Cost-effectiveness Analysis Method for Wood Biomass Power Generation using Logging Residues

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At present, logging residues are scarcely used in Japan. However, studies are being conducted on the use of this resource for wood biomass power generation at various places. In this study, we developed a cost-effectiveness analysis method for wood biomass power generation projects. Applying this analysis method will help in deciding the validity and feasibility of power generation plans using the logging residues as the raw material. The purchase price of electricity by electric company and that of wood chip have a serious influence on the success or failure of the power generation projects using the logging residues.

Keywords: logging residues, wood biomass power generation, cost-effectiveness analysis

1. INTRODUCTION

At present, Japan has hardly developed the use of logging residues as a biomass resource. However, in recent years, expectations for natural, renewable energy production is increasing, and wood biomass power generation, using chipped logging residues, is considered one of the most important initiatives. To realize such an initiative, it is necessary to sort out issues such as the feasibility of sourcing stable and inexpensive raw material, the sustainability of business operations, the extent to which greenhouse gases (GHG) would be lowered from the life-cycle point of view, and so on. It is vital that local municipalities and businesses aiming to utilize biomass study these issues comprehensively before evaluating the project and deciding whether or not to launch it (or in the case of a project that has already been launched, decide the pros and cons of continuing it).

As a part of the development of a comprehensive evaluation method for the utilization of wood biomass, this study developed a method of cost-effectiveness analysis for use in wood biomass power generation projects that use logging residues (hereafter referred to as “logging residue power generation projects”).

2. EXPERIMENTAL METHOD

2.1 Basic Concepts of Cost-effectiveness Analysis for Logging Residue Power Generation Projects

We hypothesized that local governments are undertaking wood biomass power generation, and we considered the cost-effectiveness analysis concepts that arise from public project techniques. “Cost-effectiveness Analysis For Public Forestry Projects” [1] and “Cost-effectiveness Analysis For Land Improvement Projects” [2] stood out as potential analysis techniques from public projects that could be applied to wood biomass power generation projects. As for cost-effectiveness analysis in public projects, there are many examples that typically compare if a project is progressing or not. We basically followed the same premise for logging residue power generation projects.

2.2 Cost-effectiveness Analysis Method

2.2.1 Total Benefit/Total Cost Ratio

Cost-effectiveness analysis for logging residue power generation project determines project efficiency by comparing total costs invested during a fixed evaluation period and evaluating benefits in an economic sense. Specifically, the present value of benefits (B) is divided by the present value of total costs (C), to calculate the total benefit/total cost ratio (B/C).

\[
\frac{\text{Total Benefit}}{\text{Total Cost}} = \frac{B}{C}
\]

\[
\text{Total Benefit} = \sum \left( \frac{B_t}{(1 + \text{discount rate})^t} \right)
\]

\[
\text{Total Cost} = \sum \left( \frac{C_t}{(1 + \text{discount rate})^t} \right) - \text{Asset Value of all relevant facilities as of the end of evaluation period}
\]

Bt: Effective amounts, by year
t: Number of elapsed years, with base year set at 0
Ct: Project costs, by year (including project costs, associated project costs, costs required for the redevelopment of facilities integral to the project, maintenance administration costs etc., by year)

Discount Rate: Social discount rate (4%)

2.2.2 Benefits

The benefits (effects) of logging residue power generation projects are estimated below.

1) Electric Power Production

The valuation of electric power production from
logging residue power generation plants is calculated as the price at which all the power produced has been sold to electric power companies.

\[
\text{Amount of electricity produced by logging residue (sales amount) (kWh)} \times \text{Unit sale price (¥/kWh)}
\]

2) Promotion of Wood Use

We evaluate the benefits of promoting the use of wood through the utilization of logging residues. We anticipate the biggest challenge in implementing logging residue power generation projects to be the project earnings. As it is necessary to cut costs in all areas, it is a prerequisite that the existing road network be used for gathering logging residues for its use as a raw material, rather than building a new road network. Furthermore, it is assumed that existing machinery and vehicles will be used for collection/transportation.

