FC_{ad} means fixed carbon (Air dried basis). FC_{ad} in DBSF amounts to roughly one third of that of Datong Coal. FT means ash fusion temperature.

Hong Hao *et al.* [2] utilized 2 × 1400 kW hot-water boilers and 2 × 1400 kW steam boilers as pilot targets, and the results showed that the actual measured data of hot conversion efficiency accounted for about 84% using DBSF as fuel, and the emission indicators of actual data was much lower than that of National Boiler Ambient air quality standards. Particulate pollutant emission concentration of DBSF boilers is about 30 mg/m^3, much less than that of coal boiler emission standard as 80 mg/m^3, and equal to that of natural gas combustion. The SO_2 emission concentration was about 41.3 mg/m^3, much less than that of coal boiler emission, which has a standard of 400 mg/m^3.

Meanwhile, Zong Yi *et al.* pointed out that the combustion of DBSF in the stove had the high thermal conversion efficiency of 60%–80% due to more full combustion, compared to that of 5%–8% using traditional firewood combustion [4]. DBSF combustion produces less black smoke with less concentration of C particle caused by incomplete combustion compared to the traditional direct combustion of biomass material [4]. In general, the emission concentration of SO_2, NO_x all decrease using DBSF as fuel, and DBSF is considered as a kind of clean fuel in China [2]. Therefore, DBSF promotion and application in China can play a major role in environmental improvement.

Recently, some regions of China have experienced severe threats by fog and haze, among these, *in situ* concentrated combustion of agricultural residues was considered to partly contribute to haze formation in harvest season [4]. Studies have shown that agricultural residue seasonal burning can contribute to around 30% of particle generation as concentrated combustion in one or two days in large cropland area [4]. DBSF utilization is considered to be an ideal solution for the disposal of agricultural and forestry residues, associated with reduction of land occupy and air pollutant generation. Meanwhile, DBSF as alternative to fossil energy, the emission of SO_2 and ash can reduce by 80% compared to coal under the same heat value.

In the past decade, DBSF utilization has been broadly expanded in many countries across the world including China. According to "the national renewable energy medium and long-term development plan in China", the annual consumption of DBSF in China would have reached 50 million tons by 2020 [5]. In order to achieve the goal of DBSF utilization, industrial development should inextricably link with the incentives and preferential policies with relevant departments of the central and local governments. Therefore, it is meaningful for China to analyze the industrial policies to support the development of DBSF utilization. However, there are a number of issues associated with DBSF exploitation and utilization, such as its supply chain, availability and distribution.

Focusing on the particular stages of the supply chain may enable policy advocates or policy makers to identify particular interventions to target bottlenecks to utilization, interaction effects of policies, or to assess the degree to which current policy practices are conducive to objectives. Such a framework may contribute to increase understanding of the factors critical to DBSF development in China. Although the main focus of the paper is on China, it would be relevant to other developing countries, which would be looking to further develop their DBSF industry [6]. Therefore, this review paper focuses on DBSF policies and strategies in China based on the supply chain classification, in particular by addressing the following issues with a holistic approach: (1) what is the potential of DBSF in China; (2) what are the DBSF industrial strategies and policies in China, and how were the strategies articulated and executed for attaining policy objectives in each supply chain stage, and (3) what is the deficiency of current DBSF industry policies in China, and how can it be improved?

2. Introduction of Densified Biomass Solid Fuel (DBSF) in China

2.1. The Resources of DBSF

The majority of raw materials of DBSF come from crop straw, agricultural processing and forestry residues [2,3]. Among them, agricultural and forestry residues are the primary sources for DBSF. The distribution of agricultural and forestry residues in China are illustrated in Figures 1 and 2.

As China's basic farmland protection system does not change and the basic agricultural planting structure is relatively consistent, annual output of agricultural residue is correspondingly stable [3,5]. The total amount of agricultural residue was 630 million tones recently [5,7]. Among the generated agricultural residues, crop and wheat straws are occupying the largest proportion, reaching 270 million tons. Rice husk, corn cob, peanut shells and other processing residues can also be used as the raw materials of DBSF. In addition to the loss of collection and transportation, the use of returning to field, feed or other stuffs, the best estimate suggests that the consumption of agricultural residues as fuel is about 168 million TCE (ton of standard coal equivalent) [8].

