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Original Article

The Cost-Benefit Analysis of Investment in Waste to Energy Power Plant for Four-Provincial in Isan Area of Thailand

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Abstract *- Feasibility study of constructing a Waste-To-Energy (WTE) power plant using incineration in the Four-Provincial in the Isan Area of Thailand for investment decision-making and to address the current waste problem. This research analyzes the economic feasibility and evaluates carbon emissions, which are factors impacting the environment. The Four-Provincial in the Isan Area of Thailand generates an average total of 3,037 tons of waste per day, making it suitable for constructing six waste-to-energy incineration power plants with a capacity of 9.75 MW each. Each plant can handle 500 tons of waste per day, with 7,200 hours of electricity production per year and a project duration of 20 years. The economic feasibility analysis results show that Net Present Value (NPV) is 2,392,360,485.35 baht, the Internal Rate of Return or IRR is 7.58%, and Recuperation duration is 6.81 years, under the condition that Thailand government currently has measures to promote the purchase of electricity from renewable energy by buying electricity at a price 0.7 baht per unit higher during the first 8 years The greenhouse gas emissions analysis of waste disposal, comparing the emissions between landfill disposal and waste-to-energy conversion, based on the emission factor from the Thailand Greenhouse Gas Management Organization, found that waste-to-energy disposal releases 899,643.269 tons of CO2 equivalent per year than landfill disposal.*

Keywords *- Power plant, Greenhouse gas emissions, Four-Provincial in Isan Area, Thailand, Waste to energy, Waste management.*

1. Introduction

Electricity is a fundamental and essential factor for human life. Currently, the demand for electricity in Thailand has been increasing. In the first six months of 2023, electricity consumption increased by 2.2% compared to the previous year, 2022, based on information on energy use provided by the Office of Energy Policy and Planning.

The proportion of fuels used to generate electricity is as follows: natural gas accounts for 59%, coal for 14%, renewable energy for 9% (wind, water, biomass, waste, solar and geothermal), hydroelectric for 4%, oil for 1%, and imports from abroad for 13%. From the data on the proportion of fuel used to generate electricity, although Thailand can produce electricity, it is insufficient compared to domestic demand. Therefore, Thailand must import electricity and fuels used in electricity production from abroad, which could lead to an energy shortage in the future [1].

Currently, Thailand generates a large amount of waste, with an expected continuous upward trend in the future. This is directly due to population growth and economic expansion. Although there have been studies on converting waste to energy in the Yasothon area, the study found that it is suitable to invest in constructing a WTE power plant with a capacity of 1.5 MW, operating for only 8 hours per day due to the relatively small amount of waste [15]. Therefore, this research focuses on the four provinces in the Isan region, including Ubon Ratchathani, Amnat Charoen, Si Sa Ket, and Yasothon.

In 2023, the four provinces in the Isan region of Thailand generated an average daily amount of 3,037 tons of garbage. It is eliminated using the dumping approach. When calculating the average annual waste generation (365 days), it is found that in 2023, the accumulated landfill waste totals 132,494 tons [2-5]. Each province has different main waste components. According to data from the Pollution Control Department [6, 7].

From the issues of domestic energy demand and improper waste disposal, the idea arose to convert the generated waste into electricity for the four provinces in the Isan region, which the US EPA has named WTE one of the cleanest energy sources [16]. This approach involves comparing greenhouse gas emissions between landfill disposal and converting waste into electricity as an alternative to improper waste disposal through landfilling.

2. Analysis of the Suitability in Selecting Waste Disposal Methods

2.1. Analysis of the Suitability of Power Plants

The Department of Alternative Energy Development and Efficiency or DEDE claims several methods for converting waste into energy suitable for the country have been studied. The researchers have chosen to use incineration technology for energy production from waste [9]. DEDE has outlined guidelines for designing energy production from waste using incineration. This involves calculating the heat value based on the composition of the waste according to the main elemental components: Carbon, Hydrogen, Oxygen, Nitrogen, and Sulfur. The calculation can be done as follows [9, 10, 15].