According to cost-effectiveness analysis used in public forestry projects, benefits resulting from woodland maintenance include timber production benefits, and so on. One such benefit that can be calculated is the promotion of wood use. For logging residue power generation projects, existing forest roads will be used, but by installing power plants, we assume that thinnings and small trees can be used that were traditionally cut down and thrown away. This can be calculated in the equation below.

\[
\frac{(R_T - R_0)}{100} \times V_t \times @
\]

- \(R_T\): Ratio of thinning utilized after the construction of power plant (%)
- \(R_0\): Ratio of thinning utilized prior to establishment of power plant (%)
- \(V_t\): amount of wood from thinning harvest in area used prior to the construction of power plant, t years later (m³)
- @: Market price of wood from thinning (¥/m³)

3) Reduction of GHG (CO₂) Emissions

We can estimate the benefit from reducing CO₂ emissions from existing thermal power plants, in proportion to the electric power generated by logging residue power generation projects and sold to electricity providers. The reduction in CO₂ is given as follows:

\[
\text{Amount of reduction in CO₂ due to the introduction of logging residue power generation (t) × base unit monetary price of CO₂ (¥/t)}
\]

The amount (t) by which CO₂ emissions are cut as a result of the introduction of logging residue power generation, is the reduction found by taking the amount of electricity produced by logging residue generation from the amount of CO₂ emissions produced by existing thermal power plants. Basically this is given as follows:

\[
\text{CO₂ emission amounts from existing thermal power generation (t) – CO₂ emission amounts from logging residue power generation (t)}
\]

However, where no CO₂ is emitted by logging residue power plant at the point of generation, the amount by which CO₂ emissions are reduced because of the introduction of logging residue power generation can be regarded as follows:

\[
\text{CO₂ emission amounts from existing thermal power generation plants (t) × CO₂ emission coefficient of existing thermal power generation plants (t·CO₂/kWh)}
\]

Existing thermal power plant CO₂ emission coefficients are not officially published, but on the premise that within the total amount of power (power supply) generated by electric power companies, it is only thermal power that produces CO₂ at the point of generation. We can estimate the total amount of CO₂ emissions from existing thermal power plants as follows:

\[
\text{Power supply (kWh) × officially published CO₂ emission coefficient as stipulated in the Law Concerning the Promotion of Measures to Cope with Global Warming (t·CO₂/kWh)}
\]

Furthermore, while we may regard logging residue (wood biomass) power plants as emitting no CO₂ at the point of power generation, CO₂ is produced during the construction and decommissioning of the plant. However, the emission coefficient relating to power generation by existing power plants does not include CO₂ emissions that result from plant construction and decommissioning. Moreover, on the premise that far more CO₂ would be emitted during the construction and decommissioning of a thermal power plant, compared to a wood biomass power plant, estimates have not been made for CO₂ emissions from the construction and decommissioning of logging residue power plant.

2.2.3 Costs

Costs relating to logging residue power generation projects are estimated below.

1) Fixed Asset Installation Cost

As a logging residue power generation plant is basically a new build, the installation costs can be calculated by the formula below:

\[
\text{Fixed Asset Installation Cost} = \text{Project Expenses} + \text{Related Project Expenses} - \text{Asset Value of all relevant plant as of the end of the evaluation period.}
\]

Formula for the value of depreciable assets is based on the straight line method of depreciation (amount of outstanding depreciable assets)

\[
\text{Asset Value} = \text{Plant Construction Costs} \times (1 - \frac{\text{(elapsed no. of years of serviceable life / standard no. of years of serviceable life)}}{100})
\]

2) Operating/Maintenance Costs

Increased operating/maintenance costs can be expected to arise from increased use of machinery, vehicles, forest roads, etc., in the collection and transportation of timber upon implementation of logging residue power generation projects. Furthermore, there will be necessary costs associated with the operating/administration and repair of the logging
residue power plant itself. Therefore, the operating/maintenance costs associated with logging residue power plant generation projects can be estimated as per the formula below:

Operating/Maintenance Costs (for the project being carried out) – Operating / Maintenance Costs (for that being not carried out).

3. RESULTS AND DISCUSSION
3.1 Cost-effectiveness Analysis
This calculation is based on the premise that the Kansai Electric Power Co., Inc. and the Chugoku Electric Power Co., Inc. carry out the logging residue power generation projects within their remit, and subtract the equivalent amount of the electricity from those generated by their thermal power plants. Government statistics showing emission coefficients by power provider for the years 2006–2010 show Kansai Electric to have the lowest average emission coefficients for those years, and Chugoku Electric to have the highest. Calculation specifications as detailed below were used in this cost-effectiveness analysis.

