B-52 Study On The Technology Of Generating Electricity With A Woody Biomass And Supplying Capacity Of Biomass Resources

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1. Introduction

Although biomass energy has attracted a great deal of attention in view of global warming and Kyoto protocol, there are few commercial plants of woody-biomass energy in Japan. For practical uses of woody-biomass energy, it is necessary not only to develop technologies of generating electricity with a woody biomass, but also to evaluate forest resources and supply systems by socioeconomic approaches.

2.Research Objective

The objective of this study is to evaluate potentiality of generating electricity with a woody biomass and supplying capacity of woody-biomass resources. This study has four subjects. First is to evaluate supplying capacity of domestic woody-biomass resources using forest inventory and methods of forestry mensuration. Second is to evaluate supplying capacity of overseas woody-biomass resources, focusing on Eucalyptus in Thailand. Third is to evaluate the technology on generating electricity with a woody biomass. Fourth is to establish woody bio-energy supply system with sustainable woody-biomass resources, including researches of existing bio-energy systems and a feasibility study.

3.Results

(1) Evaluation Potentiality Woody-Biomass Resources In Japan

We estimated maximum supply of woody biomass for fuel of Japan origin domestic Japanese forest by a calculation model. This woody biomass consists of residual of forestry activity and sawmill such as treetop, root-stump, bark, branch, leaf, and mill-waste and extra growth of Japanese forest exclude prohibition of felling forest and growth for the Kyoto protocol 3rd article Sub-Section 4. The quantity of unused biomass origin forestry activity and sawmill was estimated about 6.7 million dry-weight ton/yr by at 1995. Maximum supply of

woody biomass with extra growth was estimated about 25 million dry-weight ton/yr by at 1995. This is equivalent to about 2.3% of the first energy consumption of Japan in 2000.

And we make more detailed unused biomass calculation model in Touno city, Iwate prefecture for Sugi cedar and Japanese Larix, by use investigated data of tree diameter distribution, taper curve, bark thickness, distribution ratio of the trunk/branch/leaf, waste at felling site, and waste at saw-mill. The biomass of a Sugi was estimated about 130 ton/ha at 50 years old at medium site class and the saw-dust, stem butt crookedness, leaf and intermediate waste log are much. The biomass of a Larix is estimated about 90 ton/ha at 50 years old at medium site class and the saw-dust, branch and stem butt crookedness are much (Fig.1). In broadleaf forest, the residual biomass is about 25ton/ha in almost felling site. We estimated woody-biomass supply is about 43 thousand ton/yr in Touno city.

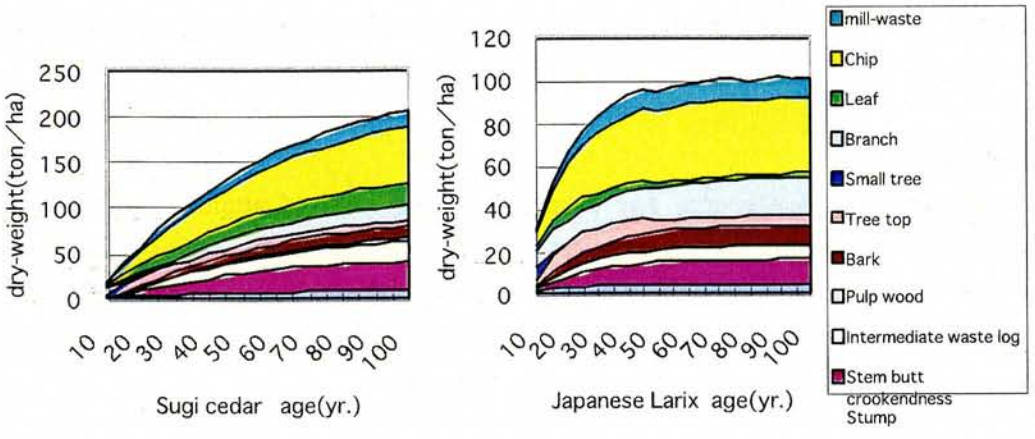

Fig.1 Unused biomass of Sugi cedar and Japanese Larix stand in Touno area, Iwate prefecture at medium site class.