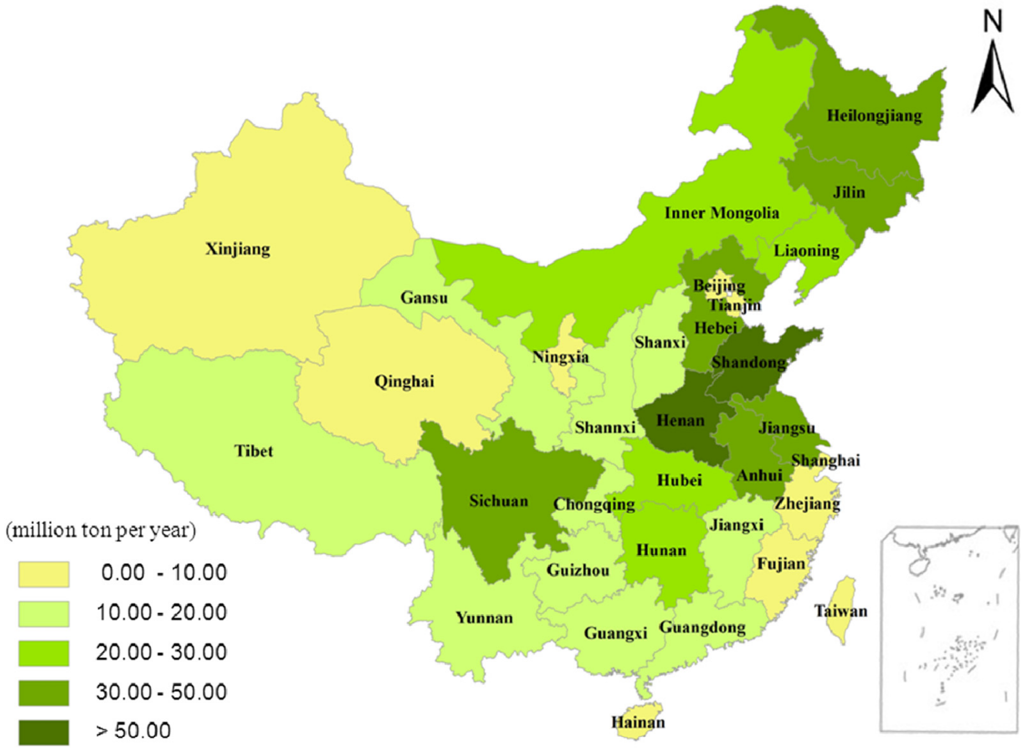

Figure 1. The distribution of the average output of agricultural residues in China.

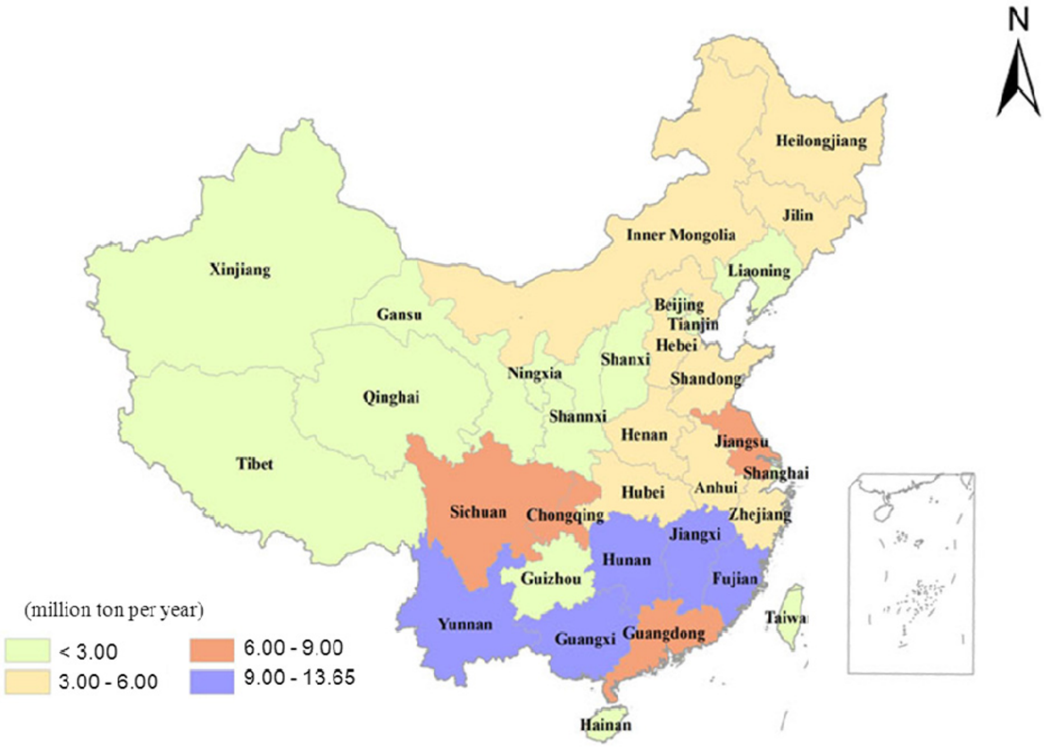

Figure 2. The distribution of the average output of forestry residues in China.

Meanwhile, forestry biomass resources are mainly from forestry logging, tending and processing residues. The available amount of China's annual tree branches and forestry residues can reach about 900 million tons, while about 300 million tons can be utilized as energy equivalent to 200 million TCE [9]. Although agricultural and forestry residues have some different features, both of them are important DBSF sources in different regions of China. Abundant agricultural and forestry residues make it suitable for DBSF development in China.

2.2. The Classification of DBSF Supply Chain

DBSF supply chain has been defined as the integrated management of DBSF production from harvesting biomass resources to energy conversion facilities. Generally speaking, in order to facilitate the subsequent policy analysis, the long DBSF supply chain can be divided into three stages. The complete DBSF supply chain is shown in Figure 3, while the products of DBSF are illustrated in Figure 4. The entities or enterprises involved in the DBSF processing stages may include:

Stage I: The companies or entities related to raw materials collection, *i.e.*, harvest, storage and transportation;

Stage II: The enterprises or companies related to DBSF production process, including the production of DBSF, the design and manufacture of DBSF production equipment, storage and transportation of DBSF products, *etc*;

Stage III: The enterprises or entities related to market application of DBSF, including the market-oriented fuel use, the design and manufacture of DBSF boilers and other terminal utilization equipment, the design and production of energy conversion equipment.