2.1.1. Higher Heating Value (HHV)

HHV refers to the heat value of 1 kilogram of biomass after removing water and moisture content. It is calculated using the biomass's elemental makeup, comprising Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N) and Sulfur (S) according to the following equation.

$$HHV = (80.60C) + 339.10\left(H - \frac{O}{8}\right) + (5.56N) + 22.2S \quad (1)$$

2.1.2. Lower Heating Value (LHV)

LHV refers to the heat value of 1 kilogram of biomass with moisture content. It is calculated using the following equation.

$$\mathrm{LHV} = \mathrm{HHV} - 5.72(9\mathrm{H} + \mathrm{M}) \quad (2)$$

2.2. Economics Value Analysis

2.2.1. Value of the Net Present (NPV)

The disparity between the present value of the expected annual financial inflows and Outflows is referred to as net present value or NPV, calculated over the entire duration of the project at a specified discount rate. To calculate the net present value, one needs information on the net investment inflow cash, the yearly inflows of net cash during the course of the project, the project duration, and the discount rate. NPV can be calculated and expressed as a mathematical equation as follows [11-15].

$$\mathrm{NPV} = -\mathrm{C}_0 + \sum_{t=1}^{n} \frac{\mathrm{B_t} - \mathrm{C_t}}{(1+r)^n} \quad (3)$$

Where, C_0 is the Initial cost, B_t is the net cash flow received from projects in year t, t is the project years range from 1 to t, n project age, and r is the reasonable discount rate or interest rate.

Investment decisions must be analysed to NPV. In the case where the net present value is greater than 0, it is considered suitable for investment. Moreover, if the net current value is less than 0, it is considered not worth investing.

2.2.2. The Internal Rate of Return (IRR)

IRR equates the present value of the return to the present value of costs. Therefore, IRR is the discount rate (r) that brings the net present value of the project to zero (NPV= 0). All projects with an IRR higher than the desired rate of return. That is, the cost of capital or opportunity cost of capital is acceptable, but if the IRR is lower than the interest rate, it is not worth investing [11-15].

2.2.3. Recuperation Duration (RD)

Recuperation Duration (RD) is a number of years that the business will receive the initial outlay of funds of the project. Recuperation durations are typically used to make decisions only to point out project liquidity. Because the value of the money is not considered in the period between Recuperation duration s. Therefore, projects that provide benefits back early in a short period of time are more likely to be considered because they reduce the risk of changes in areas of time, such as political policy, environment, economy, and social policy. Technology that can be modified at any time [11-15].

2.2.4. Environmental Impact Value Analysis

The environmental impact analysis compares greenhouse gas emissions into the atmosphere between using solid waste to generate electricity and managing waste in landfills. This can be done using the following tools: Carbon Footprint refers to the amount of greenhouse gas emissions in various activities calculated in the form of Carbon Dioxide Equivalent. This information was referenced from the Thailand Greenhouse Gas Management Organization [15, 17].

$$CO_2 \text{ Emission} = \text{Activity Data} \times \text{Emission Factor} \quad (4)$$

Where, activity data is information on activities that cause greenhouse gas emissions, and emission factor is a constant used to convert activity data into emissions values.

3. Results and Discussion

3.1. Analysis Results of the Suitability of the Power Plant

Four provinces in the Isan area generate a total of 3,074 tons of waste per day. The waste quantities for each province are as follows: Ubon Ratchathani Province 1,514 tons per day, Amnat Charoen Province 223 tons per day, Si Sa Ket Province 864 tons per day, and Yasothon Province 436 tons per day [2, 3]. Each province has different main waste components, as shown in Table 1. According to data from the Pollution Control Department, the calorific values from the waste composition in each province can be calculated as shown in Table 2 [6, 7].

Table 1. Percentage of waste composition

Province	HHV (kcal/kg)	LHV (kcal/kg)
Ubon Ratchathani	2605.71	2115.31
Amnat Charoen	2458.19	2008.01
Si Sa Ket	2391.79	1948.39
Yasothon	2510.31	2059.31

Table 2. Heating value of waste

The Amount of Waste Entering the Incinerator (Tons / Day)	Heating Value of Waste in the Furnace (kcal/kg)	Power Capacity (MW)
500	1700	9.35
500	1800	9.75
392	2300	9.75

DEDE has determined the suitability of electricity generation capacity by considering the Lower Heating Value, as shown in Table 3 [9].

Table 3. The relationship of the amount of waste entering the incinerator and the heating value

Group of Population	Amount of Waste Generated (Ton/Day)
Group 1	500.46
Group 2	513.22
Group 3	492.92
Group 4	516.26
Group 5	508.78
Group 6	505.36

Therefore, Four-Provincial in Isan Area is suitable for a power plant with a production capacity of 9.75 MW, which can handle 500 tons of waste per day. Consequently, it is necessary to build 6 power plants.

