Economic Impact of Utilizing Woody Biomass to Manufacture High Value-Added Material Products: a Study of Cellulose Nanofiber and High Standard Chip-Dust Production in Maniwa, Japan

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This study estimated the economic effect of utilizing woody biomass as a raw material for high value-added (HVA) material products such as master batch of cellulose Nanofiber (CNF-MB) and high standard Chip-dust (HSD) in Maniwa, Japan. In order to analyze the economic effects, two scenarios were described and compared: the BAU scenario and the HVA scenario. The results show that utilizing woody biomass for manufacturing material products can increase the net benefits to businesses as well as stimulate the economic ripple effect and job creation in a local region such as Maniwa. Moreover, the effects of HVA products can be greater than those for the four kinds of existing products. These results could help clarify the effectiveness of utilizing woody biomass in material products as a method to promote woody biomass business and regional development.

Key Words
Utilization of woody biomass, High value-added material products, Cellulose Nanofiber, Cost and benefit, Regional economic ripple effect

1. Introduction

Recently, there is great interest in Japan to promote the use of woody biomass such as logging residues and mill residues. The Japanese government has determined to increase the utilization rate of logging residues, a kind of woody biomass, to 30% by 2030 through the National Basic Plan for the Utilization of Biomass (the basic biomass plan) 1). As a concrete measure to increase the utilization of woody biomass, the government implemented a Feed-in-Tariff (FITs) scheme in 2012. Under the FITs scheme, electricity generated by applicable renewable energy sources, such as woody biomass, solar, wind, and hydro are purchased by power generation facilities at a fixed price during a certain period 2). Therefore, many Japanese local governments are interested in developing specific plans to establish a woody biomass based electric power generating system in their region.

Although woody biomass is recognized as a new renewable energy resource, Okayama prefecture has suggested a way for using woody biomass to make material products. Maniwa city, located in the northern part of Okayama prefecture, has built an integrated woody biomass station (IWBS) for utilizing logging residues collected from forests in the city. Currently, four types of woody products - wood chip for paper, wood chip for fuel, bark, and wood dust - are manufactured in IWBS from two types of woody
biomass: logging residues and mill residues.

In addition, Okayama prefecture is currently developing a method to produce two types of high value-added (HVA) products in the Maniwa IWBS: master batch of cellulose nanofiber (CNF-MB) and high standard chip dust (HSD) - using logging residues and mill residues. CNF are fibrous materials prepared from any cellulosic material, which have diameters in the range of 1 - 100 nm and aspect ratios (length/diameter) of more than 100. HSD is a kind of chip dust which has been ground to the size of 150 μm - 1 mm. Both of these products can be used to substitute for plastic composites used primarily for automobile parts. The production of CNF-MB and HSD is hoped to bring many economic benefits from woody biomass. Moreover, Okayama prefecture also expects that activation of the regional economy can be promoted as well.

Several previous studies have shown that the woody biomass utilization for bioenergy or biofuel production can stimulate regional economy and create jobs in the regions. However, even though wood biomass-to-energy systems have become a mainstream business in the world, the contributions to the regional economy of utilizing woody biomass to manufacture material products, especially HVA products should also be considered.

This study aims to clarify the economic impact on a local region of utilizing woody biomass for manufacturing material products, especially HVA products. We selected Maniwa as the target area, and we examined the economic impact of the production of CNF-MB and HSD, two HVA products that are planned to be manufactured in Maniwa. The specific objectives of this study were firstly to quantify the cost and benefit of utilizing woody biomass for manufacturing CNF-MB and HSD, and secondly to estimate the regional economic effects of material use for HVA products to Maniwa. To evaluate the economic effects for manufacturing HVA products, we describe and compare the following two scenarios: (1) the current situation in which four kinds of existing products are produced, and (2) the planned situation in which four kinds of existing products - chip for paper, bark, and chip dust are about 89%, 8%, and 3%, respectively. The fixed ratios of producing chip and chip dust from MRbb are about 97% and 3%, respectively. MRb from sawmills is used entirely to manufacture bark.