Major customers of stage III include household use, as well as commercial heating, steam supply, *etc.* As the policy support is hard to cover all aspects of the DBSF industry chain, and the support for transport and storage is relatively weak compared with other links of DBSF industry chain. In order to simplify the analyses of policy on the complicated supply chain, the policy on transport and storage is not considered as a key link to analyze.

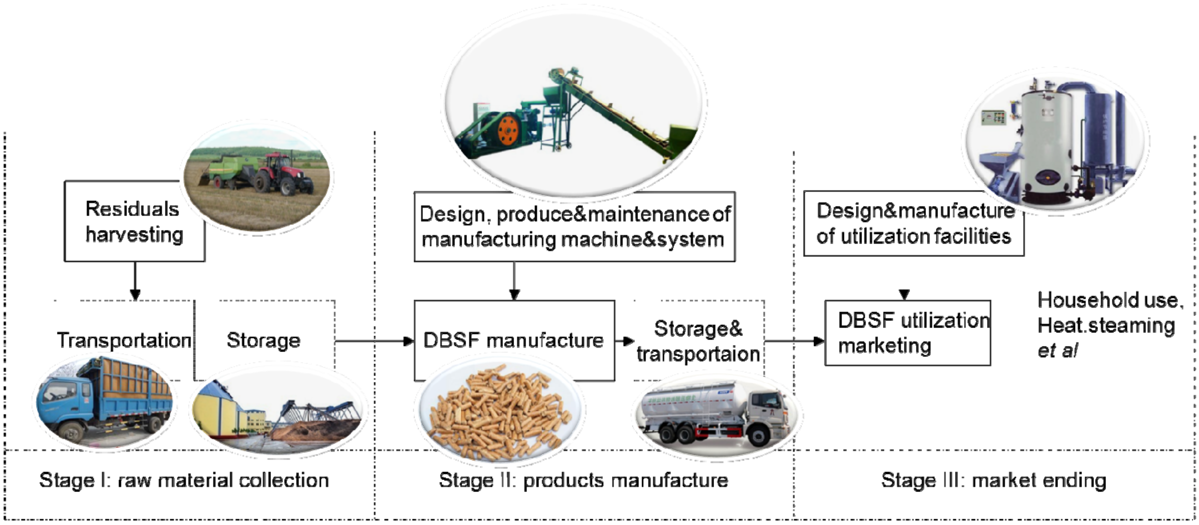

Figure 3. The DBSF supply chain classification.

Figure 4. The main products of DBSF.

2.3. Issues of DBSF Supply Chain

Since 2004, the DBSF industry has grown more than 18% per year at the global scale. As yet, DBSF industry in China is in the initial stage of industrial development, with small market scale [3–5]. The main issues of DBSF utilization in China have been concluded in full view of supply chain as below.

2.3.1. The Issue of Resource Collection

There always exists a contradiction between the scattered bio-resource distribution and the concentrated industrial production of DBSF in medium and large scale, together with seasonal harvest and successive production demand. At the same time, the district expansion of supply and demand inevitably leads to the raw material price soaring. As the dispersion and seasonal instability of feedstock, collecting agricultural and forestry residues in traditional ways cannot meet the large-scale commercial production. Actually, feedstock process should have a balanced mechanism to achieve a good dynamic equilibrium, so that the enterprise can receive sufficient raw materials with reasonable and stable price [6].

2.3.2. The Issue of Production Technology

In terms of DBSF production, the biomass solidification technology is considered to be the core issue. Generally, these technologies can be divided into thermoforming and compressed-forming according to the temperature required for the processing. Roller die extrusion, piston stamping and screw extrusion are the three major types of solidified fuel processing machines. Nowadays, the technologies used in some developed countries are highly specialized and automated and are characterized by high thermal efficiency and less pollution. However, because of high equipment price, high power consumption, improper combustion parameters that may induce slag in stoves and limited variety of feedstock suitable for processing, these technologies are not suitable for China. China is a latecomer in the research of biomass solidification technologies, and there exists a large gap between the technologies used in China and in developed countries. In order to encourage the development of biomass solidification technology, the government has moved to improve its incentives for DBSF research and production. The detailed R&D projects are described in Section 4.2.

2.3.3. The Issue of Market Application

Market demand for DBSF as the last part of supply chain is considered to be insufficient in China. The fundamental way to promote DBSF in large-scale applications is in place of fossil energy, e.g., coal. However, it is restricted by the obstacle of DBSF price fluctuation with unstable raw material supply. Actually, the issues in different links of the supply chain interact and transfer from the beginning to the end. On the other hand, a number of heating enterprises cannot accept the concept of DBSF as an alternative energy due to a lack of correct understanding of DBSF as a clean and renewable energy. In comparison, DBSF has already been successfully applied in extensive fields in foreign countries, particularly in Europe. In addition to the central heating boiler, DBSF application has entered into ordinary home use. In China, the domestic and commercial applications have not been fully developed, and the market field is extremely limited.