(2) Evaluation of supplying capacity of overseas woody-biomass resources

Based on field surveys of Eucalyptus plantations in northeast Thailand, a framework to estimate potentiality of biomass supply was developed (Fig.2). The framework shows following steps to estimate potentiality of biomass supply. Firstly, area of farmlands that are suited for Eucalyptus plantation is estimated using land-use maps and maps of salt affected soils. Secondly, a ratio of available area of plantation is estimated by socio-economics survey that interviews to land owners on intent to plantation. Thirdly, productivity per unit are estimated based on field surveys and biomass investigations. At last, potentiality of biomass production is estimated by multiplying the area of available farmlands, the ratio of available plantation area and the productivity per unit.

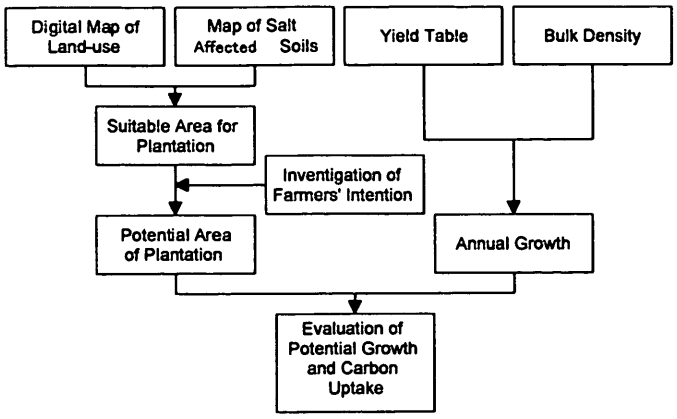

Fig.2 Framework to estimate potentiality of biomass supply

Using the land-use map of Thailand in Global maps and the salt affected soil map by Department of land development and UN Mekong secretariat, area of farmlands that are suitable for Eucalyptus plantation was estimated to be 716,000 ha in Nakhon Ratchashima province. Interviews to land owners on intent to plantation showed that a determining factor to Eucalyptus plantation is size of land area, and led a regression equation on land areas to plantation areas. Using the equation and ratios of land area to total areas for land size classes, 13.7% of farmlands was estimated to be available for Eucalyptus plantation in Nakhon Ratchashima province.

Using results of biomass surveys of Eucalyptus plantations, yield tables for Nakhon Ratchashima province and Konkaen province was developed. Because it shows dry weight of stems is 47 t/ha at 5 years old as a standard harvest age, biomass productivity of Eucalyptus plantations was evaluated to be 9.4 t/ha/y or 4.7 Carbon t/ha/y.

Integrating the results above, area of available farmlands for Eucalyptus plantation in Nakhon Ratchashima province was evaluated to be 98,000ha, and potentiality of biomass was evaluated to be 920,000 t/y or 460,000 carbon t/y there.

However, biomass production by Eucalyptus plantation have been saturated or close to excess production. Therefore, if CDM promotes plantation without optional political measures such as subsidy for plantation and development of new demands, it would destroy wood-chip markets there. Especially, it would be effective for both CDM and domestic economics that bio-energy utilization makes new markets for biomass production.

The method to evaluate potentiality of wood biomass productivity was developed focusing on Eucalyptus plantation as CDM. The method is based on not only evaluation of available land by land uses and conditions, but also more realistic evaluation by socioeconomics investigation. Although available land uses and conditions for plantation may vary in districts and countries, the basic concept of the method that is a combination of scientific and socioeconomics investigation must be available for any projects.

