Research article

Supply Chain Analysis for Determining the Requirements for Continuous Woody Biomass Energy Utilization Systems: Comparison of the Actual Management Conditions in Japan

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Abstract In Japan, the number of newly constructed woody biomass power plants are expected to increase with the introduction of the Feed in Tariff mechanism. However, many woody biomass energy plants, including heat supply systems, face difficulties because of issues such as high fuel costs and find it difficult to maintaining a stable supply. This study aims to reveal the requirements for continuous business regarding woody biomass energy, focusing on four factors: wood supply, fuel manufacturing, energy supply, and energy demand. Specifically, we selected multiple Japanese cases that focus on the types of woody fuels such as cordwood, wood chips, and wood pellets, conducted semi-structured interviews, and compared and examined how their supply chains successfully developed. We found that integral cooperation among the four factors was essential, and support regarding each factor, economic viability, as well as balanced supply and demand for wood were necessary for ensuring continuous woody biomass energy utilization systems.

Keywords renewable energy, forest industry, regional revitalization, wood fuels

INTRODUCTION

In regions with abundant forests, woody biomass is a potentially promising renewable energy resource and is expected to develop into a regional industry. In Japan, the utilization of woody biomass to generate electric power expanded with the introduction of the Feed in Tariff (FIT) in 2012, which resulted in the construction of woody biomass power plants in various parts of the country. In addition, energy supply systems using woody biomass heat were being introduced as government subsidized projects. After a biomass energy system has been created, trees must be cut down and transported from the forests to produce fuel. Fuel has to be fed to heat boilers; its combustion must also be controlled. Therefore, to ensure the continuity of a biomass energy system, it is vital to establish a stable system to supply woody fuel from the upstream to the downstream end of the system.

This study was based on the idea that it was important to build a supply chain that ensures business feasibility for organizations that stabilize supply, and maintain cooperative relationships between these organizations. For a biomass supply chain, of course it was important to balance expenditures and income to ensure continuous operation. Further, because of the large number of

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organizations characteristically involved, business feasibility and inter-organizational relationships were selected as the themes of this study. Regarding woody biomass energy utilization systems, Raychaudhuri (2015) surveyed the literature on biomass supply chains in some countries in Asia and Europe, but Japan was not included. Becker (2011) suggested supply chain analysis framework for assessing policies in the United States. Tahvanainen (2011) and Yoshida (2016) analyzed costs of wood chip supply chains in Europe and the US respectively. In Japan Sato (2015) designed a model for wood biomass supply chains in Tohoku area. However, there was no research related to biomass energy utilization systems in Japan that evaluated actual supply chains from the perspective of business feasibility. Further, there was very little research on the supply chains of the systems in Japan from the perspective of inter-organizational relationships and the balance between biomass supply and demand among the players. Therefore, this study analyzed supply chains from three perspectives: business feasibility, the related inter-organizational relationships and the balance between biomass supply and demand.

OBJECTIVE

This study examined Japan's woody biomass energy utilization systems that utilize forest resources in order to identify the entire supply chain formed by a series of linked business organizations, and the state of operation of each constituent player in this supply chain based on actual cases. Next, based on the information obtained, the supply chain and its constituent players were analyzed from the perspectives of their business feasibility and inter-organizational relationships and the balance between biomass supply and demand among the players in order to state the conditions required to ensure the continuity of the system.

METHODOLOGY

This study proposed the framework shown in Fig. 1, which divided the supply chain for a woody biomass energy utilization system into four constituents: raw material supply, fuel production, energy supply, and energy demand. For a system to be sustainable each player in the system should have business feasibility and all players should be interconnected. Raw material supply referred to the cutting of trees in the forest, the transportation, and sale of timber. Fuel production referred to the production and/or sale of woody fuel (including firewood chips or pellets). Energy supply included burning woody fuel in the equipment and supplying the energy to users as heat or electric power. Energy demand referred to consumption of electric power or heat for air conditioning, hot water in households, businesses, public baths, and similar facilities.

