Profitability Improvement Effect of a Lumber Company Establishing a Biomass Power Generation Business

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We verified the profitability improvement effect of a lumber company (large-scale sawmill) in Japan establishing a feed-in tariff (FIT) biomass power generation business using its own sawmill residues. Various profitability indexes were compared between the following two scenarios: Scenario 1, the lumber company sells by-products such as chips, sawdust, and shavings to other paper companies or stockbreeding companies; and Scenario 2, the lumber company establishes a power generation company based on FIT near the sawmill and sells its by-products to own power generation company. In Scenario 2, the calculated IRR and NPV of the power generation company were low because the investment cost of the project was high, and it takes more time to recover the cost of the investment. However, it is guaranteed that the generated electricity will be purchased at a fixed price under FIT for 20 years. In the case of an only 3% reduction in the sales unit sales price of sawmill products, the profits were greatly reduced in Scenario 1, whereas all the evaluation indexes were better in Scenario 2.

Key Words
Wood energy, Profitability evaluation, Operation of a sawmill, Feed-in Tariff, Steam turbine

1. Introduction

A feed-in tariff (FIT) system in Japan started on July of 2012, and now 80 FIT wood power plants (total introduced power output: 886 thousand kW) are running (as of September 2017) 1). Furthermore, there are 462 FIT wood power plants planning to operate (estimated total output: 12 million kW, as of September 2017) 1). The background of the rapid introduction of wood power plants in Japan is public opinion expecting the creation of new energy sources because of growing concern triggered by accidents at nuclear power plants. However, in a capitalist economy, the most important objective of private enterprises is to pursue profits. Therefore, unless the profitability of the power generation business has been assured through a fixed price preferential treatment in the form of a FIT, it was considered that such rapid expansion of the business could not have been realized.

An outline of the FIT system in Japan is as follows. The purchase period of electricity made from wood biomass as a raw material is 20 years and the fixed prices are determined by the type of raw material and the plant scale, namely, the rated power output. Table 1 shows current fixed prices of biomass of the FIT system in Japan 2). Among the raw materials, the highest fixed price is set for forest biomass (defined as wood biomass harvested and produced according to appropriate forest management norms).
Regarding the plant scale, the fixed price is higher in plants
with lower rated power outputs.

We have previously developed a business simulation
tool for biomass power generation \(^3\) \(^4\). When the data
related to the amount and purchase unit price of wood
biomass supply are input, the simulator is able to estimate
the power output, the efficiency based on a heat balance
calculation, and the profitability from its sales and the profit
under Japanese accounting standards. We have evaluated
the profitability of several types of FIT power generation
projects. Example results showed that power plants of
approximately 5,000 kW or greater scale consuming
forest biomass have good business prospects and also that
profitability greatly improves as the scale increases.

Although the profitability of power plants consuming
forest biomass is high, it is not easy to expand the plant
scale. The reason for this is that the supply is very tight
using only raw material from forests around power plants,
considering the current supply of domestic logs. Even
though Japan is a forest country, 63% of the domestic log
demand is for lumber \(^5\), especially for building materials;
thus, keen competition exists for domestic logs between
building material usage and energy usage.

To date, more than a few policies have been
implemented for sawmills consuming domestic logs to
counter imported products. However, the profitability of
a sawmill consuming domestic logs is lower than that of
manufacturing industries generally \(^6\). We have developed
business simulation tool for sawmill factory and estimated
the profitability of a lumber company \(^7\). Since unit sales
prices cannot be raised easily because of relatively cheap
imported wood products, it is difficult to improve the
profitability of this business unless the manufacturing scale
of the sawmills is expanded as in Europe and the North
America. At a sawmill, more than half of the raw material
will become by-products such as chips, sawdust, and
shavings (hereinafter called mill ends). It is common that
these mill ends be used for pulp for paper, livestock bedding,
and biomass boiler fuel. However, since the unit sales prices
of these mill ends are significantly lower than those of the
main lumber products, it is difficult for them to contribute
to the total sales of the lumber company.