Many studies suggest that the main issues representing the DBSF utilization and promotion in China focus on the manufacturing technologies in stage II. Yet in this paper, the main obstacles are not just concentrated on production technology, but also exist in the collection phase and application market. Therefore, we adopt the analysis on the overall policy contents combined with the supply chain.

3. China's DBSF Development Strategies

3.1. Policy Conceptual Framework

The framework of DBSF related policies and regulations can be divided into three levels, shown in Figure 5. The first level is the basis of the legal documents, such as the "Renewable Energy Law" which is a comprehensive legal framework of renewable energy including DBSF. The second level is determined by the national governments in accordance with the general legal framework and basis for planning the development of industry specific milestones, such as the renewable energy planning in the period of the "12th Five-Year Plan". The third level is identified as a set of policy instruments, e.g., positive incentive and reverse punishment to ensure the realization of milestones [10,11]. Detailed policy instruments built upon the DBSF supply chain are analyzed thoroughly in Section 4.

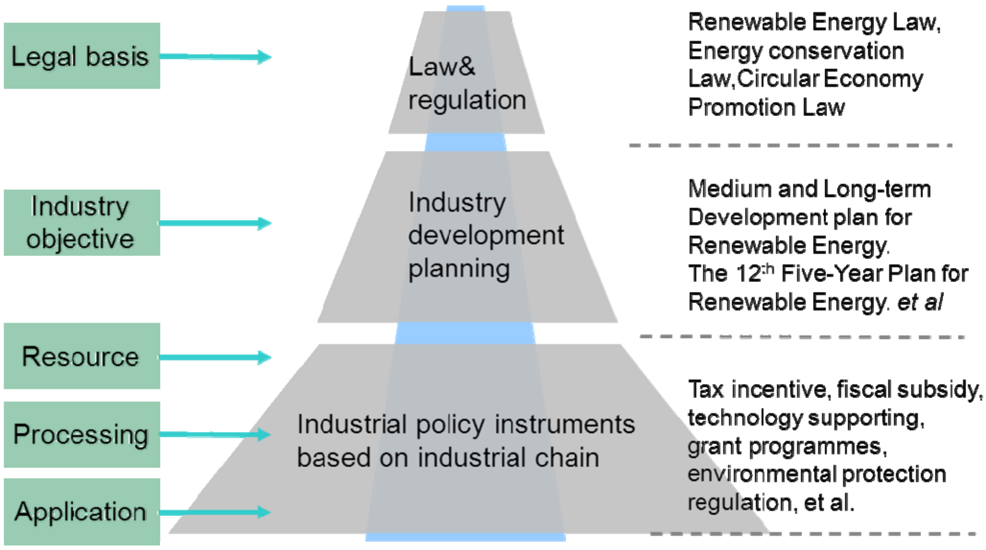

Figure 5. The conceptual framework of DBSF related policy.

3.2. Laws Related to DBSF Development

On the first level, law and regulation at the state level is shown in Table 2, e.g., the Renewable Energy Law, and the Energy Conservation Law. The legal basis laid the basis for the development of the DBSF industry aiming to limit the high-polluting industries, to encourage the development of clean energy, like DBSF utilization.

Table 2. The main laws related to DBSF in China.

No.	Name of Law	Date of Issue	Relative Items
1	"Renewable Energy Law of the People's Republic of China"	28 February 2005	Article 16: The state shall encourage clean and efficient development and use of biomass fuels.
2	"Energy Conservation Law of People's Republic of China"	28 October 2007	Article 7: The State encourages and supports development and utilization of new energy resources and renewable energy resources. Article 59: The State encourages and supports vigorous development of marsh gas, and popularizes biomass, and other renewable energy in rural areas…
3	"The Circular Economy Promotion Law of the People's Republic of China"	29 August 2008	Article 34: The state encourages and supports agricultural producers and relevant enterprises to employ advanced or applicable technologies to make a comprehensive utilization of straws of crops by-products from the processing of agricultural products. Article 35: The people's governments above county level and their departments of forestry shall ... encourage and support forestry producers and relevant enterprises to employ timber-saving and alternative technologies to make a comprehensive utilization of forestry wastes, inferior woods, short ends, fuel woods and sand shrubbery *etc.*, and improve the comprehensive utilization rate of timbers.

3.3. Plans Related to DBSF Development

On the basis of laws and regulations, the country has established a set of development planning tools, such as the Medium and Long-term Development Plan for Renewable Energy, and the Five-Year Plan for Renewable Energy in the "Eleventh Five-year" and "Twelve Five-year" periods. The core items of each plan are described in Table 3.

Table 3. The main plans to DBSF development in China.

No.	Name of Plan	Date of Issue	Relative Items
1	Medium and Long-term Development plan for Renewable Energy in China	4 September 2007	By 2020, the use of DBSF in China nationwide will reach 50 million tons. By that time, DBSF will have become a commonly used form of high quality fuel.
2	The 11th Five-Year Plan for Renewable Energy	18 March 2008	Accelerate the development of biomass energy, enlarge production capacity of DBSF...
3	The 12th Five-Year Plan for Renewable Energy	6 August 2012	By 2015, the use of DBSF in China nationwide reaches 10 million tons.