3.2. Analysis Results of the Power Plant Site Location

Due to the large area of the regional group and the widespread population distribution, it is necessary to analyze and identify suitable areas for constructing power plants. This is divided into 6 groups, with the condition that the total waste generated must be no less than 500 tons per day.

The Pollution Control Department of Thailand has specified the waste generation rate in relation to the population [18]. This data is used to analyze and identify 6 groups of potential power plant sites, as shown in Table 4.

Table 4. Results of analysis of the amount of waste generated according to population density

Province	C	H	O	N	S
Ubon Ratchathani	58.61	7.38	32.16	1.64	0.21
Amnat Charoen	55.88	7.09	34.51	2.27	0.25
Si Sa Ket	57.1	7.23	33.37	2.05	0.25
Yasothon	57.17	7.24	33.2	2.15	0.24

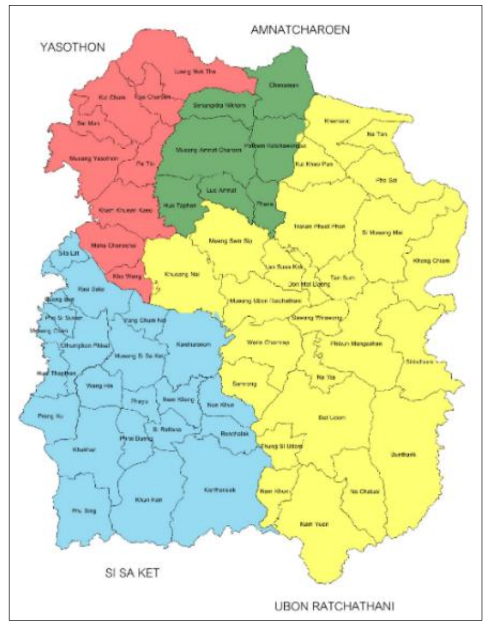

Fig. 1 Area of four-provincial in Isan Area

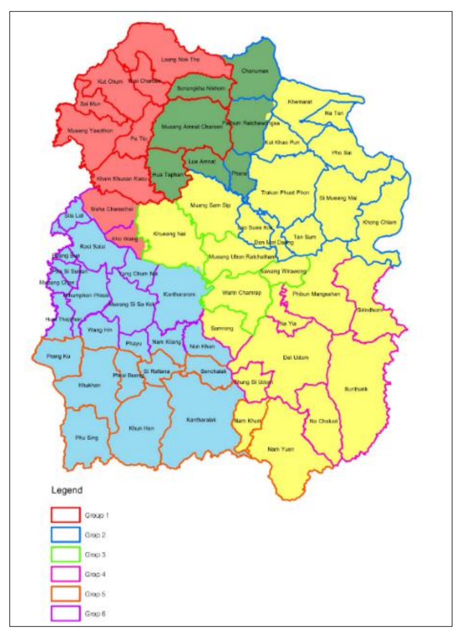

Fig. 2 Population grouping for the construction of 6 power plant

3.3. Results of Economic Analysis

The cost of constructing a power plant from waste is very important under a worthwhile budget. The construction costs are divided into multiple categories. The details are as follows: cost of construction outside the building, cost of building construction, cost of construction of an ash landfill and wastewater treatment system, cost of construction of waste-to-energy power plants. DEDE has estimated the construction cost of a 9.75 MW power plant capable of processing 500 tons of waste per day to be 2,137,649,540 baht.

Table 5. FiT electricity purchase rate

Project Life	FiT_F	FiTv	FiT Premium	FiTi
In the First 1-8 Years	2.39 THB/Unit	2.69 THB/Unit	0.7 THB/Unit	5.78 THB/Unit
In the Last 9-20 Years	2.39 THB/Unit	2.69 THB/Unit	-	5.08 THB/Unit

In Thailand, the Energy Regulatory Commission (ERC) has implemented measures to promote the purchase of electricity from Feed-in Tariff (FiT) programs pertaining to renewable energy sources. The Feed Tariff structure consists of three components: a fixed electricity purchase rate (FiTF), a variable electricity purchase rate (FiTv), and a special electricity purchase premium rate (FiT Premium). Details are provided in Table 5 [19].

