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Economic and environment feasibility of landfill gas project in Indonesia

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Abstract. Waste is a serious environmental problem in Indonesia. The waste based energy production using Waste Landfill Gas project is beneficial in the context of economic and environment aspect. The average electricity production cost from landfill gas project is 808.95 Rupiah for per KWh. This is comparatively cheaper than the production cost of gas turbine, diesel, combined cycle, geothermal sources. The emission of CO2 from the coal, oil, gas and natural gas is significantly higher than the waste landfill gas unit. This finding can benefit the policy making and manage the waste problem in Indonesia.

1. Introduction

Meidiana [1] and Kawai [2] stated that waste management is the most crucial issue that held in Indonesia. Haskarlinus [3] tries to make the best monitory on Landfill in Jakarta, Indonesia. Based on this issue, Indonesia needs method to deal with. LFG or landfill Gas as the one technique which can use to solve this problem. Many countries in the world, special in Southeast Asia apply this technique to deal with their problem of trash such as India, Malaysia, and Thailand. This technique also can overcome another issue such an electricity. To sum up, Landfill gas can be one of the best way to deal with waste problem in Indonesia.

On the other hand, to build Landfill gas system need more attention in many field such as the technology and the LFG technique. Methane, Hydrogen Sulfide, and Carbon dioxin are the emission which will occur in this project. It also the main exist emission as hot issue about environment in the world. Kumar [4] and Kalantarifard [5], used IPCC, CLEEN model and Land GEM to measure CH_4, CO_2, and H_2S in landfill site. Zero and order-decay method as the basic rules that they used to measure it. Furthermore, Dowling [6] measures the economic from landfill gas project. Therefore, this research attempts to know about the feasibility of LFG project, to show the advantages and disadvantages of the project and compare it with other electricity sources in Indonesia.

2. Materials and methodology

2.1. Landfill sites

Two landfills in Indonesia are investigated in this paper. One of them is in the large city of West Indonesia (Surabaya) and another one is in the metropolitan city of East Indonesia (Makassar). It is used to determine and evaluate the feasibility of landfill gas to energy projects.

2.1.1. Benowo Landfill (LF 1). LF 1 is ± 37.4 hectares in size and its final height will be between 5 – 12 m. The Benowo landfill begins on November 2001 and it accepts waste from whole Surabaya which is the part of East Java. The planning of Benowo landfill closure year is 2030. Table 1 shows yearly disposed quantities of Benowo landfill.

Table 1. Yearly disposed quantities of Benowo landfill.

Year	Quantity (ton/year)
2003	204,000.00
2004	335,618.50
2005	467,237.00
2006	598,855.50
2007	540,200.00
2008	459,425.50
2009	448,741.95
2010	463,779.05
2011	478,816.14
2012	493,853.24
2013	508,890.33
2014	531,403.50
2015	539,342.25

Source: central bureau of statistic, Indonesia

2.1.2. Antang Landfill (LF 2). LF 2 is ± 14.3 hectares in size and its final height will be between 5 – 12 m. Most of the areas/phases have been capped or are almost at full capacity. However, the city is currently in negotiations regarding expansion of this landfill. Antang landfill begins in 1993 and it accepts waste from whole Makassar which is the part of South Sulawesi. The planning of Antang Landfill closure year is 2032. Table 2 shows yearly disposed quantities of Antang landfill.

Table 2. Yearly disposed quantities of Antang landfill.

Year	Quantity (ton)
2003	1,027,495
2004	1,077,874
2005	1,128,254
2006	1,178,633
2007	1,229,012
2008	1,279,391
2009	1,329,770
2010	1,380,149
2011	1,432,085
2012	1,480,907
2013	1,531,287
2014	1,581,666
2015	1,632,045

Source: central bureau of statistic, Indonesia

2.2. Landfill gas generation model

Landfill Gas Emission Model (Land GEM) software is used by estimating emission rates for total landfill gas of municipal solid waste landfill. The United State Environmental Protection. Agency (US EPA) is the organization that develop this software. The model determines the mass of methane generated using the methane generation capacity and the mass of waste deposited.

Current research also calculates the electricity generation potential from the landfill. EPA defines between 75-85% of the produced methane and the calorific value of methane is 4.5 kWh/year and the form to find the potential electricity. Based on Land GEM rule, CO_2 emission is calculated from the production of methane and the methane content percentage.

2.3 Landfill Gas Energy Cost Model (LFGcost-Web)

LFGcost-Web is an LFG energy project cost estimating tool developed for EPA's LMOP. LFGcost-Web estimates LFG generation rates using a first-order decay equation. Variation in the gate and types of incoming waste, site operating conditions, and moisture and temperature conditions may provide substantial variations in the actual rates of generation.