In the 11th five-year plan, there was no specific objective or indicator for DBSF industry development, except some descriptive requirements. However, the 12th five-year plan has explicitly put forward the development target of DBSF industry which illustrates DBSF can speed up development during the 12th five-year period.

4. Policy Instrument Analysis Based on DBSF Supply Chain

Central and local governments have developed and implemented a series of policy instruments to support and motivate the development of DBSF industry, e.g., financial subsidies of straw energy utilization, preferential income tax and Value Added Tax (VAT) policies, science and technology projects supporting policies, the coal-fired limits policies, *etc.* These policies have played a decisive role in promoting the production and use of DBSF. The policy instruments based on the supply chain are illustrated in Figure 6.

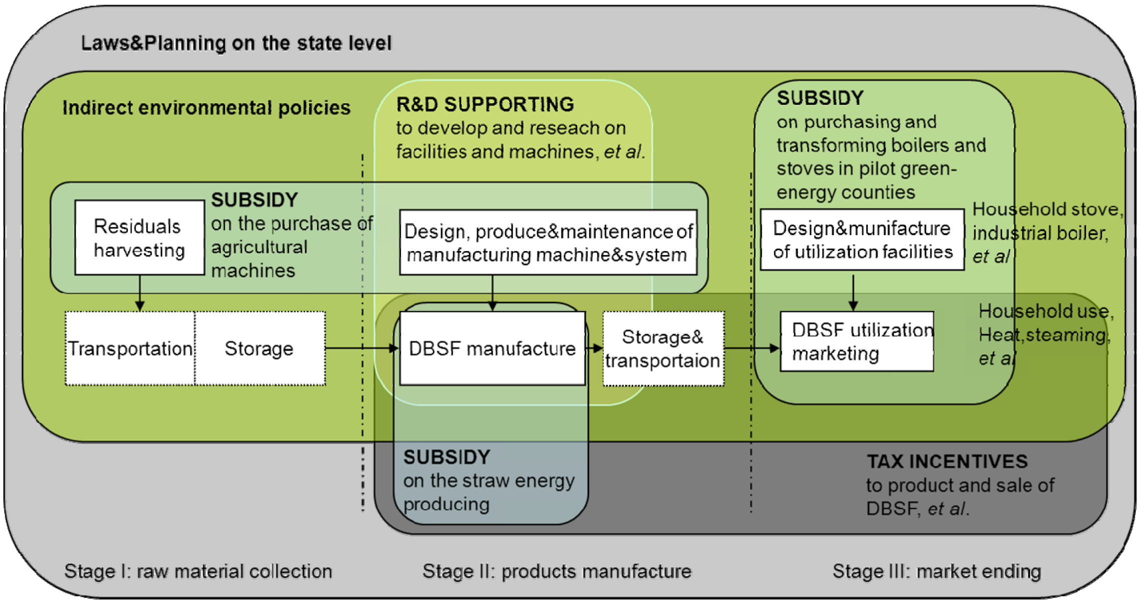

Figure 6. The policy instruments based on DBSF industry chain.

4.1. Policy Related to Resource Collection

The first phase of DBSF supply chain is defined as the collection and storage of agricultural and forestry residues. Among them, the existing policies mainly focus on the harvesting of agricultural residues. Forestry residue, as another available DBSF resource, is so far absent in the consideration of policy makers.

4.1.1. Subsidy on the Purchase of Agricultural Machines

For enterprises engaged in the harvest of agricultural residues, especially small businesses, the cost of agricultural machinery and equipment is a huge burden. In order to accelerate the pace of agricultural mechanization in China, an agricultural machinery purchase subsidy policy has been implemented in recent years. The list of equipment types in agricultural purchase subsidy policy, includes corn harvester, cotton harvester, tall crops swather, peanut harvester, rapeseed harvester, binder machine, baling machine, pick-up baler, straw chopper, peanut shelling machine, feed crusher, dryer, *etc.* [12]. A great many of these mechanical functions are coincident with those of DBSF's collection and pretreatment features. Financial subsidies on the purchase of these machines can help reduce the DBSF resource collection cost.

4.1.2. Prohibition of Burning Straw

Recent studies have shown that centralized straw burning in farmland can cause serious air pollution event. National Satellite Meteorological Center (NSMC) of China Meteorological Administration would regularly publish the information on Satellite-Remote-Sensing-Based Monitoring of Straw Burning in harvest season. It is shown that the air pollution problem is very serious caused by burning straw in Anhui, Henan, Jiangsu and other provinces in harvest season [13].

Therefore, some local governments have developed a set of corresponding local prohibiting policies of burning straw to reduce the air pollution especially in harvest season. The amount of straw returning to the field and other losses only accounts for about 20% of the total straw generation [2]. DBSF is accepted as an efficient solution for agricultural residues. In fact, the prohibition of burning straw in rural areas contributes to the local straw harvest and pretreatment, and is considered to be the driving force for the comprehensive utilization of straw and the production of DBSF.

4.2. Policy Related to DBSF Producing

The subsequent phase of the DBSF supply chain is mainly about DBSF production and processing, as well as the manufacture of DBSF production equipment. The subsidy and incentive policies are mainly inclined to this section.