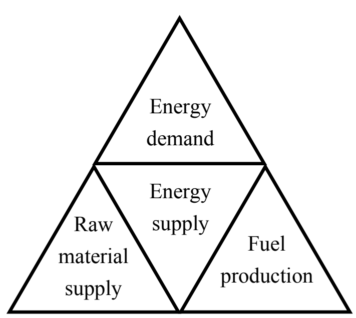

Fig. 1 Analysis framework of the woody biomass energy system

This study evaluated the four constituents of the supply chain of a woody biomass energy system from the following three perspectives. The first was the business feasibility of each constituent player,

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whether each could be established alone without the support of external financial subsidy. The second perspective was the relationship between the constituent players. The third was the balance between biomass supply and demand among the players. To build a supply chain, the links between its players were indispensable. It was also important for them to establish business relationships to ensure smooth business. Moreover, it was equally important that they balance biomass supply and demand through the links between them.

This study conducted a survey to analyze a supply chain consisting of the four constituents explained above by selecting six cases as typical energy utilization systems from among energy systems such as electric power systems, heat systems. The six cases selected were shown in Table 1. The supply chain and constituent players of the energy systems in each of these cases were shown in Table 2. In Cases D, E, and F, local governments played major roles in building the overall supply chains; therefore, these local governments as supporter were also included in our study.

Semi-structured interviews were conducted. The questions dealt with the business which the player conducts, stakeholders such as its suppliers and customers, quantities of biomass-related products it acquired and sold, business costs such as the cost of production equipment, total sales, business prospects, and business challenges. The interviews were conducted from August 2014 to September 2016.

Table 1 Cases analyzed

Case	Form of fuel	Energy equipment	Energy demand	Amount of biomass fuel (wet-t/y)
A	Firewood	Stoves	Heating	1,900
B	Firewood	Boilers	Hot water	300
C	Chips	Generator	Electric power generation	20,000
D	Chips	Boilers	Cooling/Heating/Hot water	1,600
E	Pellets	Stoves/boilers	Heating/Hot water	500
F	Pellets	Stoves/boilers	Heating/Hot water	1,300

Table 2 The supply chain and constituent players in each case

Case	Raw material supply	Fuel production	Energy supply	Energy demand	Supporter
A	Forestry association, Citizens association, Independent forester	Company selling wood stoves	Households	Households	—
B	Independent forester	Community group	Public baths	Public baths	City government
C	Lumber company, Orchard operator	Private enterprises	Electric power utility	Households	—
D	Lumber company	Sawmill operator	Third-sector	Public facility	Town government
E	Sawmill operator	Third-sector	Public facility Households	Public facility Households	City government
F	Forestry association	Cooperative association	Public facility, Business office	Public facility, Business office	City government

RESULTS AND DISCUSSION

1) Case A (wood stoves)

The system was principally supplying firewood for use in wood stoves used to heat households. With regards to raw material supply, suppliers sorted out raw timber from managed forests for lumber and firewood. With regard to fuel production, a wood stove company purchased the raw material and part-

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time workers used wood-splitting machines to process and naturally dried the material for producing firewood. The processing was partly contracted to the raw material suppliers. Households equipped with wood stoves purchased the firewood and used the energy to heat up their households.

The wood stove company established the supply chain. It had developed its firewood supply system and home-delivery service, which helped to expand its wood stove market. Concurrently, the demand for firewood rapidly surpassed forecasts, and with the production unable to keep up, stocks became inadequate. This in turn led to deliveries being made after artificially drying the firewood for a temporary duration. While the firewood fuel production system had balanced incomes and expenditures, profits from new wood stove sales were higher; therefore, firewood fuel production was not the principal business of the organization.

2) Case B (firewood boiler)

The system comprised a community group processing raw timber, which was supplied by independent foresters, into firewood, which was subsequently supplied for use in a firewood boiler used to meet the demand for hot water in public baths. In this case, the community group led the establishment of the supply chain by forming an organization that purchased raw timber and made firewood. It purchased the timber, with half of the necessary funds contributed by a local government. It built three yards (places to collect thinned wood), and in addition to firewood, handled the timber to sell to paper makers. It also encouraged independent foresters to receive forestry training. A firewood boiler was installed with the support of subsidies that covered two-thirds of the cost.