After September of 2017, the fixed price of electricity
made from wood mill residues (mill ends), imported wood
and agricultural residues was reviewed twice and lowered.
According to our estimates, the profitability of power
generation plants larger than 10,000 kW in scale has been
shown to have decrease greatly already. In the past, many
FIT certifications of large power plants consuming cheap
palm kernel shell (PKS) imported from Southeast Asia were
acquired, but we are anticipating that these plants will
be fewer in the near future. On the other hand, business
opportunities still remain for power plants less than
10,000 kW in scale that consume mill ends.

In this paper, we estimated the profitability of a
lumber company consuming domestic logs and focusing
on a power generation project less than 10,000 kW in scale
consuming mill ends. Specifically, we calculated how sales
and profits of a lumber company and a power generation
company will change when the mill ends from the sawmill
are sold to a power generation company established by the
lumber company itself.

2. Experimental

2.1 Outline of evaluation scenario

The following two main scenarios were considered
for this simulation: Scenario 1, only a lumber company is
established and managed; Scenario 2, lumber and power
generation companies are established and managed (Table 2).
The power generation company in Scenario 2 is operated as
a subsidiary of the lumber company. Fig. 1 shows business
flow in each scenario.

Furthermore, the following two sub-scenarios were
set regarding the unit sales price of the products of the lumber
company: Sub-scenario 1, the current market price
is used as the unit sales price of products of the lumber

| Type of power generation method or raw material | Output per plant | Fixed price (JPY/kWh) | Biomass examples |
|-----------------------------------------------|------------------|-----------------------|-----------------|
| Methane fermentation                           | -                | 39                    | sewage sludge, livestock waste, and food residue |
| Forest biomass                                 | 2,000 kW >       | 40                    | thinning logs, final cutting logs, and forest residues |
|                                               | 2,000 kW ≤       | 32                    |                 |
| Wood mill residues, imported wood and agricultural residues | 10,000 kW > | 24 | sawmill residue (bark, sawdust, and chips), imported chips and pellets, and palm kernel shell |
|                                               | 10,000 kW ≤ | determined by bidding | palm oil and bioethanol |
| Demolition wood from building site              | -                | 13                    | used wooden construction material |
| General waste (other biomass including wood waste) | -                | 17                    | pruned branches, paper, food residue, and black liquor from chemical pulp mill |
Company (hereinafter called the default case); Sub-scenario 2, 3% lower than the current market price is used as the unit sales price for the lumber company (hereinafter called the reduction case) (Table 2).

### 2.2 Detail of sawmill business

The sawmill scale was set to an annual log consumption of 300,000 under-bark solid m³/year (24-hour operation). This setting was chosen as representative of a large-scale sawmill consuming domestic logs operating in Japan in recent years. The type and ratio of manufactured goods from the sawmill, though difficult to set because of regional differences between lumber company and the variety of possible trading partners, were estimated based on interviews with a company operating a large-scale sawmill consuming domestic logs. The interview results obtained from a large-scale sawmill were also used for the production yield by product, basic unit of energy consumption for wood drying, and number of factory workers. Steam produced by a dedicated biomass boiler installed in the sawmill is used for drying lumber, and the mill ends are used as the heat source. Therefore, the amount of mill ends to be sold is the amount after deducting that used for lumber drying in the sawmill from the total amount of generated mill ends.

Table 3 shows amounts of materials bought, sold, and used in the sawmill boiler. Production volume of the lumber was determined in reference to interview results of production yield from a large-scale sawmill. Production volume of mill ends was calculated based on production yields of sawmill using Japanese Cedar (*Cryptomeria japonica*). In addition, it was assumed that all of the products are sold immediately after manufacture and thus surplus stocks are not generated. The purchase unit price of logs and the unit sales prices of the products were decided based on a market report and interview results. Table 4 shows unit purchase and sales prices for lumber company.