4.2.1. Subsidy Funds for Straw Energy Utilization

The Ministry of Finance established funds to support the straw industrial development, and formulated "Interim Measures on financial subsidies for straw energy utilization" [14] (referred to as the "Interim Measures") in October 2008. "Interim Measures" explained that this fiscal subsidy only supports enterprises engaged in straw energy production, such as DBSF producers; enterprises applying for grant funds shall have more than 10,000 tons of annual straw usage capacity. In 2011, a total of 50 enterprises in straw energy production received the principal subsidy funds, in which 46 enterprises engaged in the production of DBSF.

4.2.2. Subsidy Policy on the Purchase of Agricultural Machines

As mentioned in Section 4.1, agricultural machinery can receive subsidy. The equipment of DBSF briquette and pellet production in the second stage of DBSF supply chain is also included in the agricultural machinery to enjoy farm machinery purchase subsidy.

4.2.3. The policy on VAT of Resource Comprehensive Utilization Products

On 21 November 2011, the Ministry of Finance and the State Administration of Taxation issued "A notice on the adjustment and improvement VAT policy on the resources comprehensive utilization and services" [15]. Enterprises such as DBSF producers can enjoy the support of immediately returning VAT, if the production uses rice husks, peanut shells, corncobs, camellia shells, cottonseed hulls, forestry residues, and small fuel wood as raw materials. In order to encourage the enterprises comprehensive utilization of agricultural and forestry residues, this policy has clarified VAT would be refundable for those DBSF production enterprises as soon as it is imposed.

4.2.4. Science and Research Project Support

Currently, the support of science and technology projects, mainly concentrated for DBSF production equipment and molding technology research and development in stage II of supply chain [16,17]. The main R&D programme on DBSF production is listed in Table 4.

Table 4. R&D programme on DBSF production in China.

Starting Year	Supporting Organization or Project	Name of Programme	Main Contents or Outputs
2006	National Key Technology R&D Program in the 11th Five year Plan	"DBSF products and equipment development" programme	R&D of the movable DBSF equipment with integrated function of the raw material pretreatment, grinding, molding process on a large scale with low energy consumption.
2011	Chinese government, the World Bank (WB) and the Global Environment Facility (GEF)	China Renewable Energy Scale-up Programme CRESP)	(1) Develop the PM485-II biomass pellet molding machine with high-efficiency and low-cost; (2) Optimization of biomass pellet fuel molding technology and equipment with low-cost; (3) R&D of biomass briquetting technology and equipment at room temperature with low power consumption, which can solve the problem of high moisture of straw materials; (4) R&D of Biomass compact molding equipment, which should complete the split ring molded briquetting machine design;
2013	National Key Technology R&D Program in the 12th Five year Plan	"Low-cost DBSF equipment research and application" programme	Within this programme, "Large-scale DBSF technology integration and industrialization demonstration" projects should form 100,000 tons of annual DBSF production capacity and 300 sets of DBSF molding equipment.

4.3. Policy Related to DBSF Application

The equipment for DBSF utilization is quite different from normal combustion equipment using coal or other fossil energy. The companies involved in stage III are classified as those who provide heat or steam using DBSF as energy and the manufacturers of DBSF boilers and stoves.

4.3.1. The Preferential Policies on Enterprise Income Tax and VAT

On 20 August 2008, "Preferential Catalogue for Enterprise Income Tax for Comprehensive Utilization of Resources" was promulgated collectively by the Ministry of Finance, the State Administration of Taxation, and the National Development and Reform Commission [18]. In this document, the types of heating companies generated by DBSF from straws and other agriculture residues were listed, which means preferential policies on Enterprise Income Tax can apply to these companies.

4.3.2. Subsidy Fund for Green Energy Counties

On 10 December 2009, the National Energy Administration published a "Notice of Recommending Green Energy Counties". The National Energy Administration, Ministry of Finance, and Ministry of Agriculture collectively organized the construction of Green Energy Demonstration Counties. Demonstration subsidy funds mainly focused on DBSF utilization project and rural energy service system.

Theoretically speaking, each project should provide heat for the daily cooking of 1000 rural households and public institutions as hospitals, schools, government institutions, kindergartens, and nursing homes. The demonstration subsidy funds should only be used for purchasing and transforming boilers and stoves using DBSF as fuel [19,20].

4.3.3. The Promotion of BDSF Boilers

Local governments established compulsive policies against burning coal or low-quality coal in urban districts, including Zhengzhou, Kunming, Shijiazhuang, Changsha, Suzhou, Ningbo, Luoyang, Weifang, *etc*. Therefore, regional environmental policies promoted the application of DBSF indirectly. For example, on 20 June 2007, Zhengzhou government published "Notice of proceeding the transformation of clean fuel boilers". The document declares the following aspects: coal-burning boilers below 10 T/h should be removed or transformed to use clean energy or clean fuel. With the implementation of the policies above, Zhengzhou greatly increased the market demand for DBSF. It has become a common scene that coal-burning boilers below 10T/h are replaced by DBSF boilers in recent years, which promoted the producing and selling of DBSF.

5. Effects of Policies on DBSD Development

5.1. The Effect on Technical and Technological Development

Researchers considered that the foremost technical bottleneck in DBSF supply chain is DBSF production [7,9], namely biomass solidification technology. In order to promote the development of biomass solidification technology, Chinese government has extended the supporting on production technology through policy incentives and R&D projects [21]. Currently, the gap between the technologies used in China and developed countries has been gradually reduced, and the direction of DBSF production technologies can be highly automatic with high thermal efficiency, less pollution, and more reasonable process.