3) Case C (generating electricity with chips)

The system was the supply of woody chips for fuel to a woody biomass power plant. In this case, an electric power utility built the supply chain. Fuel production was performed by a company affiliated with the power utility. The fuel production company signed raw material contracts with a group of lumber companies in order to stabilize supplies of raw material. The raw material consisted of about 80% thinned wood, and woody waste was 20%. Energy supply was achieved by burning wood chips to generate electric power for households. The purchase price of the electric power was supported by FIT system, such that the power could be bought for a good price in relation to the overall production costs set according to the type of raw material used as the woody fuel.

4) Case D (chip-powered boilers)

In this system, wood chips were supplied to a biomass boiler that supplied heat to a group of public facilities. The town built the supply chain. At the suggestion of the town, a wood chip company financed by a lumber company and a sawmill operator was established. Energy supply was the role of the third-sector public company that operated and maintained chip boilers owned by the town. The cost of installing the three boilers was incurred by the town, prefecture and national government subsidy. It cut the total value of fossil fuel costs in 2013 by 38.6 million yen per year. On the other hand, the town paid 38 million yen for chip supply and equipment management. The town not only bore the cost of the chip production facility, it also signed supply contracts to help stabilize the income earned by the system for stable supply of the fuel.

5) Case E (pellet stoves and pellet boilers)

In this system, a city built a supply chain as a pellet production system to utilize forest resources. The raw material (chip dust) for pellets was provided by chipmakers. In fuel production, a third-sector company was formed with funds invested by the city, a forestry association, and small-scale shareholders. Total funding for the fuel production equipment was provided by the city and national

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government subsidy. Initially, it was predicted that it would supply pellets for stoves in households. However, because stoves had not gained as much ground as was expected, most of the pellet was consumed by the city hall, schools, and welfare facilities.

6) Case F (pellet stoves and pellet boilers)

In this system, pellets were supplied to stoves in business offices and to pellet boilers installed in public baths in a city. Regarding raw material supply, raw timber was supplied through a market. In fuel production, a cooperative association produced chips for paper makers in addition to those used to produce pellets. Energy supply and demand were primarily regarding pellet boilers and pellet stoves owned by the city along with demand for hot water supply and heating. The city led the development of the supply chain. It supported the formation of a cooperative association to manufacture pellets and worked to create demand for these pellets in order to revitalize the forestry industry. The city installed pellet boilers in public facilities, and pellet stoves in schools.

Analysis of the Supply Chain from Three Perspectives

1) Business Feasibility of Constituent Players

As seen from the six cases, in all systems, each constituent system could be operated stably. However, it could not be concluded that their systems were established economically, as many of these constituent players covered costs of equipment for fuel production and energy supply with subsidies. In Case C, it was clear that the system could continue as long as the FIT system was maintained. Regarding Case A which acquired no subsidy, the system was established in combination with other business. The system was achieved by combining the production of firewood with the sale of stoves. In addition, there were also cases where a player established its own systems in combination with other business. Regarding fuel production in Case B and F, biomass was a source of secondary income for the players. They manufactured and sold materials to paper makers separately from biomass energy utilization systems. Previous studies state that business feasibility requires an increase in efficiency through measures such as increasing the scale of fuel production or changing the location of the chipper, or financial assistance to initial investments in each system. However, these studies do not discuss combining different businesses together.