Table 5 shows fuel property of mill ends. Wood density was a set value determined as Japanese Cedar (*Cryptomeria japonica*). Lower calorific value was calculated by formula 16.

### 2.3 Detail of power generation business

At the power plant in Scenario 2, electricity is generated consuming only all of the sales volume of mill ends listed in Table 3. Specifications of the power plant were estimated using our business simulation tool of biomass power generation. Table 6 shows estimated specifications and electricity production of power plant in Scenario 2. Just for information, the unit sales price of electricity is 24 yen/kWh as determined by FIT for less than 10,000 kW of rated power output (Table 1).
Table 3 Amounts bought, sold, and used in the sawmill boiler

| Item 1          | Item 2                     | Value               | Unit        |
|-----------------|----------------------------|---------------------|-------------|
| Bought          | Log                        | 300,000             | under bark solid m³/y |
| Sold            | Kiln-dried lumber          | 22,886              | solid m³/y  |
|                | Substrate material         | 20,477              | solid m³/y  |
|                | 2 × 4 standardized material| 7,227               | solid m³/y  |
| Green lumber    | Lamina (for gluilam)       | 47,850              | solid m³/y  |
|                | Packing and pallet material| 47,850              | solid m³/y  |
| Total amount    |                            | 146,290             | solid m³/y  |
| Mill ends       | Bark                       | 8,453               | bulk m³/y   |
|                | Sawdust and shavings       | 258,633             | bulk m³/y   |
|                | Chips                       | 67,500              | solid m³/y  |
| Used in the sawmill boiler | Mill ends | Bark                     | 45,547 | bulk m³/y |

Table 4 Unit purchase and sales prices for lumber company

| Item 1          | Item 2                     | Price Default case | Price Reduction case | Unit | Data source |
|-----------------|----------------------------|--------------------|----------------------|------|-------------|
| [Purchase]      | Log                        | 13,100             |                      | JPY/under bark solid m³ | Literature 9 |
| Kiln-dried lumber| Structural material        | 53,000             | 51,410               | JPY/solid m³ | Literature 10 |
|                | Substrate material         | 51,000             | 49,470               | JPY/solid m³ | Literature 10 |
|                | 2 × 4 standardized material| 53,000             | 51,410               | JPY/solid m³ | Literature 10 |
| Green lumber    | Lamina (for Glulam)        | 28,000             | 27,360               | JPY/solid m³ | Literature 10 |
|                | Packing and pallet material| 37,000             | 35,890               | JPY/solid m³ | Literature 10 |
| Mill ends       | Bark                       | 800                | 776                  | JPY/bulk m³ | Interview |
|                | Sawdust and shavings       | 1,500              | 1,455                | JPY/bulk m³ | Interview |
|                | Chips*1                    | 2,905              | 2,817                | JPY/solid m³ | Literature 10 |

*1 It was assumed that basic density (oven-dry density) of wood was 334 kg/m³

Table 5 Fuel property of mill ends

| Item 1          | Item 2                     | Value     | Unit  |
|-----------------|----------------------------|-----------|-------|
| Moisture content | Bark                       | 100 %     |       |
|                | Sawdust and shavings       | 30 %      |       |
|                | Chips                       | 40 %      |       |
| Lower calorific value | Bark                     | 81 MJ/kg |       |
|                | Sawdust and shavings       | 13.8 MJ/kg |       |
|                | Chips                       | 12.6 MJ/kg |       |
| Density        | Bark                        | 209 kg/bulk m³ |       |
|                | Sawdust and shavings       | 136 kg/bulk m³ |       |
|                | Chips                       | 440 kg/solid m³ |       |

*1 Oven dry basis
*2 Lower calorific value was calculated by formula as gross calorific value and Hydrogen content of wood is 20 MJ/kg and 6%, respectively
*3 Rate of increase from solid volume to bulk volume is three times
*4 Wood density was a set value determined as Japanese Cedar (Cryptomeria japonica)