From Table 4, electricity distribution in FiT format in the first 1-8 years is equal to the sum of FiTF, FiTv and FiT Premium, which is 2.39 + 2.69 + 0.7 = 5.78 THB/unit, while in the last 9-20 years it is equal to the sum of FiTF, FiTv and FiT Premium, which is 2.39 + 2.69 = 5.08 THB/unit. According to the Office of EPPO, investments in constructing waste-to-energy power plants will be granted a tax exemption for a period of 8 years [19].

The project income is divided into 2 parts: the first part is the income from the sale of electricity, and the second is the income from waste disposal fees. Revenue from the sale of electricity. There are two types of electricity distribution rates as follows: Time-of-use rate and Feed-in Tariff rate. The income from waste disposal fees is 500 THB/tons [20]. The economic value of a 9.75 MW power plant (operating 7,200 hours per year), considering revenue from electricity sales after taxes, construction costs of the waste-to-energy plant, and operation and maintenance costs (including personnel) as well as machinery research costs and operational expenses, has been assessed. The discounted recuperation length, internal rate of return, and Net Present Value (NPV) are calculated using diverse data with a discount rate of 10% annually during a 20-year project lifespan, as detailed in Table 6.

Table 6. Cost-benefit analysis results

Project Model	Amount	Unit
Revenue from Electricity Distribution after Tax for the 1-8 Year	2,568,798,969.00	THB
Revenue from Electricity distribUtion after Tax for the 9-20 Year	2,601,096,590.40	THB
Revenue from Waste Disposal Fees	1,800,000,000.00	THB
Construction Cost of Waste Power Plants	2,137,649,540.00	THB
Operating and Maintenance Costs (5 Year)	961,942,293.00	THB
Personnel Cost	652,320,000.00	THB/Year
Project Life	20	Year
Net Present Value	2,392,360,485.35	THB
Internal Rate of Return	7.58	Percent
Recuperation Duration	6.81	Year

3.4. Results of Analysis of Economics Environmental Impact

Currently, the four provinces in the Isan region manage waste using the dumping method and are transitioning to landfill waste disposal. However, there are still issues regarding the availability of suitable land for landfill operations. Converting waste into energy by constructing a waste-to-energy power plant can help reduce landfill space and minimize environmental impacts. Therefore, a comparison of greenhouse gas emissions between waste-to-energy conversion and landfill disposal has been conducted. According to data from the Thailand Greenhouse Gas Management Organization, emission factors for various activities that release greenhouse gases have been defined as follows: electricity generation using grid mix is 0.5986, landfill waste disposal is 1.0388, and waste dumping is 0.7933. However, emission factors for construction or demolition activities have not yet been established. Based on this information, greenhouse gas emissions can be calculated using Equation (4) with an average waste generation rate of 3,074 tons per day (365 days), and the results are presented in Table 7. The difference in greenhouse gas emissions shows that converting waste into electricity results in 899,643.269 tons of CO_2 equivalent emissions per year, less than landfill disposal.

Table 7. Co_2 emission

Activities	Amount	Emission Factor	CO_2 Emission (Ton of Co_2 eq./Year)
Landfill	1,108,505 Ton/Year	1.0388	1,151,514.99
Dumping	1,108,505 Ton/Year	0.7933	879,377.02
Waste to Energy 9.75 MW	70,128 MWh/ Year	0.5986	251,871.72

4. Conclusion

This study analyzes the costs and benefits of investing in waste-to-energy power plants in Four-Provincial in the Isan Area, with a total installed capacity of 9.75 MW across 6 facilities. The study uses population density and presumes a project duration of 20 years with an interest rate of 10%. The findings indicate that the investment is worthwhile and promising. If the waste is used to generate electricity, it could significantly reduce CO2 emissions released into the atmosphere, amounting to 899,643.27 tons of CO2 equivalent per year. This would help mitigate environmental impact and global warming while also addressing the growing waste management problem anticipated for the future.

Additionally, if this project is pushed forward, it will create jobs in the provincial areas, contributing to the growth of the national economy and increasing energy security for the government. Furthermore, before proceeding with constructing the waste-to-energy power plant for all 6 groups, it is necessary to review the legal requirements related to urban planning to ensure that the site selection is appropriate and complies with Thai legal regulations.

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