Many studies suggest that the main technical barriers of DBSF development in China focus on the manufacturing technologies in stage II. However, the main technical issues also exist in the collection phase and application market. One of the major challenges in DBSF supply chains is to ensure that raw material is exploited in a resource efficient manner [22]. There exist evidences that resource consumption for energy production is often implemented without setting a proper plan of replacement planting [23,24]. Considering the seasonality and instability of biomass resources, these inefficiencies could trigger future scarcities of biomass feedstocks, baffling the resilience of biomass supply chains. The research proved that the current feedstock management systems find it extremely difficult to meet the requirements of large scale bioenergy developments, because they are only designed for small-to-medium scale handling and logistics requirements. Therefore, resource and supply chain efficiencies and process productivity consist of the main technical or technological factors of biomass supply chains, and current studies should consider the whole DBSF supply chain.

5.2. The Effect on DBSF Production Enterprises

Through data collection of the companies who gained grant fund of straw energy utilization, and trade information statistics from the Industry Bureau registration website, this paper has compiled a DBSF enterprise distribution map in China, as shown in Figure 7. Enterprises with an annual DBSF production capacity of less than 10 thousand tons are not involved in the statistical data.

Figure 7. The distribution of DBSF production enterprise in China.

It is illustrated that the production enterprises are mainly situated in Hebei, Shandong, Henan, Heilongjiang, Jiangsu, and Guangdong provinces. The district setting of production Enterprises in China mainly follows the proximity-based principle, to reduce transportation and storage costs of raw materials. Henan, Hebei, and Shandong are China's major crop production regions, and Heilongjiang Province is among the main national grain bases, that all could provide abundant agricultural biomass resources. Meanwhile, the environmental protection policy and the incentive subsidy could be the main driving forces behind DBSF production in these three provinces. The local prohibition of straw burning guides the peasants to find a reasonable disposal method of agricultural residues. Subsidy on the manufacturing machines and tax incentives like VAT actually has positive effect on enterprises establishment and development.

Otherwise, the impetus of the regions in Jiangsu, Guangdong and other provinces for the most part relies on the vigorous demand for energy, as they are all located in coastal areas and classified as developed areas with higher industrial production output values. These regions need the multiple schemes of fossil energy alternatives, and DBSF is selected as energy supplement. In the same way, medium-density agricultural crops and forest resources in Jiangsu and Guangdong province reflect sufficient raw materials could meet the DBSF production demands. The subsidy and tax incentive cannot be considered as the core elements of positive effects but the energy demands, that a little different from above regions.

5.3. The Effect on DBSF Market Utilization

The market is the major benchmark of industrial development; therefore, only the products can meet the market demand and gain market recognition and acceptance, which will ultimately drive the rational industry development. The annual DBSF consumption amount in China has been concluded and illustrated in Figure 8. DBSF industry is among the latecomers to the Chinese market, and the initial stage could be identified from 2004 to 2010. Until 2010, the annual consumption amount of DBSF was only 2.5 million tons [9]. Resent policy instruments seem not to play a powerful role in pushing the DBSF utilization in stage III of supply chain.

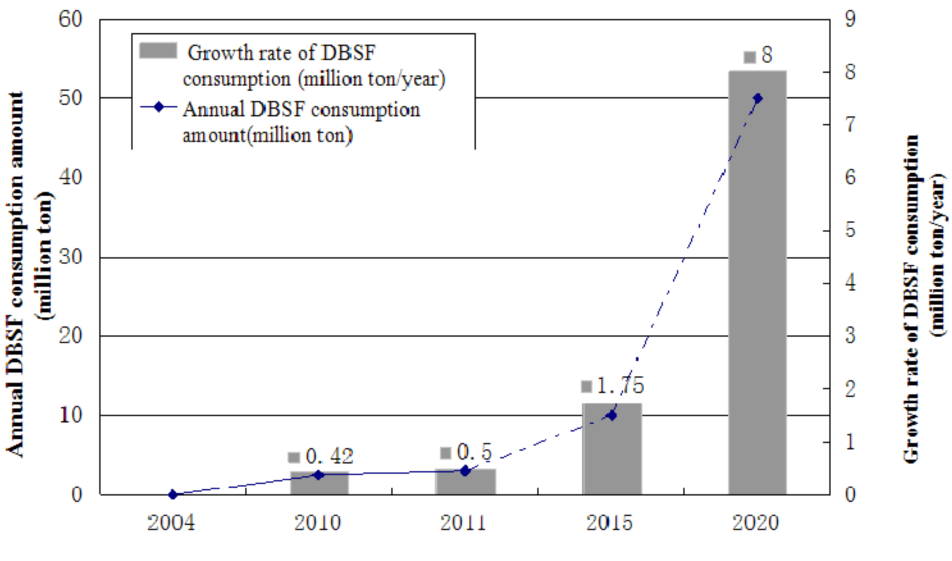

Figure 8. The annual DBSF consumption amount and growth rate in China.