Table 6 Estimated specifications and electricity production of power plant in Scenario 2

| Item 1          | Item 2                     | Value     | Unit |
|-----------------|----------------------------|-----------|------|
| Specification   | Steam pressure             | 5.9 MPa   |      |
| of boiler       | Steam temperature          | 454 ℃     |      |
| Evaporation     |                            | 384 t/h   |      |
| Power output    | At a power generation end  | 8,308 kW  |      |
|                 | At a transmission end      | 7,219 kW  |      |
| Power generation efficiency at a power generation end  | 27.2 % |      |
| Operation time  |                            | 7,920 h/y |      |
| Electricity production |                    | 57,176 MWh/y |      |

2.4 Investment cost

Investment costs were estimated as follows. The investment cost of the sawmill was calculated based on 0.6 rule relating scale economy using known cost and capacity of existing equipment of a sawmill project, for which the sawmill had a log consumption of 74,000 under-bark solid m³/year (8-hour operation/day) and the investment cost was 2.31 billion JPY. The government subsidy ratio for sawmill construction was set at 50%.

The investment cost of the power plant was based...
on the price estimated from a regression equation. The regression equation is based on the project costs including the planned value announced until 2012. We confirmed the deference of 5700 kW class plants cost between average value of six plants completed from 2012 to 2017 and the calculated value of regression equation. As a result, the average of actual project costs was 120% of the cost by the regression equation. Therefore, we decided to adjust the result of the regression equation with 120%.

The government subsidy ratio for the power plant was set at 0%. The breakdown of the investment cost was used to calculate a fixed property tax and depreciation expenses.

For each investment cost, the proportion of borrowing was set at 80% against the amount excluding subsidies, and the interest rate was set at 3%. The repayment period was set as 8 years for the lumber company and 15 years for the power generation company.

2.5 Evaluation index and accounting method

To evaluate the profitability of each scenario, our business simulation tools previously developed for biomass power generation and sawmill factory were used.

The evaluation period is 20 years from the start of the business. Evaluation index was set as sales, income, income ratio, income per worker, internal rate of return (IRR), net present value (NPV), and payback period of investment cost. Here we set that the “income” is “income before income taxes”. Each evaluation index was calculated based on both non-consolidated accounting and consolidated accounting. Here, non-consolidated accounting means stand-alone financial statements. In contrast, under consolidated accounting, the lumber company and power generation company are considered to be in the same group company, and transaction amounts between the two companies are not reported. Since the mill ends are sold to the power generation company at the same price as the market price of pulp chips and livestock bedding (Table 4), the sales and profit margins of the lumber company in stand-alone financial statements are fixed.

3. Results and Discussion

3.1 Results of default case

Table 7 shows the results of the stand-alone financial statements for each scenario in the default case. The results show that neither company had a negative income. The income ratio, IRR, and the NPV of the lumber company are 3.9%, 20.7%, and 3,287 million JPY, respectively. Those of the power generation company are respectively 17.2%, 9.3%, and 2,830 million JPY. The calculated IRR and NPV are low for the power generation company because the investment cost of the project is high, while it takes more time to recover the investment cost.