2) Interrelationships between Constituent Players

An analysis of the six cases confirmed that private companies, administrative bodies, or community groups acted as the builders of supply chains by creating business relationships between the various players. Moreover, even after a supply chain had been constructed, the local government was seen to play the role of overall manager of the chain in Case D, E and F. There were also cases where the builders also took part in the formation of constituent players or fuel production system of the supply chain in Case A, B and C. For example, in Case B, a community group created a purchasing system and provided independent foresters with practical forestry training. It also assisted with preparations of subsidy requests to introduce firewood boilers that would be later supplied with firewood through the system. Previous studies point to the need of coordinating with the stake holders and present case studies where timber owners manage their businesses by outsourcing of fuel production. The role of the supply chain builders in our study incorporates all these activities.

3) Balanced Biomass Supply and Demand between Organizations

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In many cases each constituent ensured multiple suppliers and purchasers in order to prepare for fluctuations in demand for their energy systems. For example, in Case A, the firewood producer associated with multiple suppliers, and also entrusted to the suppliers some part of processes in firewood production. While in Cases D, E and F, the local governments created a large demand by increasing the number of boilers in public facilities. Even after their supply chains were completed and the systems were in operation, there were cases where it was important to watch the flow of biomass throughout the supply chain and overcome problems of quality control in the fuel and the supply system. In both ways, the builders of the supply chains played important roles. Previous studies mention the need for securing storage space, temporary workers for fuel production or the importance of communication between upstream and downstream stakeholders. The multiple suppliers and purchasers in our research extend these aspects and add management of energy demand.

DISCUSSION

Conditions of economic support for the supply chains were different between the electric power generation system and the heat system in which stoves or boilers operated. The FIT system was available for electric power generation systems, and the system economically ensured the continuity of sales. In the case of heat system, although subsidies were available to cover cost such as introducing boiler for the heat supply systems, there were no systems designed to ensure continuous operation of the heat supply system along the overall supply chain. The economic difficulty in establishing a heat system could be analyzed through the following two aspects. Firstly, the heat system competed with low-priced energy systems, such as fossil fuel. Secondly, some regions would have small or no markets for the heat system. These regions faced challenges such as few sellers of woody fuel or materials and fluctuations in supply and demand.

In the light of the above underlying circumstances, followings steps were being taken. With regards to the first point, players were believed to have established systems by combining the biomass energy business with other businesses. But, it relied on capabilities and size of the business management of the players. With regards to the second point, it was necessary for a local government or community group to build the supply chain. They should encourage the players to cooperate, help the players to obtain public fund for fuel production equipment and create heat demands in regional and public facilities. In addition to a balanced wood fuel supply and demand, the builders of the supply chain needed to encourage players to have multiple suppliers and purchasers in regions where there were no markets to trade inventory shortfalls or surpluses. Besides this, supply chain builders could not exist in all regions because it depended on the capability of the builders and their financial conditions. Therefore, just like an electric power generating system, a heat supply system also would require a system to support the overall supply chain. It was thought to be important to create, for example, a system to correct the price gap between fossil and woody fuel, or a system to subsidize the purchase price of the biomass fuel or the heat supplied.

In terms of future challenge, this study couldn't include wood biomass combined heat and power systems because of no such systems operating stably in Japan at the time of the survey. It was predicted that the future construction of many biomass power plants would rapidly increase the demand for wood and raise its price. Therefore, even in the cases surveyed for this study, changing the supply constituents would be unavoidable. These issues will have to be taken up in a future survey.

CONCLUSION

This study was undertaken by conducting interviews concerning six cases in order to clarify the requirements for continuous stable operation of biomass energy utilization systems using forest resources in Japan. The supply chains in each case were divided into four constituents and analyzed from three perspectives, that is business feasibility, relationship among constituents, and balance of the biomass supply and demand. The results showed that the following conditions were required to continuously operate a woody biomass energy utilization system.

1) For the constituent players, combining the biomass energy utilization system with another business was necessary in order to ensure business feasibility.
2) In order to link the four constituents, it was important that there was a supply chain builder to establish the necessary constituent players where none existed and to interconnect these players.
3) It was necessary to ensure multiple suppliers and purchasers for balancing the flow of materials in demand and supply between the constituents.
4) A system such as FIT for electric power systems was also necessary for heat supply systems in order to ensure the business continuity of the entire supply chain.

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