Plans are being made to add the manufacture of CNF-MB and HSD to the four kinds of existing products in IWBS as shown in Table 1. The market price of CNF-MB and HSD is expected to be high compared to existing products, even though the market for these new products does not exist yet.

3. Methodology

3.1 Process boundary

We divide the process from harvesting woody biomass to transporting material products to the consumer into five stages as shown in Fig. 1. (1) harvest, (2) transport to IWBS (TtI), (3) sawmilling, (4) manufacturing, and (5) transport to consumer (TtC). When mill residues are used, the production process goes through all five stages because mill residues are by-products of processing wood in sawmills. However, when logging residues are used, the process involves just the four stages of harvest, TtI, manufacturing, and TtC.

3.2 Scenario setting

In order to evaluate the economic impact of manufacturing CNF-MB and HSD, we consider two scenarios. The business as usual (BAU) scenario describes the current situation of woody biomass utilization in IWBS, in which four kinds of existing products - chip for paper,
chip for fuel, bark, and chip dust - are produced and sold. The high value-added (HVA) scenario describes the situation where HVA products of BAU-MB and HSD are added to the four products from the BAU scenario.

3.3 Preconditions

In this section, we describe several preconditions that we have set for establishing the business model to produce CNF-MB and HSD from woody biomass. These preconditions are based on the existing woody biomass utilization plan in Maniwa for producing CNF-MB and HSD.

Plans are being made to add CNF-MB and HSD as new material products to the four types of existing products in the Maniwa IWBS. In general, chip for fuel, bark and chip dusts are transported to and consumed at the city hall, factories or stock farms in Maniwa. On the other hand, chips for paper, CNF-MB, and HSD are transported to consumers outside of Maniwa.

In the process of CNF-MB production, 20 dry-tons of CNF are manufactured by using 52.1 tons of chip for paper made from logging residues. This CNF is mixed with 180 tons of polypropylene related ingredients to produce 200 tons of CNF-MB. When producing the 52.1 tons of chips for paper needed to make the CNF, according to the fixed production ratio 4.7 tons of bark and 1.8 tons of chip dusts will be produced as a by-product. We assume that these are used by existing consumers.

In the process of HSD production, approximately 1,516 tons of saw dust obtained by mill residues (MRsd) is used to produce 601 tons of HSD.

The resulting total inputs of woody biomass and outputs of each material product in the HVA scenario are summarized in Table 1.

The total amount of fixed costs for the machine for HSD production is subsidized by the government. On the other hand, the machine for CNF-MB production is paid entirely without government subsidy.

3.4 Quantifying cost and benefit

Information related to income and expenditure of woody biomass utilization for manufacturing the four existing material products in IWBS was obtained from internal financial records of IWBS released by officials of Maniwa City Hall and IWBS. An estimate of income and

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Table 1 Summary of the total amounts of woody biomass input & products output for each manufacturing process in the HVA scenario

|                           | Total     | Existing products | HVA products |
|---------------------------|-----------|------------------|--------------|
|                           | Chip for paper | Chip for fuel | Bark | Chip dust | CNF-MB | HSD |
| Total products            | 24,517.5  | 18,907          | 267  | 3,901.7  | 640.8  | 200 | 601 |
| Total input               | 25,284.6  | 18,907          | 267  | 3,901.7  | 640.8  | 521 | 1,516 |
| Logging residues          |           |                 |      |          |       |     |     |
| Type 1                    | 14,437    | 12,670          | 179  | 1,155    | 433    | -   | -   |
|                           | 58.6      | (52.1)          | -    | 4.7      | 1.8    | 521 | -   |
| Type 2                    | 4,296     | 3,770           | 53   | 344      | 129    | -   | -   |
| Mill residues             | MRbb      | 2.579           | 2.467 | 35 | - | 77 | - | - |
|                           | MRb       | 2.398           | -    | 2.398    | -      | -   | -   |
|                           | MRsd      | 1.516           | -    | -        | -      | -   | 1,516 |

※ Moisture contents of woody biomass in Maniwa is set to approximately 52%  
※ The figures on this Table are on a wet-weight basis

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![Fig. 1 The process boundary of woody biomass utilization in Maniwa](image-url)
expenditure for CNF-MB and HSD production was obtained from internal data provided by officials of associated companies and Okayama prefecture.