Table 8 shows results of the consolidated financial

| Table 7 | Results of stand-alone financial statements for each scenario in the default case |
|---------|--------------------------------------------------------------------------------|
| Sawmill co. | Table 8 Results of stand-alone financial statements for each scenario in the default case |
| Scenario (Default) | Scenario 2 (Default) | Unit |
| **Total investment cost** | 2.77 ← billion JPY | **Included subsidy** | 1.34 ← billion JPY |
| **No. of workers (A)** | 110 ← people | **Sales** | **Lumber** | 5,751 ← million JPY/y | **Mill ends** | 590 ← million JPY/y | **Total(B)** | 6,341 ← million JPY/y |
| **Income (C)** | 248 ← million JPY/yearly avg. | **Income ratio (B/C × 100)** | 3.9 ← %/yearly avg. | **Income per worker (C/A × 100)** | 2.3 ← million JPY/person-yearly avg. | **IRR** | 20.7 ← % |
| **NPV** | 3,287 ← million JPY | **Payback period of investment cost** | 7 ← years |
| Power generation co. | **Total investment cost** | 4.18 billion JPY | **Included subsidy** | 0 ← billion JPY |
| **No. of workers (A)** | 16 ← people | **Sales** | 1,372 million JPY/y |
| **Income (C)** | 236 million JPY/yearly avg. | **Income ratio (B/C × 100)** | 172 %/yearly avg. | **Income per worker (C/A × 100)** | 147 million JPY/person-yearly avg. | **IRR** | 9.3 % |
| **NPV** | 2,830 million JPY | **Payback period of investment cost** | 12 ← years |

* Average value per year for 20 years

* Each value is before income taxes and evaluation period is 20 years

* Discount rate is 3%
statements for each scenario in the default case. The sales, income, income ratio, income per worker, and NPV of Scenario 2 are higher than those of Scenario 1, with differences of 782 million JPY, 227 million JPY, 2.8%, 1.5 million JPY, and 2,698 million JPY, respectively. However, the IRR of Scenario 2 are lower than those of Scenario 1 by 8.4%. In addition, the payback period of Scenario 2 was 3 years longer than that of Scenario 1.

3.2 Results of reduction case

Table 9 shows results of the stand-alone financial statements for each scenario in the reduction case.

Although the income did not become negative in either business, the income ratio of the lumber company declined remarkably. The income ratio, IRR, and NPV of the sawmill company are 0.9%, 5.9%, and 456 million JPY, respectively. In contrast, those of the power generation company are 18.4%, 9.8%, and 3,090 million JPY. All evaluation indexes of the power generation company were higher in the reduction case than in the default case. The reason for this is that the power generation cost is less reduced because the purchase unit price from the sawmill is decreased by 3%

Table 10 shows the results of the consolidated financial statements for each scenario in the reduction case.

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Table 8: Results of consolidated financial statements for each scenario in the default case

| Scenario 1 (Default) | Scenario 2 (Default) | Difference | Unit |
|----------------------|----------------------|------------|------|
| Sales (A)            | 6,341                | 7,123      | + 782 million JPY/y |
| No. of workers (B)   | 110                  | 126        | + 16 people |
| Income (C)*1         | 248                  | 475        | + 227 million JPY/yearly Ave. |
| Income ratio (C/A×100)*2 | 3.9              | 6.7        | + 2.8 %/yearly avg. |
| Income per worker (C/B×100) | 2.3              | 3.8        | + 1.5 million JPY/person/yearly avg. |
| IRR*2               | 207                  | 123        | - 8.4 % |
| NPV*3               | 3,287                | 5,985      | + 2,698 million JPY |
| Payback period of investment cost | 7                     | 10         | + 3 years |

*1 Average value per year for 20 years
*2 Each value is before income taxes and evaluation period is 20 years
*3 Discount rate is 3%

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Table 9: Results of stand-alone financial statements for each scenario in the reduction case

| Sawmill co. | Scenario 1 (Reduction) | Scenario 2 (Reduction) | Unit |
|-------------|-------------------------|-------------------------|------|
| Total investment cost | 2.77 ← billion JPY | ← billion JPY |
| Included subsidy      | 1.34 ← people |
| No. of workers (A)   | 110 ← people |
| Sales                | Lumber ← 5,578 million JPY/y | ← million JPY/y |
|                      | Mill ends ← 573 million JPY/y | ← million JPY/y |
|                      | Total(B) ← 6,151 million JPY | ← million JPY |
| Income (C)*1          | 58 ← million JPY/person/yearly avg. |
| Income ratio (B/C×100)*2 | 0.9 ← %/yearly avg. |
| Income per worker (C/B×100) | 0.5 ← million JPY/person |
| IRR*2               | 5.9 ← % |
| NPV*3               | 456 ← million JPY |
| Payback period of investment cost | 15 ← years |