The default inputs and cost estimated by LFGcost-Web are based on typical project designs and for typical landfill situations. The model attempts to include all equipment, site work, permits, operating activities, and maintenance that would normally be required for constructing and operating a typical project, however, Individual landfill may require unique design modifications which would add to the cost estimated by LFGcost-Web. First-Order Decay Equation for Average Annual Waste Acceptance Rate as shown in equation (1).

$$Q_t = (1/(CH_4/100)) \cdot L_o \cdot R \cdot [e^{-kc} - e^{-kt}] \tag{1}$$

Where Q_t is the landfill gas generation rate at time t (ft^3/year), CH_4 is the methane content of landfill gas (%), L_o is the potential methane generation capacity of waste (ft^3/ton), R is the average annual waste acceptance rate during active life (tons), k is the methane generation rate constant (1/year), c is the time since landfill closure (years), and t is the time since the initial waste placement (years). First-Order Decay Equation for Waste Disposal History is shown in equation (2).

$$Q_t = \sum_i [(1/(CH_4/100)) \cdot k \cdot L_o \cdot M_i \cdot e^{-kt_i}] \tag{2}$$

Where Q_t is the landfill gas generation rate at time t (ft^3/year), CH_4 is the methane content of landfill gas (%), k is the methane generation rate constant (1/year), L_o is the potential methane generation capacity of waste (ft^3/ton), M_i is the waste acceptance rate in the i-th section (tons) and t_i is the age of the i-th section (years).

After total of gas generation is calculated, it will calculate the gross power generation potential (NPGP) in year. Where is the collection system efficiency, typically 85%, is the energy content of landfill gas, typically 500 BTU/cf, and is the heat rate of equipment. Afterwards, the annual electricity is generated as shown in equation (3).

$$\text{AEG} = \text{NPGP } (24)\ (365)\ 85\% \tag{3}$$

Where net power generation potential (AEG) is estimated by subtracting the parasitic loads, 24 is hours per day, 365 is days per year, and 85% re represent the assumed average percentage of the time in a year that equipment is producing electricity at its rate capacity (net of maintenance, downtime, etc.).

3. Result and discussion

3.1. Generation Cost Landfill gas generation from Antang and Benowo landfills

Using the financial assumptions (table 3) and collection and flaring system assumptions (table 4), the waste-in-place from LFGCost-WebV3.0 as well, this research finds that an electricity price around $0.06 by operating cost, net income, and simple payback in table 5. Figure 1 describes landfill gas generation, collection and utilization curve.

Table 3. Financial assumptions.

Project life (years)	15
Project start year	2016
Down payment	20%
Loan rate	6%
Loan period	10 years

Depreciation	Straight line
Corporate tax	35%
Renewable energy tax credit	0 $/kWh
Discount rate	12%

Table 4. Collection and flaring system assumptions.

Cost Component	**Cost (2013$'s)**	**Cost Unit**
Drilling and pipe crew mobilization Installed cost of vertical	$20,000	per system
gas extraction wells	$4,675	per well
Installed cost of wellheads and pipe gathering system	$17,000	per well
Installed cost of knockout, blower, and flare system	$(x)^{0.61}$ * $4,600	$, x = ft^3/min
Engineering, permitting, and surveying	$700	per well
Annual O&M for collection (excluding energy)	$2,600	per well
Annual O&M for flare (excluding electricity)	$5,100	per flare
Electricity price (depends on type of project)	$0.090	per kWh with a
Project Component	**Quantity**	
Average depth of landfill waste (ft)	65	
Number of wells (1 well per acre)	10	
Number of flares (1 flare per system)	1	
Collected landfill gas design flow rate (ft3/min)	2,374	
Electricity usage by blowers (kWh/ft3)	0.002	
Installed Capital Costs:	2016	
Mobilization:	$21,224	
Extraction Wells:	$49,611	
Wellheads and Pipe Gathering System:	$180,405	
Knockout, Blower, and Flare System:	$559,314	
Engineering, Permitting, and Surveying:	$7,428	
Total Capital Costs Including Cost Contingency	$817,984	

Table 5. Operating cost, net income, and simple payback.