Total expenditure can be estimated by adding variable expenditure to fixed expenditure. Based on the data that we obtained, variable expenditure involves the costs of raw materials, light diesel oil, electricity, water consumption, and transport. The variable expenditures per unit of production are shown in Table 2. The total variable expenditure is obtained by multiplying the unit expenditures of each stage by the amount of woody biomass input for each product. The total fixed expenditure, which includes costs of depreciation, maintenance, personnel, general management, and land lease, accounted for approximately 31.3% of total expenditure.

Total income is obtained by adding variable income and fixed income. Variable income is found by multiplying the amount of woody biomass input for each product by the unit costs of sales, which are shown in Table 2. Total fixed income, including government subsidy, accounted for about 10.4% of total income.

We obtain the net benefit by subtracting total expenditure from total income.

### 3.5 Estimating regional economic ripple effect and job creation

Based on the calculated costs and benefits, we used I/O modeling to evaluate the regional economic ripple effect and number of new jobs created as a result of woody biomass utilization for HVA products.

In order to use I/O modeling, we need to obtain the change in the final demand resulting from wood chip utilization and the Leontief inverse matrix for the region. Generally, the Leontief inverse matrix is calculated by inverting the matrix that results from subtracting the identity matrix (I) from the technical coefficient matrix (A), where the technical coefficient matrix is derived from the I/O table. However, when estimating regional impact in regions or countries that depend highly on imports, such as Japan, the value of imports should be treated as endogenous variation. For this reason, we use the I/O model that considers the value of imports and exports, shown as Equation (1):

\[
X = [(I - (I - M)A)^{-1} [(I - M)f^d + E]
\]

Here, \((I - (I - M)A)^{-1}\) is the Leontief inverse matrix; \(M\) is the diagonal matrix; \(f^d\) is the vector of district final demand; and \(E\) is the vector of export.

Three types of ripple effects can be analyzed by I/O modeling: direct impact, indirect impact and induced impact. Using these impacts, we can estimate the increased number of jobs as shown in Equation (2):

\[
iE = cE \times RI
\]

Where \(iE\) is the increased number of jobs; \(cE\) is the employment coefficient which is given as \(cE = nE / GRP\); \(nE\) is the number of jobs in Maniwa; \(GRP\) is the Gross Regional Product in Maniwa (mil. JPY); and \(RI\) is the regional ripple impact.

Here, we use the 2008 I/O table for Maniwa, which has been developed based on the data about intra-industry and inter-industry trade in Maniwa industries obtained from questionnaire and telephone surveys by Chugoku Regional Research Center (CRRC).

### 4. Results

#### 4.1 Cost and benefit

The resulting incomes and expenditures for each scenario are shown in Fig. 2. In the BAU scenario, the unit costs for expenditure and income are 7,466 JPY/ton and 8,026 JPY/ton respectively, so the net benefit is 560 JPY/ton. In the HVA scenario, 14,206 JPY/ton is spent as expenditure, and 15,641 JPY/ton is gained as income. Therefore, the net benefit is 1,435 JPY/ton. These results indicate that by adding the two HVA products to the BAU scenario, expenditures are almost doubled and net benefits can be increased by more than 2.5 times.

#### 4.2 Cost efficiency of each product

From the results of income and expenditure in the
HVA scenario, we analyzed the cost efficiency of each product. Here, we calculate cost efficiency by dividing income by expenditure.