According to "Medium and Long-term Development plan for Renewable Energy in China", the annual consumption of DBSF in China should reach 10 million tons until 2015 and 50 million tons in 2020. That indicates an annual growth rate of DBSF consumption rises up to 8 million tons per year from 2016 to 2020. In order to achieve this speed of development, China needs to enter the stage of rapid development of DBSF industry during the year of 2016 to 2020.

5.4. The Effect on Environment and Economy Improvement

DBSF production and application has solved the growing problem that tons of agricultural and forestry residues stack *in situ*, and tend to eliminate chaotic and direct burning of biomass resources. Promotion policies have made DBSF a substitute for coal as energy resource with less ash and lower SO_2/NO_x [20,21]. DBSF utilization would decrease the atmosphere pollution caused by the combustion of coal or other fossil energy. According to the plan data in 2015, the annual consumption amount of DBSF is up to 1.75 million tons, equivalent to reducing 875 thousand tons of coal usage. To some extent, DBSF utilization in most rural families can also decrease the use of firewood to improve indoor air-quality and peasants' living conditions.

Moreover, local peasants would increase their incomes through the harvesting and collecting of agricultural and forestry residues. Coming to the fee of 150 Yuan per ton of straw, it would increase local farmers' income by about 150 million Yuan when the amount of straw harvesting reaches 1 million tons. During the process of DBSF harvesting and production, plenty of job opportunities would be provided that is beneficial to absorb social surplus labors. Obviously, through the promotion policies of DBSF utilization, it is proven to bring positive economic, social and ecological benefits in China.

6. Suggestions

By sorting and analyzing the policies on DBSF development, we submit some suggestions as follows.

(1) The resources of DBSF are classified as wood and agricultural residues. Among these, wood material only occupies a small portion of DBSF utilization. Unlike energy utilization of straws, which has subsidies from central government, the production cost of wood (pellet) molding fuel is relatively high. Unless the users have strict demands on the quality of molding fuel, general users cannot afford the high cost of wood particles molding fuel. As a result, developing a specialized subsidy policy for DBSF that use forestry residues as raw material is necessary. There are subsidies, awards, and tax preference and reduction policies on the production and utilization of DBSF that come from agricultural residues. Now these preferential policies should also apply to DBSF that use forestry residues as raw materials.

(2) By analyzing each preferential policy of the supply chain, we conclude that these policies tend towards intermediate link—DBSF production. Moreover, expanding production scale and improving productivity of DBSF is considered to be the vital themes for China's DBSF development by government and research institutes. In contrast, there exists few influential policies on resource harvesting, collection and market utilization. In the field of scientific research projects, however, it is particularly imbalanced and extremely centralized. Input for scientific research is restricted in the upstream and downstream of the supply chain. From this view, state-supporting science and technology projects in DBSF should

concern the technical bottlenecks from the whole supply chain, combining the strength of enterprises, universities and research institutions.

(3) In fact, the promotion driving dynamics differ from province to province and the incentives play a different role of DBSF market in different provinces. The central government has established industrial development goals, so it is necessary to distribute these goals to each province and autonomous region based on resources, markets, funds, development foundations and market demands. Provincial governments should have specific implementing regulations for each plan on the development of DBSF, such as a comprehensive utilization plan for straw, a forestry energy plan, a circular economy plan, *etc*. One of the conditions in the implementation of a specific plan is to enhance the management of the plan. Concretely speaking, the management should include the distribution of the plan goals and the establishment of implementing regulations.

(4) Once the supporting projects or incentives suspend, how is the sustainable development of biomass utilized, especially DBSF? This is a realistic question for most developing countries. As for the construction project of green energy demonstration counties in China, there are a few unsolved problems after the construction of the DBSF project. The first is how to make the sales of DBSF continuous in rural market and another is to ensure companies that invest on these projects have sustainable proper profits. Therefore, that makes the policy makers contemplate the idea that the present policy should be sustainable.

7. Conclusions

China has endowed with abundant biomass resources, such as forestry and agricultural residues, to promote DBSF utilization. However, due to the seasonality and instability of agricultural and forestry resources, imbalance in resources such as feedstocks could trigger future scarcities of DBSF productivity, baffling the resilience of biomass supply chains. In this research, China's DBSF policies were reviewed and analyzed based on the views of supply chain.

The policy framework has been categorized as three levels. Policies on laws and plans have an important directing impact on the strategy and schedule of DBSF industrial development. The third level is defined as a set of policy instruments, e.g., financial subsidy, tax incentive, and R&D project support, which would ensure the realization of DBSF development milestones. Policy has a straightforward boosting or restraining influences on company operations.

Through the analysis of current policies based on the supply chain, weak links in contemporary policy systems have been described. The present DBSF market is on a small scale, lack of balance in supply chain, and short of market drive, which severely restrains the healthy development of DBSF industry. The effects of policies on R&D, production enterprises distribution, market utilization and environment and economy have been analyzed, and then proposed some suggestions. The policy makers also should be concerned with the bottlenecks from the view of whole supply chain, combining the strength of local governments, enterprises, universities and research institutions. Overall, the policy framework is important for authorities to manage and achieve the DBSF development objective in the future.

Acknowledgments

This paper was financially supported by the Supporting Program of the "Twelfth Five-year Plan" for Sci & Tech Research of China (2012BAD15B05).

Conflicts of Interest

The authors declare no conflict of interest.

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