Year	Operating Cost	Maintenance Cost	Net Income
2017	$163,784	$1,807,823	$61,351
2018	$168,195	$1,853,018	$67,099
2019	$170,956	$1,899,344	$74,276
2020	$173,771	$1,946,827	$81,792
2021	$176,642	$1,995,498	$89,669
2022	$179,570	$2,045,386	$97,926
2023	$182,556	$2,096,520	$106,588
2024	$185,602	$2,148,933	$115,677
2025	$188,709	$2,202,657	$125,219
2026	$191,878	$2,257,723	$135,242
2027	$195,111	$2,314,166	$136,670
2028	$198,410	$2,372,020	$138,092
2029	$201,774	$2,431,321	$139,506
2030	$205,207	$2,492,104	$140,912
2031	$208,710	$2,554,406	$142,308
Simple payback			9 years

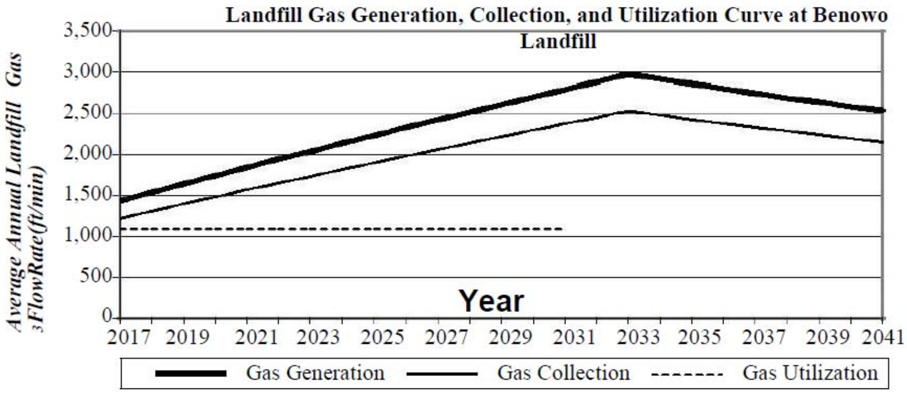

Figure 1. Landfill gas generation, collection and utilization curve.

3.2. Comparison electricity sources in Indonesia

This research attempts to compare Landfill gas CO2 emission in each power place that is used in Indonesia. Calculation of LFG CO2 Emission is got by result using LandGEM and the other sources are known by a review on the pattern of electricity generation and emission in Indonesia from 1998 to 2009 [7]. Table 6 shows CO2 comparison between LFG and other fuels.

Table 6. CO_2 Comparison between other fuels.

Fuels	CO2 Emission (kg/kwh)
LFG	0.00000000027
Gas	0.85
Fuel Oil	0.85
Coal	1.18

By the result of comparing to another source, the research find that LFG has CO2 emission lower (0.00000000027 kg/kWh) that others sources such as Gas (0.85 kg/kWh), Fuel Oil (0.85 kg/kWh), and Coal (1.18 kg/kWh). It means that LFG is one electricity generation who has possibility as electricity friendly generation for environment. It is based on CO2 as the biggest issue in Global warming.

LFGcost-Web as a software development from USA environmental protection agency is used to calculate the average generation cost if landfill gas generation is built and compare to other generation sources such as hydro generation, steam generation, diesel generation, turbine generation, geothermal generation, and combined cycle generation. Figure 2 shows comparison of different electricity production systems.

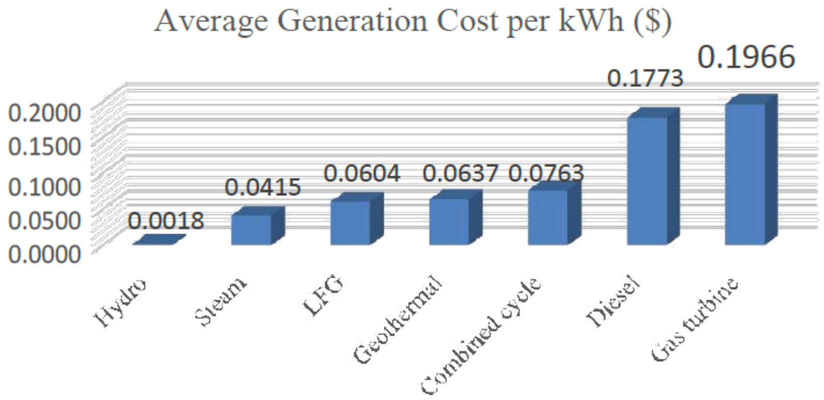

Figure 2. Comparing the different electricity production system.

Based on the figure 2, average generation of Landfill gas as the third lower generation which is \$0.0604 per kWh. It is bigger than Hydro (\$0.0018) and steam (\$0.0415) generation yet it is lower than geothermal (\$0.0637), Combined Cycle (\$0.0763), Diesel (\$0.1773), and Gas turbine (\$0.1966) generation.

4. Conclusion

From the result finding, Landfill gas project can be alternative way to deal waste problem. Change from waste to electricity could help government in electricity needs. The results show that landfill gas project more friendly in economic and environmental aspects rather than other recent electricity sources in Indonesia. To sum up, government can consider landfill gas project in Indonesia as solution for waste problem and also electricity.

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