(3) Evaluation Of Technology On Generating Electricity With A Woody Biomass

1) Assessing technologies for converting energy from woody biomass

We calculated the CO2 reduction for biomass conversion technologies of direct combustion-power generation, gasification-power generation, pyrolysis (for diesel engine-driven power generation), and ethanol fermentation (for diesel engine-driven power generation). Two transport scenarios in which power generation plant was located close to or far from biomass plantation field were considered. The result shows that among four technologies examined gasification-power generation was the most effective technology for net CO2 reduction. The amount of net CO2 reduction for gasification-power generation was 420 kg-C/t-biomass for 50km of a distance between power generation plant and plantation field and 28 kg-C/t-biomass for 20000 km of the distance.

2) Exploration of local distributed power generation systems in Japan

To examine the combustion-power and/or gasification-power generation use of biomass in Japan, we considered the appropriate scale of generation technology and the system that would suit the characteristics of a hypothesized model region. To obtain data for suitable capacity, we investigated data and references of combustion and/or gasification-power generation using woody biomass in Japan, and compared relations of capacity and electricity efficiency. Results showed that in a small city (population of about 30,000) in Japan's Tohoku region, small distributed power generation using micro gas turbine cogeneration (300 kW, multiple units) or gas engine cogeneration (100 kW, multiple units) would be suitable; if 300-kW micro gas turbine cogeneration were used, it would require 24.7 AD-t/day, which is an amount of woody biomass that this city would be able to supply.

3) Cost estimation

We investigated the cost of combustion-power generation using biomass in Japan through questionnaires. The result shows the capacity of biomass power generation plant ranged from 300 kW to 9500 kW and the mean cost of biomass power generation of 50.2 yen/kWh. The cost of biomass power generation more than 1 MW and 24 hour operation through a year was competitive with that of coal-fired power generation that was modified for CO2 reduction. Research on the cost of biomass power generation in foreign countries shows the capacity of biomass power generation plant ranged from 1000 kW to 100000 kW and the mean cost of biomass power generation of 10.9 yen/kWh. Although the mean const in Japan was higher than that in foreign countries, at the same plant capacity the cost in Japan became competitive with that in foreign countries.

We estimated the cost of ethanol production from woody-biomass fermentation in Japan through the research on ethanol production in foreign countries. Estimated cost of ethanol was 83.7 yen/L-ethanol and competitive with the present domestic cost of ethanol production of 85.5 yen/L for fermentation ethanol and 73.7 yen/L for synthesized ethanol.

(4)Study On Conditions To Form Supply System Of Woody-Biomass Energy

Woody-biomass energy utilization is very limited in Japan, because of the lack of the

systems such as fuel supply, efficient combustion plant and sufficient energy distribution. This research is to analyze conditions and solutions for promoting of woody-biomass energy utilization. First of all, present situations of woody-biomass energy and other European countries and encouragement politics on woody-biomass energy utilization in Japan is studied. Since forest industries are closely related to woody biomass, the potentiality of residue use for biomass energy in a sawmill in Japan is assessed secondary.

By using findings obtained from the above analysis, we estimate economical supply amount of logging residue and residues from timber processing in Tohno city by developing a estimation method for woody-biomass supply. Appropriate biomass energy plant size, combustion techniques, its feasibility, and conditions for its promotion are also studied with the results. Finally, we estimate long-term availability of woody-biomass resources in the city by developing a forecast model with the forest/forestry sector.

1) Conditions of use potential and promotion of woody biomass as an energy source

Demolition wood, waste wood and forest residues like branches and tops left in the forests are favorable woody bioenergy source. However, their collecting costs must be reduced in order to compete fossil fuel costs. It will be possible that pellet stoves and boilers, small scale regional thermal energy supply plants that will be able to supply energy to limited small area in a city will be popular in Japan.

Though citizens and local government officials are gradually interested in woody bioenergy use for environmental conservation, local economic activation activities and prevention against global warming, exact and useful information regarding construction of woody bioenergy plants, energy supply costs, some kinds of pellet stoves, and etc. are insufficient. It is very important to inform in terms of woody bioenergy to them.