3.1.1 Calculation Specifications
1) Logging Residue Power Plant
   - Rated Output: 5,000 kW, at generation efficiency of 20%
   - Asset installation cost: ¥ 2.5 billion [3]
   - Direct combustion and cogeneration method (However, as the costs and benefits of heat utilization are assumed to be of equal value, this has not been included in this cost-effectiveness study.)
   - Run Time: 365 days (24h per day), operation rate 80% and 90%
   - Serviceable Life: 15 years
2) Procurement of Raw Materials (logging residue chips)
   - Purchase from wood chip manufacturers: 43,000 t (in the case of operation rate 80%) and 48,000 t (in the case of operation rate 90%)
   - Assumption: source wood moisture content 50%, specific gravity 0.8, wood energy (dry basis) 3,500 kcal/kg [4]
   - Wood chip unit purchase price includes costs associated with shipping of source wood, chipping process and transport to power plant.
   - Source wood (logging residues) unit purchase price: ¥ 1,000/t [5]
3) Official CO₂ Emission Coefficients Stipulated in the Law Concerning the Promotion of the Measures to Cope with Global Warming [6]
   - Emission coefficient values for Kansai Electric Power Co., Inc. and Chugoku Electric Power Co., Inc. have been averaged out over the reporting years, based on government statistics showing emission coefficients by electricity provider for 2006–2010.
4) The Purchase Price of Production Electricity by the Electric Power Companies
   - ¥ 20.0/kWh (the value of the assumption) and ¥ 33.6/kWh [7]
5) Carbon Sequestration Benefits
   - Based on “Pre-evaluation of Public Projects Manual, Forestry Agency,” this is set at ¥ 6,046/t-CO₂
6) Others
   - Regarding logging residue power plant operation/maintenance costs, concepts on operating expenses such as labor costs, utility costs, etc., have been adopted from “Guidebook on the Introduction of Biomass Energy” (3rd edition) by New Energy and Industrial Technology Development Organization [8].
   - Estimates for forest road maintenance costs are set at ¥ 10,000,000 per year, as existing roads will frequently be used for the collection and transport of logging residues.

3.1.2 Results
The results of the cost-effectiveness analysis by calculation specifications are shown in Fig.4 from Fig.1. When the electric purchase price by the electric company is 20.0 yen, it is necessary for the prices of raw materials tip to be less than approximately 7,000 yen. When the electric purchase price by the electric company is 33.6 yen, the price of raw materials tip can be approximately 12,000 yen. And when the electric purchase price by the electric company is 20.0 yen, the improvement of the operation rate of the electric power plant doesn't affect the ability for purchase of the raw materials tip price.

And the difference of the CO₂ emission coefficient between Chugoku Electric Power Co., Inc. and Kansai Electric Power Co., Inc. affects the ability for purchase of the raw materials tip price.

![Fig. 1 Cost-effectiveness analysis (1).](image1)
Premise: operation rate of the power generation, 80%; purchase price of the electricity by electric companies, ¥20.0/kWh)

![Fig. 2 Cost-effectiveness analysis (2).](image2)
Premise: operation rate of the power generation, 90%; purchase price of the electricity by electric companies, ¥20.0/kWh)
4. CONCLUSION

With the urgency for natural renewable energy increasing, given the need to prevent global warming and in the face of the great earthquake that hit eastern Japan, there is an opportunity brewing for the proactive promotion of the practical use of logging residues as an energy source.

Given the current social situation, we think that it is important for logging residue power generation projects to be addressed as a public project concept. In this case, it is essential that thorough cost-effectiveness analysis be carried out to determine the suitability of project plans.

When it comes to logging residue power generation projects, factors such as how to improve generation efficiency, and how to procure a stable and cheap supply of wood chip raw materials, are extremely important. In the methodology used here, we have proven how a rise in the unit price of wood chips can cause a large decline in the total cost/total benefit ratio. And the electric purchase price of electric company has an extremely serious influence on the success or failure of the logging residue power generation projects.

The study of cost-effectiveness analysis methods, in regard to logging residue power generation projects from a public project point of view, has only just begun, but further improvement is required. In particular, current government studies on natural renewable energy feed-in tariffs and subsequently the unit price of biomass generated power and treatment methods for the effects of global warming prevention are all expected to lead to big changes in cost-effectiveness analysis methods and results for logging residue power generation projects. While responding appropriately to changes in social and economic conditions, it is necessary to continue to develop cost-effectiveness analysis methods that can be understood by the public at large.

Furthermore, cost-effectiveness analysis is one element in making effective use of logging residues (wood biomass). In addition to cost-effectiveness analysis, when it comes to advancing the practical uses of biomass, it is important to consider the overall assessment and inspection with regard to Lifecycle Assessment (LCA) and environmental impact, effects on regional development, etc. We hope to continue our research into comprehensive evaluation methods for logging residue power generation projects.

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