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Wood biomass supply costs and potential for biomass energy plants in Japan

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ABSTRACT

Wood biomass supply costs were estimated and the supply potential was analyzed to determine the optimum amount for suppliers and wood biomass energy plants. First, supply costs, consisting of harvesting and transportation costs, were estimated for the components of wood biomass based on transportation distances. Two types of costs were determined: one based on the current harvesting and transportation system in Japan (CC), the other based on an improved system for harvesting and transporting commonly used in several European countries, with more efficient forestry machines and larger truck container capacity (IC). Second, supply models were created for all target municipalities to estimate marginal costs (MC) and average costs (AC). Third, the amount of wood biomass was estimated when MC and AC were set at 14,000 yen t^{-1} (100 yen ≈ 1 USD), an expense appropriate under current Japanese forestry conditions. Due to improving forestry machines and truck container capacity, approximately 25% of the cost was reduced for pre-commercial thinning, 32% for final cutting and commercial thinning (including bark, leaves and branches, and low-quality timber), 25% for bark (in mills), 16% for sawdust, and 10% for chip. When MC and AC were set at 14,000 yen t^{-1}, only Regions 7 and 9 could supply by 0.1 Mt using CC. IC clearly increased the wood biomass supply, particularly for Regions 2, 7, and 9.

1. Introduction

Wood biomass is an important resource for creating energy with both economic and environmental benefits. Energy demands have been increasing in many countries particularly due to rapid industrialization and urbanization. In Japan, energy consumption has remained between 6 and 7.5 EJ since the late 1980s, declining since 2008 because of the economic downturn. In 2007, 83% of the energy consumed was generated by fossil fuels, and the energy self-efficiency rate was only 4%, mainly including biomass, water, solar energy, geothermal power, and natural gas. 13% was mainly reliant on nuclear energy, the scope of which was expanded to increase the energy self-efficiency [1]. The Japanese government strongly encourages increasing energy self-efficiency and advocates that 10% of energy consumption should be from renewable sources by 2020 [2]. In particular, wood biomass is one of the highly anticipated resources because of the abundant forests in Japan.

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Currently, three kinds of wood biomass sources are utilized for creating energy in Japan: construction-derived wood residues (CDWR), industrial, and logging residues [3]. CDWR have been mainly used as fuel for boilers because the Renewables Portfolio Standard Law supports power companies using wood biomass from CDWR. Industrial residues, meanwhile, have been more frequently utilized for paper chips than for fuel because the paper chip market has been well established [4]. However, the use of wood biomass for energy from these two sources has been reduced due to the recent economic downturn leading to a decrease in the amount of construction and high competition with the paper chip market. Therefore, to safely use wood biomass for energy, the available wood biomass supplies should be estimated from an economic perspective, and found from other possible sources, such as forests.

Forest biomass, including low-quality logs and residues from final cutting and thinning, has not been well utilized in Japan and is often left in forests because harvesting and transporting are costly. For instance, approximately 20 million m^3 of forest residues were produced from thinning in 2007, but almost none were used [3]. Yagi and Nakata insist on the importance of wood biomass from forests in future because combustion power plants generally need a certain amount of biomass. For example, plants producing more than 1000 kWh of power need tens of thousands tons of biomass [5].

Several studies have been conducted on increasing the efficiency of wood biomass supply. For example, Iuchi estimated the investment for a power plant based on available wood biomass at the municipal level [6]. Yagi and Nakata determined the suitable size, location, number, and cost of power plants, and subsequently concluded that it was difficult to collect wood biomass particularly from thinning [5]. Kamimura et al. calculated the wood biomass supply from harvesting, sawmills, and chip mill and showed the amount of available wood biomass at the municipal level [7]. These studies indicated the potential for using wood biomass in Japan. However, due to the absence of spatial circumstances for transportation and/or supply costs, it would not be straightforward to estimate the wood biomass supply potential for actually managing wood biomass energy plants.

When considering wood biomass supply costs, marginal costs (MC) are a helpful indicator for decision-makers to determine the effective (beneficial) costs for their wood biomass at given conditions (e.g. locations and power plant sizes) [8]. MC are defined as the additional costs to produce another unit of output [9] and can be found in standard economic theory, which consists of supply curve estimation [10]. Examining the wood biomass supply on a long-term basis, costs would shift to an average cost (AC), which is the total cost divided by the output. While AC is related to minimum profits, if the price is equal to MC, the decision-makers (stake-holders) would make a profit [11].

This paper aims to estimate the wood biomass supply for energy with a special focus on supply cost. First, the supply costs per unit, which consist of yarding, forwarding, chipping, and transportation expenses, were estimated based on wood biomass components and transportation distances, such as wood biomass from logging and mill (conifer and hardwood) residues, low-quality trees, trees from pre-commercial thinning, and by-product residues (bark, sawdust, and chip) from sawmills and chip mills. The costs were also based on two operating types; the current harvesting and transportation system in Japan (CC), and the improved system commonly used in several European countries (IC). Second, MC and AC were calculated using the total supply curves of wood biomass at the municipal level. Subsequently, the costs and final output were examined in order to show the adequately available wood biomass supply. In this study, calculated wood biomass is dry mass (50% of water content); thus, the unit "t" indicates the weight (tons) after drying wood biomass. As an exception, cost calculation was based on wet (fresh) mass, so the unit is expressed as "wet-t". The costs are based on the Japanese yen (100 yen ≈ 1 USD). This study partly builds on a previous study by Kamimura et al. (submitted), which estimates wood biomass supply based on transportation distances from the municipalities. This approach would be helpful for decision-makers considering supplying their wood resources to plants or planning to construct power plants.

2. Methods

2.1. Cost estimation

Two types of cost were estimated based on the harvesting and transportation systems (CC and IC), both of which consisted of yarding, forwarding, chipping, and transportation expenses. They did not include the expense of felling. Wood biomass caused by final cutting and commercial thinning is collected after harvesting, and the felling cost on pre-commercial thinning is strongly associated with government subsidies, so they are not directly related to collecting wood biomass. In addition, costs were strongly influenced by transportation distances. For instance, Goltsev found that the cost of wood biomass was lower than that of heavy oil if the transportation distance was under 50 km [12]. In this study, the transportation distance was extended to 100 km to cover the potential area for collecting wood biomass. Moreover, to calculate the supply costs, the transportation distance was classified into four lengths: 0–25, 25–50, 50–75, and 75–100 km. These distances originated from a supply point, which was defined as the position of the city hall. The costs were also categorized as forest residues, such as low-quality logs and residues from pre-commercial thinning and logging from final cutting and commercial thinning, and mill residues such as bark, pulp chips, and sawdust. Conifers and hardwood residues were also calculated respectively.

CC were estimated using a forestry governmental report showing 12 case studies on collecting wood biomass for forestry companies and associations in Japan [13]. It contains detailed information on harvesting costs including wages, machinery rental fees, fuel expenses, chipping costs, and transportation costs with the capacity of a container truck. IC were determined using hearing surveys of two fuel chip suppliers in Austria and one in Finland. The surveys were conducted from March 2005 to September 2008. These European companies were chosen because fuel chip supply