As shown in Fig. 3, the highest cost-efficiency was 1.4 for HSD, while the lowest cost-efficiency was about 0.9 for bark and chip dust. Although CNF-MB was expected to produce a large net benefit, its cost-efficiency was only about 1.1, which is similar to those of chip for paper and chip for fuel. The cost-efficiency of CNF-MB is lower because of the precondition of no government subsidies for CNF-MB manufacture. If the precondition is changed so that CNF-MB production gets the same amount of government subsidies as HSD production, the cost-efficiency increases to 1.4, which is similar to that of HSD. Therefore, the size of the government subsidies has a large effect on the cost-efficiency of the HVA products.

### 4.3 Regional economic ripple effect

In order to analyze the regional economic ripple effect, we categorized the expenditure items in the I/O table into eight industrial sectors, which are directly related to the manufacture of the six woody products as shown in Table 3.

| Industry sectors | Scenario | Items                       |
|------------------|----------|-----------------------------|
|                  | BAU      | HSD                         |
| Forestry         | 82.7     | 82.9                        |
| MFG. of wood PROD. | 7.9     | 17.6                        |
| MRG. of PETR. & coal PROD. | 4.0   | 4.4                         |
| Electricity, gas, heat & water supply | 6.9 | 23.5 |
| Plastic PROD. fabricator | 0.0 | 58.1 |
| Real estate leasing | 2.5 | 2.5 |
| SER. Incidental to transport | 31.7 | 34.9 |
| Automobile & machine repair | 5.7 | 12.9 |
| Total endogenous sector | 141.3 | 236.9 |

* "PROD" is an abbreviation for “Products”
* "PETR" is an abbreviation for “Petroleum”
* "SER" is an abbreviation for “Service”

In total, 141.3 million JPY for the BAU scenario and 236.9 million JPY for the HVA scenario are input to the industries in the region. In the BAU scenario, the direct impact is 120 million JPY, the indirect impact is 46 million JPY, and the induced impact is 17 million JPY. In the HVA scenario, the direct impact is 189 million JPY, the indirect impact is 66 million JPY, and the induced impact is 29 million JPY. Therefore, 182 million JPY and 284 million JPY are generated in total from economic ripple effects in the BAU and HVA scenarios, respectively. This result shows that the HVA scenario is able to create almost 1.6 times more economic ripple effect than the BAU scenario.

#### 4.4 Job creation

The utilization of woody biomass for material production in IWBS also can create jobs in the region. The numbers of jobs created in the eight industrial sectors for each scenario are shown in Fig. 4. The result shows that approximately 15 jobs are created in the BAU scenario, and about 4 more jobs can be generated by adding value added products from the BAU scenario. In both the BAU scenario and the HVA scenario, slightly more than 6 jobs
were generated in the forestry sector. However, in the secondary and tertiary industrial sectors, the HVA scenario results in a notable increase of created jobs compared to the BAU scenario. In the secondary industrial sectors, including manufacture of wood products, the increase in the number of jobs was more than four times higher in the HVA scenario than the BAU scenario because inputs from the plastic products related sectors are required in the process of manufacturing CNF. Jobs in tertiary industrial sectors, such as commerce and services incidental to transport, also can be increased from 4.1 jobs in the BAU scenario to 6.3 jobs in the HVA scenario.

5. Conclusion

This study examined the regional economic impacts of introducing manufacture of HVA products from woody biomass. The results show that utilizing woody biomass to make material products can increase the net benefit to businesses and also stimulate the economic ripple effect and creation of jobs in local regions such as Maniwa. Moreover, the benefits of manufacturing the four kinds of existing products can be increased further by developing HVA products.

Utilization of woody biomass to produce energy, especially electricity, is accelerating as a result of the implementation of the FITs scheme in Japan. We suggest that a new approach for utilizing woody biomass to produce both energy and materials could be even more effective. In the future, we plan to examine the tradeoffs between utilization of woody biomass for energy and for material products.

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