| Power generation co. | Scenario 1 (Reduction) | Scenario 2 (Reduction) | Unit |
|----------------------|-------------------------|-------------------------|------|
| Total investment cost | ← 4.18 billion JPY | ← 0 billion JPY |
| Included subsidy      | ← 16 people |
| No. of workers (A)   | ← 16 people |
| Sales (B)            | ← 1,372 million JPY/y |
| Income (C)*1          | ← 253 million JPY/yearly avg. |
| Income ratio (B/C×100)*2 | ← 18.4 %/yearly avg. |
| Income per worker (C/B×100) | ← 15.8 million JPY/person/yearly avg. |
| IRR*2               | ← 9.8 % |
| NPV*3               | ← 3,090 million JPY |
| Payback period of investment cost | ← 12 years |

*1 Average value per year for 20 years
*2 Each value is before income taxes and evaluation period is 20 years
*3 Discount rate is 3%
The sales, income, income ratio, income per worker, IRR and NPV of Scenario 2 were higher than those of Scenario 1, with differences of 799 million JPY, 245 million JPY, 3.5%, 1.9 million JPY, and 2,962 million JPY, respectively. Moreover, the payback period of the investment cost of Scenario 2 is 2 years shorter than that of Scenario 1.

### 3.3 Profit stability of FIT business

The IRR, NPV, and payback period of investment cost are generally used as judgment indexes in investment standards; nevertheless, these indexes for the power generation company alone were lower than those of the lumber company alone in the default case (Table 7). In other words, the FIT business was judged to be a time-consuming project in terms of recovering the investment cost. However, it is guaranteed that the generated electricity will be purchased at a fixed price under FIT for 20 years. In the case of an only 3% reduction in the sales unit sales price of sawmill products, the profits were greatly reduced in Scenario 1, whereas all the evaluation indexes were better in Scenario 2 (Table 10).

In Japan, domestic lumber products are exposed to intense price competition with imported products, which often leads to not only a lower unit sales price but also a reduced sales volume. Because of this situation, the supply amount of mill ends from the sawmill will less, and there is a possibility that the amount of raw material will be insufficient for the power plant. Then, by consuming forest biomass with a higher fixed price than the wood mill residues for power generation, it is possible to meet the raw material demand of the power plant and make much more profit. We must also mention that there is a possibility that the sawmill company can improve the corporate value by conducting business related to the environment such as renewable energy production. The addition of a FIT business to a large-scale sawmill can avoid management risks due to a decrease in sales and contribute to the stable management of a large sawmill.

In this study, the evaluation period is 20 years from the start of the business. Although the current FIT fixed price is guaranteed for 20 years, the price may be reduced after 21 years. Moreover, with regards to scale of sawmill and power plant, the results are only case studies. Further studies are needed in order to find out the differences of business profitability in changes of plant scale and purchase price of electricity.

### 4. Conclusion

The following conclusions were obtained from simulation results.

1. When a power plant consumed mill ends from a large sawmill with an annual log consumption of 300,000 m³, the rated power output of the plant was estimated to be 8,308 kW.
2. In results of consolidated financial statements in default market price, sawmill company operating FIT business was worse in IRR and NPV than sawmill business only, even though better sales and income were obtained. The data demonstrated that FIT business took more time to recover the cost of the investment.
3. However, in results of consolidated financial statements in 3% reduction of market price, the profits of sawmill business only were greatly reduced. In this case, the all evaluation indexes of sawmill company operating FIT business were better than those of sawmill business only.
4. Therefore, for a large-scale sawmill, it was assumed that the management risk due to a decrease in sales can be avoided by adding a FIT business.

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