2) Study on systematization of the sawing residue use for bioenergy in sawing process in Japan

On the basis of the investigation into the actual conditions of the large-scale sawmills, we developed the wood processing model that was handling the use of sawing residues as a new energy source for wood drying using system dynamics, and used the system dynamics model in the analysis of the potentiality of the sawing residue use.

In the case of the sawmill which processes domestic logs (Sugi and Hinoki) of 2,500m^3 per month, steam supply of wood waste burning boiler which burns mainly moulder shavings reaches at about 50% of total steam supply for wood drying.

As a result of sensitivity analysis of the model, it was clarified that to construct the combustion system for efficient use of unutilized bark was very effective in order to enhance the share of steam supply on the basis of utilization of sawing residues. Besides, results of the analysis showed that the sawing residue combustion system lowered the energy cost for wood drying. Replacing fossil fuels with sawing residues as the energy source will be both economic and environmental advantages to the Japanese sawmill industry.

3) Feasibility on Woody-biomass energy utilization in Tohno city

Woody-biomass supply potential in Tohno region was estimated through statistical method by using timber production and processing statistics and biomass yield table. This table was obtained from modification of empirical yield table by parameters led from surveys, such as trunk shape curve, diameter distribution, formula of bark thickness, log making patterns and recovery rate of log from standing volume. Woody-biomass supply price was also estimated under an assumption which logging residues will be transported cheaply after chipped on timber yard.

Public facilities located in city center of Tohno were chosen to assess the heat and power demand. As a result, we decided that small/medium size, gasification plant and gas engine was appropriate to be installed. From the view point of plant location and energy transfer methods, we made four scenarios, constructing gasification plant in Tohno wood processing complex which is located 6.5km far from the city center, A: transferring gas to gas engine by pipeline, B: transferring gas to gas engine by cylinders, constructing energy plant in the city center, C: gasification and gas engine, D: ordinary combustion and steam turbine

The amount of woody biomass in Tohno region, logging residues is almost three times lager than sawmill residues. To increase woody-biomass supply, it is important to establish a system for collecting logging residues cheaply and to activate forest sector. Comparing unit heat price of woody biomass to that of heavy oil, sawmill residues, except chip for pulp, are feasible for thermal utilization, and logging residues are also feasible, except thinned trees pre-commercially. However, from the point of view of electricity production, those biomass could not be feasible by using steam turbine generation, but by using future gasification techniques.

Economically feasible amount of woody-biomass supply in Tohno was estimated as 6,500 t/yr. This is relatively small, but it could be increased cities up to 17,000 t/yr by collecting biomass from neighboring cities. In the latter case, allocation of biomass plant must be considered carefully.

Results from scenario analysis, revenue from plant operation will only be positive in case of C, onsite gasification and gas engine CHP. We found that important conditions for the plant construction are stable and sufficient heat & power demand, closer plant construction to such a demand and reduction of construction and fuel cost.

4) Model Development for forecasting Woody-biomass energy resources

Through the surveys of recycling the unused woody-biomass resources, we discussed and decided the model structure. The model availability was studied with the case of a local town, Tohno city, Iwate. The model has been developed with customizing the timber-supply forecasting model. It could estimate the available amount of unused woody-biomass in future. The case study of the city made sure that the model might be feasible.

4. Discussion

This study focused not only on development of technologies of generating electricity with a woody biomass, but also on evaluation of forest resources and supply systems by socioeconomic approaches.

Methods to evaluate potentiality of woody-biomass resources for country wide, local scales and sawmills were developed. These methods include new data and techniques considering actual conditions of forests and sawmills. On the other hands, evaluation of technology on generating electricity with a woody biomass showed that small distributed power generation using micro gas turbine cogeneration or gas engine cogeneration would be suitable in a small city of Japan's Tohoku region.

Integrating the results, we discussed feasibility on woody-biomass energy utilization in Tohno city. The approach that consists of evaluation of woody-biomass resources, evaluation technology on generation electricity and evaluation of supply systems in specific areas would be applicable for many feasibility studies on woody-biomass energy utilization.